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Biological traits of *Glossogobius giuris* (Hamilton, 1822) in a wetland ecosystem (Northwestern Bangladesh): Implications for sustainable fisheries management

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ABSTRACT

The freshwater goby, *Glossogobius giuris*, is abundant in freshwater ecosystems across Bangladesh. The current investigation focuses on the population structure, growth pattern, and biological traits of *G. giuris* (Hamilton, 1822) in the *Beel* Kumari wetland habitat in Northwestern Bangladesh. A total of 542 specimens were collected during various trips in 2023 using gill nets (excluding June to August, the breeding season). Biometric analyses were conducted to evaluate length-frequency distributions, LWR, and LLRs. Also, allometric condition factors (KA), Fulton's condition factor (KF), and relative condition index (K_R) were examined. The growth of *G. giuris* was established as negatively allometric (b= 2.87), and their condition factors indicated a reasonably well-fed, healthy population (K_A = 0.0119 ± 0.001, K_F = 0.9597 ± 0.110; K_R =1.0162 ± 0.113). The form factor ($a_{3.0}$ = 0.0078) indicated that this species had adapted to the wetland environment. Total length and standard length had a significant linear relation (p<0.0001). The minimum size at sexual maturity (L_m) of 5.4 cm is the lowest value reported worldwide and could be a consequence of ecological disturbance. W_R ranged from 73.504 to 148.87, indicating favorable growing circumstances with particular seasonal variations. These findings establish a solid baseline for the health and growth patterns of *G. giuris* in *Beel* Kumari and also highlight the increasing ecological pressure on wetland biodiversity and tropical fisheries in the area. Therefore, there is an immediate necessity for highly effective conservation strategies to prevent further decline and potential extinction of fish species in this ecosystem.

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Introduction

The tank goby, *Glossogobius giuris* (Hamilton, 1822), a benthopelagic, amphidromous species in the family Gobiidae, is widely distributed across marine, brackish, and freshwater ecosystems (Gaut et al., 2025). This species is the sole representative of the genus *Glossogobius* documented in Bangladesh, and is commonly known as Bele in Bangladesh, Bhaila in India, tank goby in Malaysia, and goby in the Philippines (Azad et al., 2018). It is frequently observed in brackish water, estuaries, and tropical and subtropical freshwater habitats, and inhabits both lentic and lotic habitats (Ghosh et al., 2021). Being carnivorous, our observed species readily consume fish, tiny insects, crustaceans, debris and detritus, semi-digested food, zooplankton, and mollusks (Islam et al., 2022). In Bangladesh, *G. giuris* has significant importance in fisheries, particularly in the northwestern and southern regions, due to its high abundance and commercial value (Islam et al., 2023). The species is also highly preferred by consumers in South Asia because of its lower fat content, high protein, and delicious taste (Sabbir et al., 2024). Although *G. giuris* is regarded as a species of 'Least Concern' both globally and in Bangladesh (IUCN Bangladesh, 2015; IUCN, 2025).

Estimating fish growth and biological parameters, such as condition factors, length-weight relationships (LWR), form factor, and size at first sexual maturity (L_m), is essential for understanding population dynamics and ecosystem health. LWR is frequently employed to analyze length-based data and convert biomass into weight-based assessments for stock evaluation (Mehanna and Farouk, 2021). By analyzing these parameters, researchers can evaluate the condition of fish stocks, track their development over time, and make well-informed choices for conservation and management planning. Estimates of condition factor play a crucial role in assessing the health of fish and forecasting the future success of their populations, as they influence reproduction, survival, and growth (Richter, 2007). This quantitative index also enables comparison of weight and length among individual fish collected under standardized conditions (Jisr et al., 2018). Relative weight (W_R), which is a type of condition factor, indicates a fish's overall health and nutritional condition by comparing its actual weight to the predicted weight for a given length (Younos et al., 2025; Islam et al., 2024). In fact, the form factor ($a_{3.0}$) describes the body shape or morphology of teleost fishes within a particular ecosystem (Kasif et al., 2025). Additionally, size at first sexual maturity (L_m) is a key biological indicator used in fisheries management and conservation planning (Lucifora et al., 1999; Hasan et al., 2021).

