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Breeding biology, morphometric relationships and condition Factor of *Lepidocephalichthys guntea* (Hamilton, 1822)

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ABSTRACT. *Lepidocephalichthys guntea*, commonly known as loach, is a popular freshwater fish found in various water bodies. This study collected 210 specimens (148 females, 62 males) from fish markets in Noakhali, Bangladesh, to measure various length, weight, gonado-somatic index (GSI), fecundity and condition factor. To establish correlations, the relationships between length-length, length-weight, and GSI with both length and weight were analyzed. Body weight ranged from 1.99 to 8.89 g (mean 4.21 ± 1.49 g), and total length from 6.5 to 10.3 cm (mean 7.91 ± 0.77 cm). GSI peaked in June (8.63±1.16%), followed by May (6.58±0.89%), with the lowest values in September (0.01%). Mean fecundity was 7415.3±1168.54 in May and June (spawning season). The condition factor (K_F) was highest (1.04) in fish between 9.5–10.4 cm and lowest (0.87) in the 7.5–8.4 cm group. The coefficient of correlation (r^2) values showed a strong positive relationship between body weight (BW) and both total length (TL) and standard length (SL). Moderate positive correlations were found between BW and head length (HL), and BW and body circumferences (BD) in pooled and female samples. However, in male, the correlations for BW vs. HL, BW vs. BD, as well as TL vs. HL and TL vs. BD, were asymmetrical. The relationships between GSI and both BW and gonad weight (GW) showed moderate positive correlations. Conversely, the coefficient of correlation between GSI and TL in the pooled sample, and GSI with both TL and BW in males, were indicating weak correlations. This study will provide valuable insights for conservation policymakers and hatchery owners, aiding in efforts to prevent the extinction of this species in the wild.

Keywords: Length-weight relationship, Gonado-somatic index, Fecundity, Loach, Condition factor

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1. Introduction

The length-length and length-weight relationship of fish are important models in the field of fisheries biology and ecology (Kodeeswaran et al., 2023; Ferosekhan et al., 2022, Rana et al., 2022; Paul et al., 2021b; Loh et al., 2011). It serves as a valuable tool for researchers and fisheries managers, enabling them to estimate the weight of fish by considering their length, and vice versa. The significance of this connection is in its contribution to the comprehension of fish development patterns (Sarker et al., 2022; Awasthi et al., 2015), the evaluation of fish populations (Patiyal and Mir, 2017), and the facilitation of informed decision-making within the fishing sector (Samad et al., 2022).

Bangladesh is fortunate to have several inland freshwater bodies (4706171 ha) support a rich diversity of aquatic species, with fish providing over 60% of the nation's animal protein intake, where has significant contribution of small indigenous species (DoF, 2023). Moreover, small indigenous fish species (SIS) offers a unique opportunity to contribute to optimal nutrition during the first 1000 days of life, due to their content of both fatty acids and micronutrients such as iron, zinc, calcium, vitamin A, and vitamin B12,18 (Bogard et al.,2015; Paul et al., 2023). In fact, SIS pro-

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vide better nutrition because they are frequently consumed whole, including the head, bones, and eyes, utilizing all available nutrients, including micronutrients (Islam et al.,2023) These minerals are also essential for developing resistance against disease in human body (Mitra et al., 2022).

In fact, small indigenous species (SIS) are a major source of animal protein for Bangladesh's rural residents. However, there is little care for the species' biodiversity, which is steadily declining. One of the significant SIS species that can be found in Bangladeshi freshwater bodies is *Lepidocephalichthys guntea*, locally known as gutum. This species of fish is one of those recognized by the IUCN as being vulnerable in Bangladesh (IUCN Bangladesh, 2015). Freshwater bodies are the main habitat of *L. guntea.* The species recorded from Chalan Beel (flood plain area), Halti beel (flood plain area) hill streams of Mymensingh, Sylhet and Dinajpur (Akand et al., 2015). *L. guntea* found mostly in swift streams but also available in swamps and lakes (Samad et al., 2022). They prefer bottoms that are primarily sandy or fine gravel so that they may quickly flee from any danger. Recently, artificial breeding and fry production of this endangered SIS species have successfully developed (Sayeed et al., 2009). However, the assessment of the probability of this fish in the fresh water bodies, biological research of this species is essential to know more details on it.

