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Life-history traits of grey mullet, *Liza parsia* in the Passur River of Southern Bangladesh: Implications for effective management

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Abstract. The study of life-history features of least-concerned fishes like *Liza parsia* is critical for developing long-term management and conservation methods for this species. The current study delivers the very first detailed clarification of life-history traits (LHT), containing length-frequency distribution (LFD), length-weight and length-length relationships (LWR and LLR), form factor ($a_{3.0}$), condition factors, length at first sexual maturity (L_m), natural mortality (M_w) and optimum catchable length (L_{opt}) of *L. parsia* from the Passur River in southern Bangladesh. Fish samples (n =150) were randomly collected from May to August 2021, using gill nets. Each individual fish's total length (TL), fork length (FL), standard length (SL), and bodyweight (BW) were recorded. The size classes of TL were 15–17cmleadingmaximum sizes among the fish population. Length-Weight relations (LWR) from exponential b values (TL vs. BW) revealed a negative allometric growth trend (b = 2.6174). The b value based on the LLR similarly specifies the identical growth configuration. The $a_{3.0}$ score was determined to be 0.01, demonstrating that the fish has extended body morphology. K_F is the finest method for measuring the well-being of *L. parsia* in the Passur River among the four types of condition parameters. Moreover, W_R also showed a significant deviation from 100 ($p < 0.05$) signifying an unstable habitat for *L. parsia*. The calculated L_m, M_w and L_{opt} values were 11.20 cm in TL, 0.76/year and 12.64 cm in TL respectively. As a consequence, the findings of this research could be conducted in the future to effectively manage this species in the Passur River, and its interconnecting environments.
Keywords: *Liza parsia*, Condition factor, Sexual maturity, Passur River

Introduction

Fish LHTs are important criteria for fish biodiversity conservation and regular assessments of local fish populations (Samad *et al.* 2021). In the last few years, plethora of LHT studies have been conducted in a variety of fish species from a variety of riverine ecosystems, including length-frequency distribution (LFD) (Muchlisin *et al.* 2010), length–weight relationships (LWR) (Islam *et al.* 2021), condition factors (Rao and Lakshmi 2011), and length at sexual maturity (Saha *et al.* 2021). A crucial biometric measure for assessing fish recruitment rates, growth performance indicators, and mortality rates solely depend on LFD (Neuman and Allen 2007). LFD is also used to evaluate standing biomass and spawning season stocks in rivers to monitor their health (Sabbir *et al.* 2020). Oppositely, LWRs and LLRs (Length-Length Relationships) are biometric directories for comparing a range of eco-physiological aspects (Sabbir *et al.* 2020). Furthermore, the most relevant metrics for controlling a wild population in an open water setting are LWRs and LLRs (Muchlisin *et al.* 2010). Additionally, in an aquatic habitat, form factor ($a_{3.0}$) is commonly used to predict fish body structure (Froese 2006). The condition factor is a statistic used to evaluate the development, health status and reproduction of fish (Le Cren 1951). It also denotes the health of individuals living in a certain habitat and the quality of a water body (Tsoumani *et al.* 2006). Similarly, when prey-predator status is taken into account, relative weight (W_R) is the most frequently used to quantify the condition of fish in a specific environment (Froese 2006). Despite this, a detailed study of the grey mullet, *Liza parsia* life-history traits has yet to be completed. This

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fish is known as 'Parsie' in the local community and is regarded as one of the best species for coastal aquaculture because of its high nutritional content, exceptional flesh quality, high market value, and ability to resist a wide range of temperature and salinity. Furthermore, *L. parsia* is abundant in the Passur River as well as nearby rivers in the Sundarbans Mangrove forest, which serves as a vital natural breeding and nursery ground for a variety of economically important fishes (Islam *et al.* 2015). Overexploitation, pollution, habitat loss, and a variety of problems pose a serious risk to the Passur River's fish supplies (Gain *et al.* 2015). As a result, there is an urgent need to manage and regulate a diversity of fish stocks in the Passur River. In such locations, a few researches on many aspects of the LHT of *L. parsia* were conducted. As a result, extensive information on these species like LHT is required for proper management of the *L. parsia* species and the implementation of conservation strategies for the Passur River in Bangladesh. As a consequence, for proper protection and utilization of this valuable species, the current study provides a thorough and instructive elucidation of LHT of *L. parsia* from the Passur River, including LFD, LWR, LLR, condition factors, W_R, $a_{3.0}$, L_m, M_w, and L_{opt} for proper protection and utilization of this valuable species.

Materials and Methods

Study region

The Passur River, located in southwestern region of Bangladesh, is one of the longest (142 km) and most economically significant rivers (Chowdhury 2012) in Bangladesh. The Passur River, which flows in to the Bay of Bengal via the Burishwar River, is a diverse running water system (Kumar *et al.* 2019). A huge number of people rely on fishing for their livelihoods on this river, either explicitly or implicitly. This river has a diverse range of fish and shellfish species (Gain *et al.* 2015).

Fish sampling

Fish samples were taken from the Passur River (Fig. 1.) in Bagerhat-Khulna District, Bangladesh. From May to August 2021, 150 individuals of *L. parsia* were caught using gill nets with mesh sizes of 1.4 to 2.6 cm. Fish specimens were promptly chilled on ice and preserved in a 10% buffered formalin and immediately brought to the laboratory. The total length (TL), fork length (FL), and standard length (SL) were measured with a general scale as cm, and body weight (BW) was measured with a digital balance.