Due to its worldwide economic value, several investigations have been performed on this species, including length-weight relations (Tran et al., 2021), food and feeding habits (Islam et al., 2020), length-weight relations of fishes (Karna et al., 2020), morphometric relationships (Azad et al., 2018), length-weight relationship and condition factor (Islam et al., 2017). Despite the ecological and economic importance of *G. giuris*, no previous studies have examined its growth patterns, reproductive biology, and population dynamics in the *Beel* Kumari wetland habitat in northwestern Bangladesh. Therefore, the purpose of the current study is to examine biological traits by analyzing the growth patterns through length-weight relationships (LWRs) and length-length relationships (LLRs), condition factors through multiple functions, form factor, and size at first sexual maturity of *G. giuris* within a wetland habitat in northwestern Bangladesh. This research aims to establish baseline data on the species' biological status and to contribute to the formulation of appropriate conservation and management plans to support sustainable fisheries management.

Materials and Methods

Study area

Sampling for the current study was performed at *Beel* Kumari (Figure 1). *G. giuris* samples were periodically gathered from fishermen's catch between January and December 2023, except during the breeding season (June to August). Throughout the studies, a total of 542 samples were collected using gill nets (1.5-2.5 cm) in collaboration with local fishermen. After collection, the specimens were placed on ice to maintain their integrity and then sent to the lab for further examination.

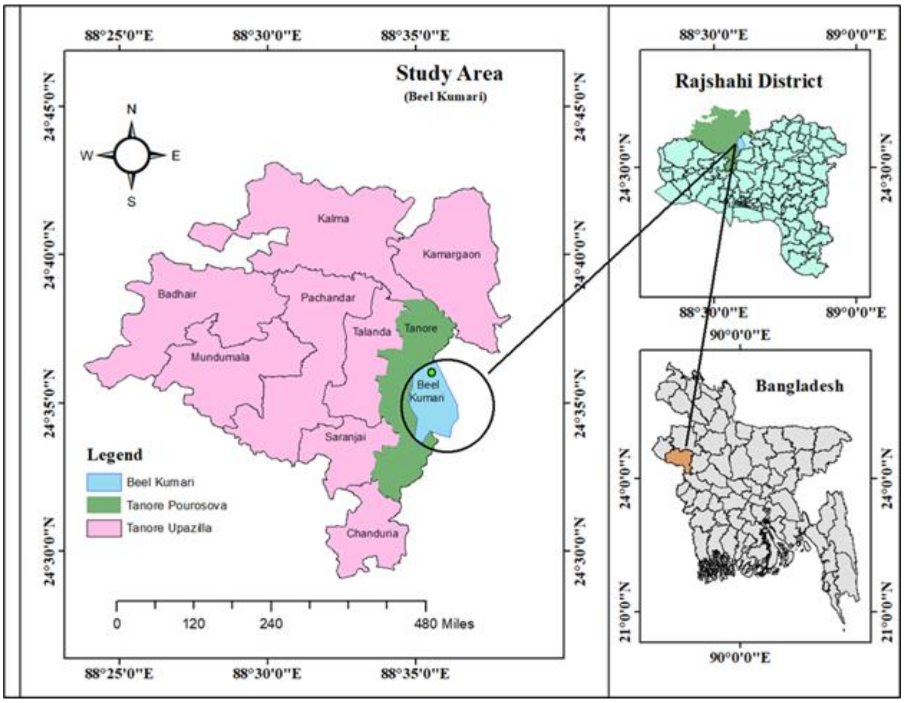

Figure 1. Map of the study area (*Beel* Kumari, Northwestern Bangladesh)

Fish Size Measurement

Experimental specimens were collected and placed on laboratory filter paper for flat-air drying. The sample's morphometric characteristics were assessed. The body weight of each specimen was recorded via a digital balance (Sartorius, Germany). Total length (TL) and standard length (SL) were measured to the nearest 0.1 cm, employing an electronic slide caliper (Mitutoyo, Japan).