Length-weight relationship (LWR) and Gonado somatic index of any fish species is a significant biological parameter in studying its growth dynamics, production, stocking density, productivity of the habitat and maturity etc. (Rana et al., 2022; Paul et al., 2021a; Hanif et al., 2020; Borah et al., 2020; Garcia, 2010). LWR and condition factor (K) also gives various information like well-being of fish in relation to habitat, its status of stock variation, assessment of growth rate, appearance of first maturity and time of spawning (Awasthi et al., 2015; Kaushik et al., 2015). In addition, GSI and fecundity values are frequently used to compare reproductive condition across individuals or across different groups of individuals. Besides, several studies successfully used GSI and fecundity values to improve accuracy in determining maturity stage or breeding season of the species (Ali et al., 2021; Paul et al., 2021c; Ganias et al., 2007; Vitale et al., 2006).

Till now, several studies have been conducted on the morphometric and meristic characteristics, length-weight relationship and condition factor of this fresh water fish *L. guntea* in India, Nepal and Bangladesh (Saha et al., 2021; Mandal and Mandal, 2021; Saha et al., 2019; Dhakal and Subba, 2003). However, there is not a single study on the relationship among gonad somatic index, length and weight of gutum fish. In fact, GSI and its relationship with length-weight study is quite unique way to understand the biology of any particular species. So, this piece of research work was designed to illustration the relationship through collect the sample from southeast Bangladesh.

2. Materials and Methods

2.1. Study Area and period

This research aimed to collect samples from the fish retail market of southern Bangladesh, to get the targeted fish from multiple aquatic resources. As a part of these three main fish markets of Noakhali district, Bangladesh such as Poura fish market (22°51'46.3"N 91°05'48.2"E), Maijdee fish market (22°52'21.4"N 91°05'31.7"E) and Sonapur fish market (22°49'25.4"N 91°06'05.1"E) were selected randomly for collection of targeted sample. Noakhali is very rich in fish biodiversity and known as hotspot for the fisheries. This species (*L. guntea*) is frequently found from the month of April to July in various water body (ponds, shrimp farms, rivers, canals, floodplains and estuaries) (Sayeed et al., 2009). The study was conducted from September 2018 to August 2019 and the species *L. guntea* was collected from the fish market in every 15 days interval.

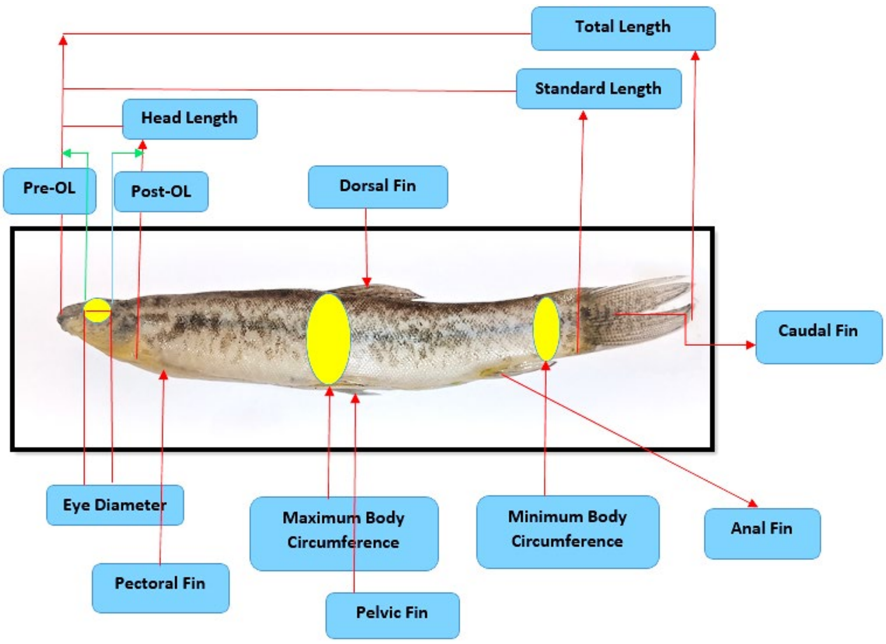

Fig.1. Measurement of morphometric parameter of *L. guntea*

2.2. Sample collection and preservation

A 210 samples were collected from the fish market in very early morning so that it can collect in fresh condition. The samples were generally chosen randomly to avoid the bias. After collection, all samples were immediately preserved with 10% formalin solution (where 10% formalin + 90% water) which helped to stop digestion of food material and autolysis, later all the samples were bring in the laboratory.

2.3. Measurement of morphometric parameters

Before measure the length and body weight, the excess water in fish body was removed by blotting paper. Slide caliper scale (±0.01 mm precise, EAGems-B00Z5KETD4) was used to determine the length of the species and electrical balance (Shimadzu UX320G) was used to determine weight of each specimen (±0.01 gm). Morphometric measurement was determined i.e. body weight (BW), total length (TL), standard length (SL), head length (HL), post-orbital length (Post-OL), and body diameter/circumferences (BD) of each specimen (Fig. 1).

For measurement of gonadosomatic index (GSI) and fecundity of female species, each female species was separated from male species on the basis of gonad. After collection of ovaries, those were dried with the blotting paper and weighted individually by an electric balance (Shimadzu UX320G) and stored in 10% formalin to the preserve the ovaries for further analysis of fecundity. A visual inspection was utilized to identify large-sized, while the staining technique involving aceto-carmine was employed to visualize tiny-sized gonads. Subsequently, the samples were examined under a light microscope to enhance contrast and facilitate clear visualization of ova. This method, described by Wassermann and Afonso in 2002, allowed for confirmation of ovary presence upon observing small-sized ova under the microscope. The Gonado-somatic Index (GSI) was calculated using the formula of Devlaming et al., 1982. $GSI = \frac{\text{Gonad weight}}{\text{Fish weight}} \times 100$.

For estimation of fecundity, we followed the gravimetric method. Three sub-samples were collected from the ovary's front, middle, and posterior sections. The number of eggs in each sample was counted, and fecundity was determined using the formula below (Behera et al., 2010): $F = \frac{\text{Gonad weight (G)} \times \text{Number of eggs in sub sample(n)}}{\text{Sub-sample weight(g)}}$,

where "F" is fecundity, "n" is the average number of eggs, "G" is the weight of the gonads and "g" is the weight of the subsample.

The well-being or plumpness of each species has been studied by using Fulton's condition factor. In this experiment, we calculated the condition factor for the pooled sex, female and male fishes. Fulton's condition factor has been calculated by using following formula Froese, 2006:

$$K_F = W \times 100/ L^3,$$

where, 'K_F' is Fulton's condition factor. 'W' is net wet weight (gm) of fish and 'L' is length in cm. The factor 100 is employed to bring K_F close to unity.

2.4. Length-Weight Relationship of Gutum Fish (*L. guntea*)

A total of 210 specimens of *L. guntea* were taken for calculating of length-weight relationship (LWRs). In this experiment, we calculated the LWRs of pooled sex, female and male fishes. The LWRs was calculated by Le Cren's (1951) formula as mentioned below;

$$W = aL^b$$

(Here, W = weight of fish (gm), L = total length of fish (cm), a = intercept. b = regression coefficient.

Logarithm-transformation of the linear regression equation, Log W = log a + b log L, was used to obtain the parameters a, b, and r^2 (coefficient of determination) (Garcia, 2010). The degree of relationship of pooled, female, male (BW *vs* TL, BW *vs* SL, BW *vs* HL and BW *vs* BD) were evaluated by calculating the coefficient of determination where a is a coefficient related to body form and b is an exponent indicating isometric growth when equal to 3 and indicating allometric growth when significantly different from 3 (Simon et al., 2009; Simon et al., 2008).

2.5. Length-length relationship of *L. guntea*

The length-length relationships between various body lengths and total length were established using the method of least squares to fit a simple linear regression model expressed as Y = a + bX. Here, Y represents the different body lengths, X denotes the total length, a stands for the proportionality constant, and b signifies the regression coefficient. This modeling approach was employed in a study conducted by Erguden and Turan, 2011. The length-length relationship of pooled sex, female and male fishes were calculated among the lengths of TL *vs* SL, TL *vs* HL, and TL *vs* BD.