Length-weight Relationships

The length-weight relationship (LWR) of fish populations is mathematically expressed as $W = a \times L^b$, where W and L are body weight in grams and total length in millimeters, respectively, "*a*" and "*b*" are the constants regressed from the equation Le Cren (1951). This equation was log-transformed to perform a linear regression: $\ln[W] = \ln[a] + b \ln(L)$. This method provides a stable alternative for estimating growth patterns and the structure of the LW relationship in fish populations (i.e., weight prediction from length). In addition to being a growth index in itself, the LWR can reflect seasonal variations in condition and standing stock biomass, and thus in population structure over time. The growth pattern was presented as coefficients *a* and *b* with 95% confidence intervals.

Length-length Relationship

The study measured both TL and SL to the nearest cm to establish a relationship between TL and SL using linear regression (Rahman et al., 2023).

Condition Factors

The allometric condition factor (K_A) assigned to Tesch (1971) was determined as: W/L^b, where W denotes body weight (BW) in g, L is the total length (TL) in cm, and '*b*' is the exponent value of the distance-weight regressions. Body condition factor (K_F) of the fish, as described by Fulton (1904), was estimated using the formula $K_F = 100 \times BW/TL^3$, where W is in grams, and L denotes the total length in centimeters. The relative condition factor (K_R) was assessed according to Le Cren (1951): $K_R = BW/(a \times L^b)$.

Prey-predator status

According to Froese (2006), the relative weight (W_R) was calculated using the formula $W_R = (W/Ws) \times 100$. In addition, Ws refers to $Ws = aTL^b$

Form Factor

Following Froese (2006), the form factor was derived using equation $a_{3.0} = 10\log^{a-s\,(b-3)}$. In this case, the regression variables of LWR between BW and TL were named as *a* and *b*, where *s* denotes the slope of the ln *a* plotted against *b*.

Size at Sexual Maturity

The L_m (size at sexual maturity) was assessed through the maximal length-based analytical model: $\log(L_m) = -0.1189 + 0.9157 * \log(L_{max})$ (Binohlan and Froese, 2009). The maximally reported length (TL) of *G. giuris* in this study is referred to as L_{max}.

Physiological Status

The physiological state of *G. giuris* individuals was evaluated using the formula $\bar{a} = BW/(TL)^{(b)}$ to determine whether they were in an ideal, lean, or fatty state (King, 2007). The fish is considered to be in ideal health when the computed value of $\bar{a}$ equals the LWR parameter '*a*'. The fish's condition can be designated as lean ($\bar{a} < a$) or fatty ($\bar{a} > a$) based on variations from this value. (Rahman et al., 2023).

Statistical Analysis

Statistical analyses were performed using GraphPad Prism 8 and Microsoft Excel 2019. The normality of allocation for every category was initially evaluated by physical inspection of histograms and afterward verified via the Kolmogorov–Smirnov and Shapiro-Wilk tests. The homogeneity deviation was subsequently evaluated. For comparisons of the total length (TL), condition variable, and body weight where normal distribution assumptions were not fulfilled, the nonparametric Mann-Whitney U test was used. The Wilcoxon signed-rank test was used when the mean relative weight (WR) deviated substantially from 100 (Anderson and Neumann, 1996). Spearman correlation (rank) test was performed to assess the relationship between the TL and BW parameters and condition variables (K_A, K_F, K_R, W_R). Statistical testing was carried out using two-tailed tests, and the significance threshold for the entire statistical analysis was set at 5% (p < 0.05).

Results

Length frequency distribution

The LFDs denoted the physical dimensions of the smallest and largest individuals, ranging from 3.4 to 8.5 cm in TL (Figure 2).