2.6. Relationship between GSI and other morphological parameters of *L. guntea*

Calculate the relationship between GSI *vs* TL, GSI *vs* BW, GSI *vs* GW of female with using a simple linear regression model expressed as Y = a + bX. Where Y represents the total length (TL), body weight (BW) and gonad weight (GW), and X denotes the GSI, 'a' stands for the proportionality constant, and 'b' signifies the regression coefficient.

2.7. Statistical Analysis

Relationship between length-length, length-weight and GSI with other morphological characters were analyzed by the software of SPSS version 22 (IBM®, New York, USA) and MS-Excel at 5% level of significance ($P < 0.05$). Data has been presented as mean ± standard deviation.

3. Result

3.1. Morphometric Characteristics

The body of *Lepidocephalichthys guntea* is characterized by its elongated, slightly compressed shape and an inferior mouth position. When considering both sexes together, the range of morphometric measurements were as follows: body weight (BW) ranged from 1.99 to 8.89 gm (mean 4.21 ± 1.49 gm), total length (TL) ranged from 6.5 to 10.30 cm (mean 7.91 ± 0.77 cm), standard length (SL) ranged from 5.10 to 8.80 cm (mean 6.52 ± 0.68 cm), head length (HL) ranged from 0.6 to 1.70 cm (mean 1.19 ± 0.14 cm), post-orbital length (Post-OL) ranged from 0.30 to 0.60 cm (mean 0.51 ± 0.07 cm), and body circumferences (BD) ranged from 3.0 to 4.90 cm (mean 3.79 ± 0.42 cm) (Table 1). The mean values of body weight (BW), total length (TL), standard length (SL), head length (HL), post-orbital length (post-OL), and body circumferences (BD) for females were 4.69 ± 1.44 gm, 8.02 ± 0.74 cm, 6.74 ± 0.65 cm, 1.22 ± 0.14 cm, 0.51 ± 0.07 cm, and 3.90 ± 0.42 cm, respectively. For males, the corresponding mean values were 2.98 ± 0.56 gm, 7.27 ± 0.47 cm, 5.99 ± 0.39 cm, 1.12 ± 0.10 cm, 0.50 ± 0.07 cm, and 3.52 ± 0.31 cm (Table 1). It was estimated that, with the increase of total length, other morphometric measurement values like body weight, standard length, head length, post-orbital length, and body circumferences are also increasing gradually. That indicates, the dependent variable (standard length, head length, post-orbital length, body circumferences) are highly correlated with an independent variable of total length.

3.2. Gonado somatic Index and Fecundity of *L. guntea*

L. guntea starts to prepare itself for breeding from the month of April to July. The study measured the GSI value of this species which was higher (8.63 ± 1.16%) during the month of June compare to other months (Table 2). This indicates that the peak breeding season was in June. Highest fecundity rate counted 9913 in June also. The decending order of GSI value was 8.63 ± 1.16% (June) > 6.58 ± 0.89% (May) > 5.44 ± 1.42 (July) > 5.25 ± 1.03 (April) > 2.77 ± 0.51% (March) > 1.6 ± 0.56% (August) > 1.34 ± 0.37% (February) > 0.1 ± 0.02% (January) > 0.01 ± 0.00% (September) > December > November > October (Table 2). In this study, the GSI value exhibited an increase from the month of March (Pre spawning Phase) and declined from the July (Spawning Phase), respectively. The mean value of fecundity was 7415.3 ± 1168.54 in the spawning season, respectively (Table 2). Compare to other months, July and august area the spawning season of *L. guntea* in this study basis on the value of GSI and fecundity.

3.3. Condition Factor

In general, Fulton's condition factor (K_F) expressed the condition of a fish, such as the degree of well-being, relative robustness, plumpness or fatness in numerical terms (Fulton, 1904). The condition factor for the length group 6.5-7.4 cm (L_1), 7.5-8.4 cm (L_2), 8.5-9.4 cm (L_3), 9.5-10.4 cm (L_4) was found 0.87, 0.79, 0.88 and 1.04 respectively (Fig. 2). The condition factor (K_F) found higher between (9.5-10.4 cm) group and the lower value was between (7.5-8.4 cm) length groups (Fig. 2). Basis on the sex, the condition factor for pooled sex, female and male fishes were 0.85, 0.86 and 0.84, respectively.