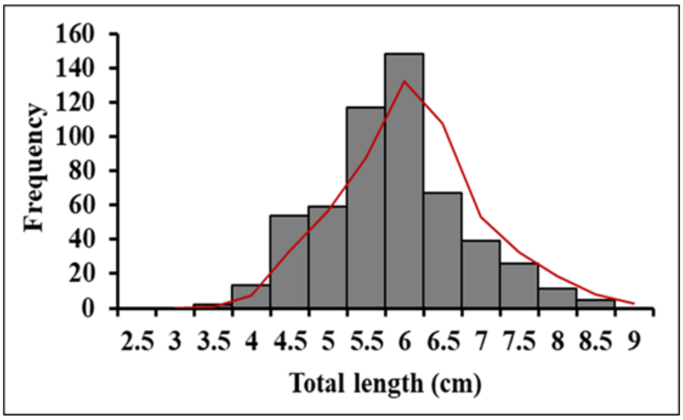

Figure 2. Total length-frequency distribution of *G. giuris* in a wetland ecosystem (*Beel* Kumari), northwestern Bangladesh

Morphometric Relationships

The findings for the length-weight relationships (LWRs) of *G. giuris* are presented in Table 1 and depicted in Figure 3, including the regression coefficients (*a* and *b*), their 95% confidence limits, the coefficient of determination (r^2), and the growth trend. The '*b'* values derived from the LWRs were profoundly below 3.0 (b <3.00; $p < 0.001$), signifying negative growth (A-). Furthermore, the LLR (TL *vs* SL) estimates the parameters '*a'* and '*b'*, their respective 95% confidence limits, and the coefficient of determination (r^2) values. LLR was highly statistically significant ($p < 0.001$).

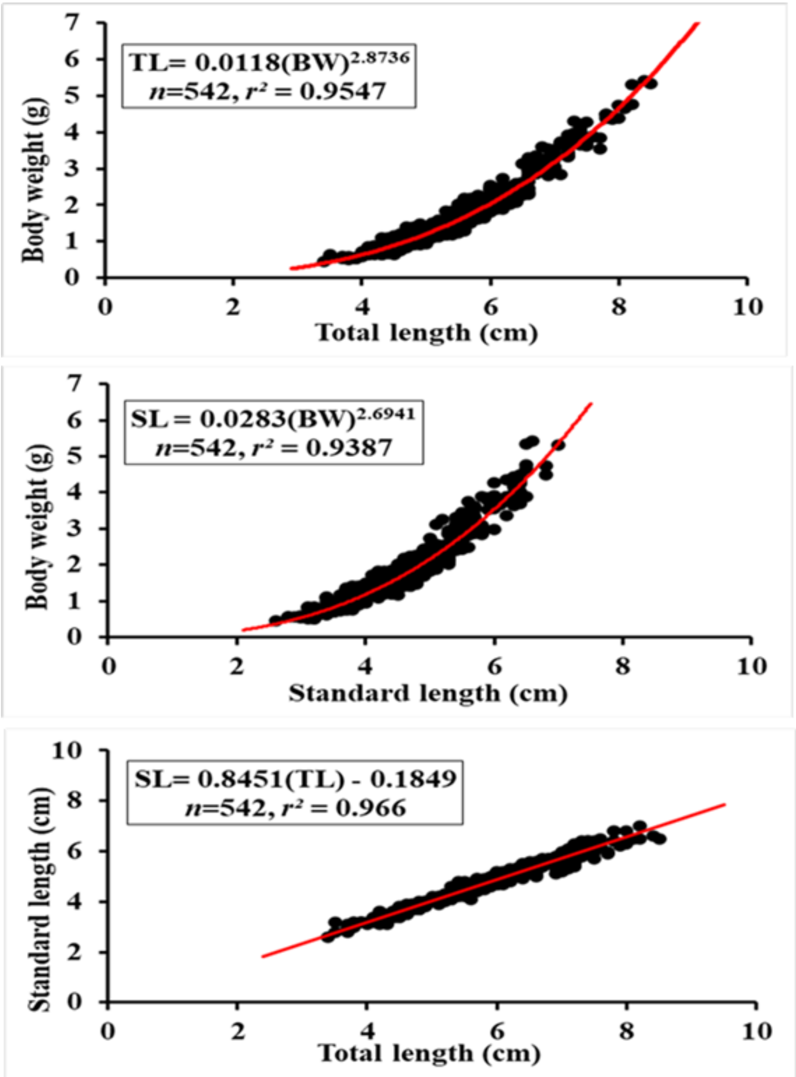

Figure 3. Length-weight and length-length relationships of *G. giuris* in a wetland ecosystem (*Beel* Kumari), northwestern Bangladesh

Table 1. Descriptive statistics and estimated parameters of the length-weight and length-length relationships of *G. giuris* captured from the Wetland (*Beel* Kumari) Ecosystem from Northwestern Bangladesh

Equation	*a*	*b*	95% CL of *a*	95% CL of *b*	r^2
$BW = a \times TL^b$	0.0118	2.87	0.0107 to 0.0130	2.81-2.93	0.954
$BW = a \times SL^b$	0.0283	2.69	0.0259 to 0.0310	2.63-2.75	0.938
$SL = a + b \times TL$	-0.1849	0.845	-0.2614 to -0.1084	0.831-0.858	0.966

TL, total length; BW, body weight; SL, standard length; *a*, intercept; *b,* slope; CL, confidence limit for mean values; r^2, coefficient of determination.

Table 2. Descriptive statistics of condition factors measurements with their 95% CL of *G. giuris* captured from the Wetland (*Beel* Kumari) Ecosystem from Northwestern Bangladesh

Condition factors	*n*	Min	Max	Mean ± SD	95% CL
Allometric condition factor (K_A)	542	0.0086	0.0175	0.0119± 0.001	0.0118-0.0121
Fulton's condition factor (K_F)		0.7133	1.4927	0.9597± 0.110	0.9503-0.9690
Relative condition factor (K_R)		0.7350	1.4887	1.0162±0.113	1.0066-1.0258
Relative weight (W_R)		73.504	148.87	101.62± 11.38	100.66-102.58

n, sample size; Min, minimum; Max, maximum; SD, standard deviation; CL, confidence limit for mean values

Condition Factors

The allometric condition factor (K_A), Fulton's condition factor (K_F), and relative condition factor (K_R) of *G. giuris* were presented in Table 2. Spearman rank correlation tests did not show significant correlations with TL for K_A and K_R, but K_F (r_s = -0.1156, p = 0.0070) showed a fairly negative association. When related to body weight (BW), K_A and K_R both showed significant correlations, and K_F was significantly less correlated with BW (p=0.0194) (Table 3).

Table 3. Relationships of condition factor with total length (TL) and body weight (BW) of Descriptive statistics on condition factors measurements and with their 95% CL of *G. giuris* captured from the Wetland (*Beel* Kumari) Ecosystem from Northwestern Bangladesh

Relationships	r_s values	95% CL of r_s	*p* values	Significance
TL *vs* K_A	0.0624	-0.0244 to 0.1483	0.1468	ns
TL *vs* K_F	-0.1156	-0.2003 to -0.0292	0.0070	**
TL *vs* K_R	0.0622	-0.0245 to 0.1482	0.1477	ns
TL *vs* W_R	0.0622	-0.0245 to 0.1482	0.1477	ns
BW *vs* K_A	0.2761	0.1940 to 0.3543	<0.0001	****
BW *vs* K_F	0.1004	0.0138 to 0.1855	0.0194	*
BW *vs* K_R	0.2760	0.1939 to 0.3542	<0.0001	****
BW *vs* W_R	0.2760	0.1939 to 0.3542	<0.0001	****

Condition factors (K_A, Allometric; K_F, Fulton's; K_R, Relative); r_s, coefficient of Spearman rank correlation test values; CL, confidence limit; ns, not significant; ****most significant; and *p*, exhibits the intensity of significance.

Prey-predator status

A relative weight (W_R) of *G. giuris* was 101.62±11.38 (Figure 4). The Spearman rank correlation analysis between TL and WR showed a nonsignificant association (r_s = 0.0622; p = 0.1477), as shown in Table 3. Nevertheless, there was a strong relationship between BW and W_R (r_s = 0.2760; p < 0.0001).