3.4. Length-Weight Relationship of *L. guntea*

To determine the length-weight parameters for male, female and the pooled (both male & female) spe-

Table 1. Morphometric measurement values (mean ± standard deviation) of *L. guntea*

Species		BW (gm)	TL (cm)	SL (cm)	HL (cm)	Post-OL (cm)	BD (cm)
Pooled Sex n = 210	Min	1.99	6.50	5.10	0.60	0.30	3.0
	Max	8.89	10.30	8.80	1.70	0.60	4.90
	Mean	4.21 ± 1.49	7.91 ± 0.77	6.52 ± 0.68	1.19 ± 0.14	0.51 ± 0.07	3.79 ± 0.42
	95% Cl	4.01-4.41	7.80-8.01	6.42-6.61	1.17-1.21	0.50-0.52	3.73-3.84
	% TL	_	100	82.43	15.04	6.45	47.91
Female n = 148	Min	2.83	6.50	5.25	0.60	0.30	3.10
	Max	8.89	10.30	8.80	1.70	0.60	4.90
	Mean	4.69 ± 1.44	8.02 ± 0.74	6.74 ± 0.65	1.22 ± 0.14	0.51 ± 0.07	3.90 ± 0.42
	95% Cl	4.46-4.93	8.06-8.29	6.63-6.84	1.19-1.24	0.50-0.52	3.83-3.97
	% TL	_	100	82.37	14.90	6.25	47.68
Male n = 62	Min	1.99	6.50	5.10	0.70	0.30	3.00
	Max	5.25	8.20	6.80	1.40	0.60	4.30
	Mean	2.98 ± 0.56	7.27 ± 0.47	5.99 ± 0.39	1.12 ± 0.10	0.50 ± 0.07	3.52 ± 0.31
	95% Cl	2.90-3.22	7.17-7.36	5.90-6.08	1.09-1.14	0.49-0.52	3.45-3.59
	% TL	_	100	82.44	15.36	6.90	48.42

Note: TL = Total length, BW = Body weight, SL = Standard length, HL = Head length, Post-OL = Post-orbital length, BD = Body circumferences.

Table 2. Variations of Gonad somatic index (GSI) and fecundity in fish *Lepidocephalichthys guntea* from Noakhali, Bangladesh.

Subject	Resting Phase		Preparatory Phase		Pre spawning Phase		Spawning Phase			Post spawning phase		
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.
GSI	0.0 ±0.0	0.0 ±0.0	0.1 ±0.02	1.34 ±0.37	2.77 ±0.51	5.25 ±1.03	6.58 ±0.89	8.63 ±1.16	5.44 ±1.42	1.6 ±0.56	0.01 ±0.00	0.0 ±0.0
Mean	0.0±0.0		0.72±0.48		4.01±0.71		6.88±1.09			0.57±0.17		
Fecundity	NC	NC	NC	NC	NC	NC	6123 ±831.4	9913 ±1073.7	6210 ±958.5	NC	NC	NC
Mean	NC		NC		NC		7415.3±1168.54			NC		

Note: NC-not counted

cies of *L. guntea,* all the data of lengths were categorized first (Table 1). The result shows, significant ($P < 0.05$) relationship existed between body weight and various lengths and of *L. guntea*.

The coefficient of regression (r^2) values indicated a strong positive relationship between body weight (BW) and total length (TL), as well as between BW and standard length (SL) (Table 3). A moderate positive relationship was observed between BW and head length (HL), and BW and body circumferences (BD) in the pooled and female samples of *L. guntea*. However, in the male specimens of *L. guntea*, the distribution of the correlation was not symmetrical for BW vs. HL and BW vs. BD (Table 3). The analysis suggests that the growth pattern of *L. guntea* with respect to body weight and various length measurements were negatively allometric (Table 3).

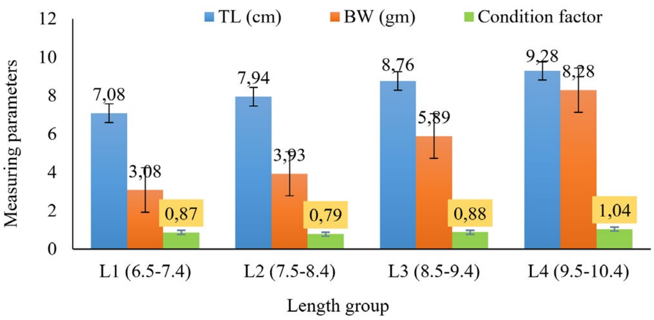

Fig.2. Condition factors of *L. guntea* based on different length groups

3.5. Length-Length relationship of *L. guntea*

In all of category (Pooled, female, male), the value of coefficient of regression for total length (TL) and standard length (SL) existed between the range of ($0.7 < r^2 < 1.0$) which indicates very strong positive correlation. Moderate positive correlation existed between TL vs HL, TL vs BD in pooled and female fishes (Table 4). However, the correlation distribution was not symmetrical for TL vs. HL and TL vs. BD in male fish, when $r \neq 0$, hence we use the Z distribution over fisher transformation to create the confidence interval (Table 4). The growth pattern among the various length measurements was negatively allometric (Table 4).

Table 3. Estimated parameters of the length-weight relationships of *Lepidocephalichthys guntea* in Bangladesh.

Species	Regression parameters									
	Equation	a	b	95% CI of a		95% CI of b		r^2	p	Growth Type
				LCI	UCI	LCI	UCI			
Pooled Sexes $n = 210$	BW = a + b × TL	-1.93	2.83	-2.14	-1.73	2.60	3.06	0.74	0.00	Neg. Allometric
	BW = a + b × SL	-1.65	2.77	-1.82	-1.48	2.56	2.99	0.76	0.00	Neg. Allometric
	BW = a + b × HL	0.52	1.07	0.49	0.55	0.75	1.40	0.17	0.00	Neg. Allometric
	BW = a + b × BD	-0.56	2.02	-0.73	-0.39	1.73	2.31	0.47	0.00	Neg. Allometric
Female $n = 148$	BW = a + b × TL	-1.98	2.88	-2.21	-1.74	2.63	3.14	0.77	0.00	Neg. Allometric
	BW = a + b × SL	-1.52	2.63	-1.72	-1.33	2.40	2.87	0.77	0.00	Neg. Allometric
	BW = a + b × HL	0.58	0.83	0.55	0.62	0.48	1.19	0.13	0.00	Neg. Allometric
	BW = a + b × BD	-0.43	1.85	-0.63	-0.24	1.52	2.17	0.46	0.00	Neg. Allometric
Male $n = 62$	BW = a + b × TL	-0.86	1.55	-1.61	-0.11	0.68	2.42	0.18	0.00	Neg. Allometric
	BW = a + b × SL	-0.81	1.65	-1.37	-0.24	0.92	2.38	0.26	0.00	Neg. Allometric
	BW = a + b × HL	0.47	0.13	0.44	0.50	-0.37	0.62	0.00	0.62	Neg. Allometric
	BW = a + b × BD	0.15	0.60	-0.17	0.47	0.01	1.19	0.07	0.05	Neg. Allometric

Note: a = intercept. b = regression coefficient; Cl = confidence limit; r^2 = coefficient of correlation

Table 4. Estimated parameters of the length-length relationships of *Lepidocephalichthys guntea* in Bangladesh.