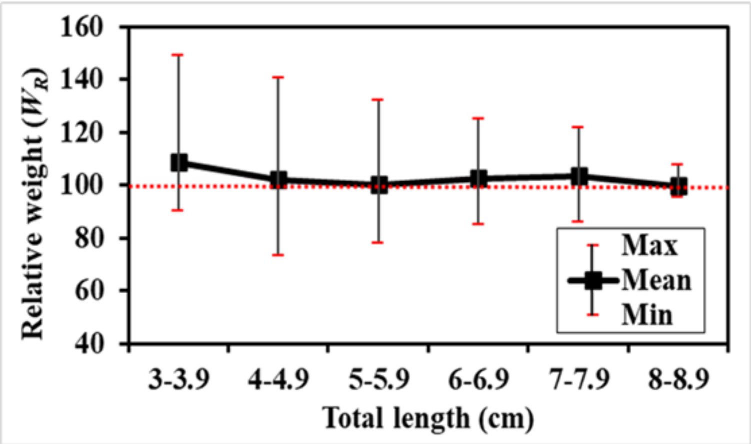

Figure 4. Relative weight of *G. giuris* in a wetland ecosystem (*Beel* Kumari), northwestern Bangladesh.

Form factor

The form factor ($a_{3.0}$) was determined to be 0.0078, which reveals the body is elongated and marginally compressed, as illustrated in Table 4.

Table 4. Calculated form factor of *G. giuris* in the Wetland (*Beel* Kumari) Ecosystem from Northwestern Bangladesh and worldwide

Water body/ Country	*n*	Length range (cm)			Regression parameters		References	Calculated $a_{3.0}$	Calculated L_m	95% CL of L_m
		Type	min	max	*a*	*b*				
The Wetland (Beel Kumari) Ecosystem, Bangladesh	542	TL	3.4	8.5	0.0118	2.87	Present study	0.0078	5.4	4.86-5.94
Red River, Vietnam	270	TL	5.8	27.0	0.008	2.90	Tran et al. (2021)	0.0058	14.54	13.09-15.99
Chilika lagoon, India	135	TL	4.9	29.1	0.008	3.01	Karna et al. (2020)	0.0082	15.42	13.88-16.96
Gorai River, Bangladesh	229	TL	4.3	26.9	0.0102	2.91	Azad et al. (2018)	0.0076	14.48	13.03-15.93
Hongshui River, Southwest China	65	TL	6.2	17.5	0.0106	2.93	Que et al. (2015)	0.0085	10.68	9.61-11.75
The Ganges River, Bangladesh	226	TL	11.3	23.6	0.006	3.06	Hossain et al. (2009)	0.0072	13.14	11.83-14.45

n, sample size; min, minimum length; max, maximum length; *a*, intercept; *b*, slope; $a_{3.0}$, form factor

Size at Sexual Maturity

The size at first maturity (L_m) was calculated at 5.4 cm Tl (95% CI: 4.86 -5.94). Table 4 also provides a summary and comparison of L_m estimates for *G. giuris* across different habitats worldwide.

Physiological status

The largest number of fatty fishes was found in 7-7.9 cm TL, representing 58.13% of the *G. giuris* population. In contrast, the best individual of fish with acceptable physiological condition, which is characterized by its size range 8-8.9 cm TL, representing 57.14% of the observed. Furthermore, individuals of *G. giuris* in a starved condition comprise 28.97% of the population, ranging from 4 to 4.9 cm TL (Figure 5).