Species	Regression parameters									
	Equation	a	b	95% CI of a		95% CI of b		r²	p	Growth Type
				LCI	UCI	LCI	UCI			
Pooled Sexes $n = 210$	TL = a + b × SL	0.61	1.12	0.34	0.88	1.08	1.16	0.93	0.00	Neg. Allometric
	TL = a + b × HL	4.59	2.78	3.81	5.37	2.13	3.44	0.25	0.00	Neg. Allometric
	TL = a + b × BD	3.05	1.28	2.34	3.76	1.09	1.47	0.47	0.00	Neg. Allometric
Female $n = 148$	TL = a + b × SL	1.00	1.07	0.68	1.31	1.02	1.11	0.93	0.00	Neg. Allometric
	TL = a + b × HL	5.21	2.44	4.33	6.09	1.72	3.15	0.24	0.00	Neg. Allometric
	TL = a + b × BD	3.46	1.21	2.64	4.28	1.00	1.42	0.47	0.00	Neg. Allometric
Male $n = 62$	TL = a + b × SL	1.51	0.96	0.74	2.29	0.83	1.09	0.79	0.00	Neg. Allometric
	TL = a + b × HL	7.19	0.07	6.13	8.25	-0.88	1.02	0.00	0.89	Neg. Allometric
	TL = a + b × BD	6.58	0.20	5.41	7.75	-0.14	0.53	0.02	0.25	Neg. Allometric

Note: a = intercept. b = regression coefficient; Cl= confidence limit; r^2= coefficient of correlation

3.6. Relationship between Gonado-somatic index (GSI) and morphometric parameter

The relationships between the gonadosomatic index (GSI) and body weight (BW), as well as between GSI and gonad weight (GW), showed moderate positive correlations, with coefficient of correlation (r^2) values below 0.50 (Table 5). In contrast, relationships such as GSI vs. total length (TL) in the pooled sample, GSI vs. TL in males, and GSI vs. BW in males were not symmetrical, with coefficient of correlation (r^2) values close to or equal to zero, indicating weak or insignificant correlations (Table 5).

4. Discussion

Life history traits are very important for any species and it's basically carried out for the conservation and management of wild fisheries (Rana et al., 2022; Que et al., 2015; Young et al., 2006;). Thus the present study focused on its important biological feature like length- weight relationship, length -length relationship and the relationship among Gonad somatic index with length and weight. From the very recent study Saha et al. (2021) recorded, *L. guntea* may reach highest 10.5cm in length in Bangladesh where the present study recorded the average length of *L. guntea* 7.91cm. However, the highest length of this species recorded 15cm (Froese and Pauly, 2021). The environmental conditions like heavy stock size may be the possible feature for the highest recorded length compare to the present study. Besides, highest weight was recorded for the female species which is similar to the findings of Kangsabati river (Mandal and Mandal, 2021). In fact, the heterogeneity of morphometric characters may vary due to difference in physiological activities like feeding, stress, photoperiod and light regime, circannual and circadian rhythms etc in the male and female fish (Sudasinghe et al., 2023; Rana et al., 2022; Patiyal and Mir, 2017).

It was observed that the values of 'b' were higher in females than those of males may be due to the enormous growth of ovaries in the females as compared to that of testes in the males. The similar results also observed in other literature conducted their study in different aquatic bodies (Mandal and Mandal, 2021; Saha et al., 2021; Paul et al., 2021b; Dhakal and Subba, 2003). The degree of variation of 'b' value takes place with sex feeding; developmental stages of the gonad, especially the ovary affect the weight different population of a species (Paul et al., 2021b; Simon et al., 2008; Vitale et al., 2006). The values of 'a' and 'b' not only vary in different species but also sex, maturity stage, feeding intensity etc. vary in same species. The study revealed that the 'b' value for the length-weight and length-length relationships was below 3, indicating negative allometric growth, while positive allometric growth was observed between GSI and BW in pooled and female fish. The value of 'b' indicates from the present finding that weight increases more than with the increase of length. But in case of male, weight was not increased along with the increase of length. The negative allometric growth observed in males is likely due to energy loss during breeding behavior, as noted in the present study. This finding is consistent with the observations made by Kumari et al., 2021; Paul et al., 2021a; Patiayal and Mir, 2017.

Measuring the condition factor offers valuable insights into fish health and habitat conditions. In this study, the condition factor of *Lepidocephalichthys guntea* varied across three size groups, all showing values below 1. This is likely due to their detritivorous nature and preference for muddy habitats, which may lower their condition. Poor ecosystem services negatively impact fish spawning rates and spawning seasons (Taylor et al., 2019; Biswas, 1993; Froese, 2006). Saha et al. (2019) reported condition factors between 0.78 and 1.34, consistent with this study's findings. A condition factor below 1 suggests that most *L. guntea* in this ecosystem are not in optimal health (Paul et al., 2021a; Mandal and Mandal, 2021; Paul et al., 2021b; Awasthi et al., 2015; Froese, 2006).