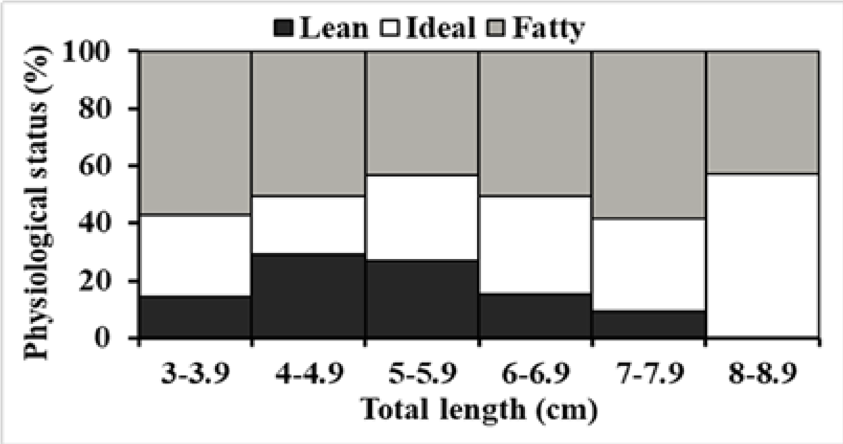

Figure 5. Physiological condition (i.e., fatty, ideal and lean) for *G. giuris* in a wetland ecosystem (*Beel* Kumari), northwestern Bangladesh

Discussion

An adequate management plan must be tailored for the river and other natural wetlands to preserve *G. guiris*. Knowledge about biometric indices is essential for formulating appropriate management and conservation strategies of any aquatic species in its natural habitat (Nadia et al., 2023). Morphometry of fish, including measurements and statistical correlation studies of various body parts, is important for both fisheries biology and a taxonomic perspective (Tripathy, 2020). These studies are an essential and highly valuable tool for maintaining fish stocks worldwide, as they provide data on condition, ontogenetic changes, growth trends, and population dynamics (Simon et al., 2009). The current research is the earliest detailed investigation of biological characteristics related to *G. giuris* (family Gobiidae) in the wetland ecosystem (*Beel* kumari), northwestern Bangladesh.

The length-frequency distribution (LFD) is an important biometric parameter that has been widely used in dynamic population models to estimate recruitment patterns, growth rates, mortality regimes, and yields in aquatic systems (Kasif et al., 2025). The maximum TL (cm) of the species recorded in *the Beel Kumari aquatic system, NW Bangladesh, was 8.5 cm, which is also low compared to* other aquatic habitats. For instance, the maximum size observed fish in the Red River, Vietnam as 27.0 cm (Tran et al., 2021), as well as in Chilika Lagoon, India values exceeded by a large extent, as 29.1 cm (Karna et al., 2020). Intermediate lengths were obtained from the Hongshu River in China at 7.5 cm (Que et al., 2015). The difference in maximum sizes observed at the ecosystem level was remarkable and supports the overall idea that local environmental factors, including perhaps fishing and population structure, affect growth. Life-history features, that involves growth trends (isometric or allometric), were evaluated using the length-weight relationship (Samad et al., 2022). The length-weight relationship (LWR) serves as an indication of a fish's growth trend, with a regression coefficient (b) near 3.0 indicating isometric growth. Any deviation away from this value indicates allometric growth, with $b >$ 3.0 representing positive allometry, whereas $b < 3.0$ indicates negative allometry (Zhang et al., 2025). The current study recorded a negative allometric growth pattern that indicates relatively less weight than length increase was gained and makes a slender body at the observed condition. In this study, the length-weight relationship exponent (*b-value) was estimated at 2.87 for G. giuris in the Beel* Kumari wetland, indicating negative allometric growth. *Beel* Kumari has a negative allometric growth curve, indicating a slower rate of weight gain with length. This value is similar to those obtained in the Red River, Vietnam (2.90, Tran et al., 2021) and the Hongshui River, China (2.93; Que et al., 2015); indicating a conserved growth pattern within comparable ecological conditions. A higher *b* value (3.01) was obtained from Chilika Lagoon, India (Karna et al., 2020), indicating isometric growth which might be because of increased food availability and optimal habitat conditions. These differences in *b-values across ecosystems illustrate the effects* of habitat type, resource availability, hydrological regime, and anthropogenic disturbance on fish growth patterns.