Measuring GSI and fecundity provides key insights into the reproductive health and spawning season of fish (Kumari et al., 2021). Reproductive biology

Table 5. Relationship between the gonado-somatic index (GSI) and body parameters of *Lepidocephalichthys guntea* from Noakhali, Bangladesh.

Species	Regression parameters									
	Equation	a	b	95% CI of a		95% CI of b		r^2	p	Growth Type
				LCI	UCI	LCI	UCI			
Pooled Sexes $n = 210$	GSI = a + b × TL	-1.96	2.06	-3.05	-0.86	0.96	3.16	0.05	0.00	Neg. Allometric
	GSI = a + b × BW	-5.24	5.57	-6.19	-4.29	4.58	6.57	0.32	0.00	Pos. Allometric
	GSI = a + b × GW	0.40	0.60	0.31	0.49	0.50	0.69	0.39	0.00	Neg. Allometric
Female $n = 148$	GSI = a + b × TL	-1.40	1.68	-2.52	-0.28	0.57	2.78	0.05	0.00	Neg. Allometric
	GSI = a + b × BW	-5.56	5.91	-6.84	-4.28	4.62	7.21	0.32	0.00	Pos. Allometric
	GSI = a + b × GW	0.50	0.60	0.39	0.60	0.45	0.75	0.27	0.00	Neg. Allometric
Male $n = 62$	GSI = a + b × TL	0.85	-1.23	-2.13	3.83	-4.32	1.85	0.01	0.43	Neg. Allometric
	GSI = a + b × BW	-2.80	2.78	-5.68	0.08	-0.46	6.02	0.04	0.09	Neg. Allometric
	GSI = a + b × GW	0.10	0.48	-0.07	0.26	0.36	0.61	0.43	0.00	Neg. Allometric

Note: a = intercept. b = regression coefficient; Cl = confidence limit; r^2 = coefficient of correlation

is influenced by environmental conditions, as well as the age and size of fish species (Samad et al., 2022; Paul et al., 2021c). Saha et al. (2021) reported that *Lepidocephalichthys guntea* spawns from May to August, with a peak in July, a finding consistent with the present study. However, the fecundity rate observed here is lower, likely due to differences in the fish's length and weight. In fact, body weight, total length and gonad weight has significant relationship with the Gonado somatic index of *L. guntea* (Hasan et al., 2020) which is similar to the present study. The higher value of 'b' in females and pooled sex revealed that, the body-weight relationships with GSI might be affected by the general condition of appetite and gonadal contents of the fish (Paul et al., 2021b; Devlaming et al., 1982). The b value for both male, female and combine sex range between 0.483-5.91 which means the gonado-somatic index has both positive and negative allometric relationship with body weight, length and gonad weight. In fact, the length-weight relationship with GSI in fish is affected by a number of factors including sex, diet, stomach fullness, health, and preservation techniques as well as season and habitat (Ferosekhan et al., 2022; Kumari et al., 2021; Paul et al., 2021c; Devlaming et al., 1982).

5. Conclusion

In this study, the highest recorded weight of *Lepidocephalichthys guntea* was 8.89 g. The breeding season was identified as May to June based on GSI values and fecundity. The condition factor (KF) was highest at 1.04 in fish measuring 9.5–10.4 cm, and lowest at 0.87 in the 7.5–8.4 cm size group. Moderate positive correlations were found between GSI and both body weight (BW) and gonad weight (GW). The coefficient of correlation (r^2) values indicated a strong positive relationship between BW vs. total length (TL) and BW vs. standard length (SL), while moderate correlations were observed between BW vs. head length (HL) and BW vs. body circumferences (BD). Asymmetrical relationships were found within the morphometric parameters in male fish. These findings will be vital for policymakers in developing conservation strategies to protect this species in the freshwater habitats of Noakhali district, Bangladesh.

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Conflict of interests

The authors did not report any probable conflicts of interest in relation to the publication of this manuscript.

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