The condition factor is a well-known indicator of fish condition that can be used as an index to evaluate the impact of both biotic and abiotic environmental variables on the physiological state (Anene, 2005). Values for K_A, K_F, and *KR were* 0.0086-0.0175, 0.7133–1.4927, and 0.7350-1.4887 with mean 0.0119 ± 0.001, 0.9597 ± 0.110, and 1.0162 ± 0.113, respectively. In general, the condition factor values are appropriately extended to the ecologically compatible ecosystem of the study area for *G. giuris*. Relative weight (W_R) was between 73.50 and 148.87, with a mean of 101.62 ± 11.38. An average W_R just greater than 100 suggests that the population of *G. giuris* is prey-abundant and predator-limited rather than prey-limited. A few variations were observed; however, the majority of individuals showed WR values near or above the reference level, indicating a very healthy population structure in a wetland ecosystem. Furthermore, *G. giuris* of W_R were slightly lower than 100 (p<0.0001), indicating that the habitat at *Beel* Kumari, northwestern Bangladesh, is prey-rich and predator-scarce.

The form factor ($a_{3.0}$) of *G. giuris* is 0.0078, estimated in the *Beel* Kumari wetland, which is less than that reported from relatively open or lotic systems such as Chilika Lagoon (India), Gorai River and Ganges River (Bangladesh), and Hongshui rivers (China), but more than those given for Red River (Vietnam), showing a region-specific morphological plasticity. This relatively reduced body size indicates a body morphology geared toward maneuverability over continuous high-speed swimming, probably indicative of adaptive responses to the structurally complex wetland habitat, localized hydrological conditions, and food resource availability, in line with consistent patterns observed across regional populations (Mawa et al., 2022). The outcomes from the current investigation indicated that L_m (*Beel* Kumari 5.4 cm TL) of *G. giuris* is much lower than those in the Red River (Vietnam), Chilika Lagoon (India), and Ganges and Gorai River, Hongshui River (China), suggesting regional specificity of maturation length. This relatively low L_m is likely related to earlier maturation in response to adverse water conditions and ecological stress (Neuheimer and Grønkjær I, 2012). Regional differences in L_m suggest that a single global value for maturation should be approached with caution, while reinforcing the need to develop adaptive, region-specific prior distributions for stock assessments under ecological pressure.

Harvesting *G. giuris* in the 7.0-7.9 cm TL range, based on current physiological status and growth patterns, should be approached cautiously to avoid compromising recruitment and stock structure; while this size class may offer favorable flesh yield and robust condition, it risks removing individuals before reaching maturation in some populations and could shift growth and maturation trajectories. In addition, a targeted investigation of the breeding season is recommended to deepen understanding of reproductive timing and energy allocation in this ecosystem, thereby enhancing interpretation of maturation shifts.

Conclusion

The current aspect of *G. giuris* from *Beel* Kumari shows the negative allometric growth and early sexual maturation at a size 5.4 cm, which is the lowest value recorded in the world perspective. These findings suggest that habitat alteration could affect their growth and reproductive strategies, thereby threatening their long-term survival. Hence, management measures are needed, such as size-structured harvesting regulations and the preservation of their juvenile habitats, to ensure the sustained viability of *G. giuris* and the whole *Beel* Kumari wetland system for the future. Furthermore, ecological pressure has a significant effect on maturation and growth compared to other water bodies. Such approaches help protect the environment, facilitate biodiversity conservation, and support the retention of sustainable fisheries management amid ecological pressures.

Conflicts of Interest

The authors declare no conflicts of interest.

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Author Contributions

M.S.H.: Conceptualization, Formal analysis, Writing - original draft; **S.I.:** Data curation, Writing - original draft; **S.A.:** Data curation, Visualization; **T.A.K.:** Formal analysis, Writing - review and editing, **M.M.H.:** Software, Methodology; **M.S.R.:** Writing - review and editing; **M.F.I.:** Writing - review and editing, Supervision. All authors have read and approved the final manuscript.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethics Statement

The fish specimens utilized in this study were deceased at the time of acquisition from the fishermen. Consequently, no specific animal rights or welfare considerations were noted during the fieldwork.

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