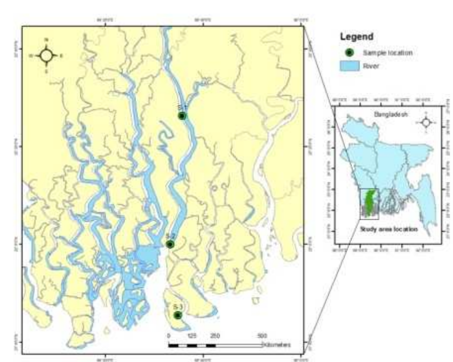

Fig. 1. Sampling locations of *L.parsia* from the Passur River in Bangladesh.

Length-frequency distribution (LFD)

To assess the age and optimum growth of fish, the LFD is required. One cm class intervals of total length (TL) were used to reveal LFD for the population of *L. parsia*. Using PAST software, a normal distribution curve was generated for the TL frequency distribution of *L. parsia* (Hammer *et al.* 2001).

Length-weight relationships (LWRs) and length-length relationships (LLRs)

The LWRs were determined using the formula $W=a*L^b$, where W represents body weight and L represents total length. The variables a and b were calculated using natural logarithms and linear regression analysis: $\ln(W) = \ln(a) + bx \ln(L)$.The coefficient of determination $r^2$and the 95% confidence intervals of a and b were also calculated. Significant differences in slopes and intercepts among the relations were investigated using analysis of covariance (ANCOVA) (Goldberg and Scheiner 2020). A linear regression model was used to estimate the LLRs (TL vs FL and TL vs SL).

Condition factors

Distinct populaces of the identical species can have diverse condition aspects, revealing information on food availability, breeding timing, and spawning length (Samad *et al.* 2021). The condition factor can also be used to assess a fish's health (Olopade *et al.* 2018). Tesch (1968) calculated the allometric condition factor (K_A) using the equation $K_A = W/L^b$, where W is the body weight, L is the total length (TL), and b represents as slope of the LWR parameters. The Fulton condition factor (K_F) was also calculated using Fulton's (1904) equation: $K_F = 100\ (W/L^3)$, where W is the BW and L is the TL. To make the K_F closer to unit, a transformation function of 100 was utilized. Additionally, the relative condition factor (K_R) was determined by following Le Cren (1951) equation: $K_R = W/(a \times L^b)$, where, W represents the BW, L represents the TL, and a and b represent the LWRs parameters. The relative weight (W_R) was computed byusing Froese (2006) approach as follows: $W_R= (W/W_s) \times 100$. Where, W_s is the predicted normal weight as calculated by the equation ($W_s = a \times TL^b$).

Form factor ($a_{3.0}$)

The $a_{3.0}$ of *L. Parsia* was computed by using Froese (2006) equation: $a_{3.0} = 10\log^{a\text{-}s\ (b\text{-}3)}$, in this equation, a and b are LWR regression parameters. Considering evidence on LWRs for this species is not available for estimation of the regression (S) of lna vs. b, a mean slope S = -1.358 was utilized in this study to assess the $a_{3.0}$.

Length at first sexual maturity (L_m)

The $L_m$of *L. parsia* was determined using the empirical model, $\log(L_m) = -0.1189 + 0.9157 * \log(L_{max})$, wher, L_{max} is the maximum length measured (Binohlan and Froese, 2009).

Natural mortality (M_W)

The model, $M_W= 1.92\text{year}^{-1} *(W)^{-0.25}$ (Peterson and Wroblewski, 1984) was used to compute the M_W of *L. parsia*, where M_W = Natural mortality at mass W; and $W = a*L^b$, where, a and b are LWR regression parameters.

Optimum catchable length (L_{opt})

The optimal catchable length (L_{opt}) is the length at which the maximum number of fish can be caught (Froese *et al.* 2018). L_{opt} was calculated using the Binohlan and Froese (2009) model: $\log L_{opt} = 1.0421*\log(L_\alpha)-0.2742$, where L_α is the asymptotic length.

Statistical analyses

Microsoft Excel and PAST software were used for data processing and statistical analysis (Hammer *et al.* 2001). The relationship between the condition parameters and TL, FL, SL, and BW was assessed using the Spearman rank correlation test. To distinguish the average relative weight (W_R) from 100, a Wilcoxon sign-ranked test was utilized. All statistical analyses were done at a significance level of 5% ($p < 0.005$).

Results

Length–frequency distribution

TLs of the *L. parsia* specimens varied from 10.20 to 19.80 cm during the study period, whereas BWs ranged from 16.00 to 66.00 g (Table I). The LFD revealed that the TL size ranges of 15.00 to 17.00 cm (representing 76.00% of the entire population) were statistically dominant in the Passur River (Fig. 2).

Table I. Descriptive statistics of *L. parsia* in the Passur River, Bangladesh

Measurements	n	Minimum	Maximum	Mean ± SD	$CI_{95\%}$ (Lower-Upper)
Total length (TL)	150	10.20	19.80	14.7376 ± 2.1432	14.3918 – 15.0833
Fork length (FL)		9.68	18.21	13.9376 ± 2.0991	13.5987 - 14.2761
Standard length (SL)		8.43	16.20	12.2832 ±1.8934	11.9778 – 12.5887
Body weight (BW)		16.00	66.00	40.0010 ± 14.0473	37.7335 – 42.2664

Abbreviations: n, sample size; CI, Confidence interval for mean values

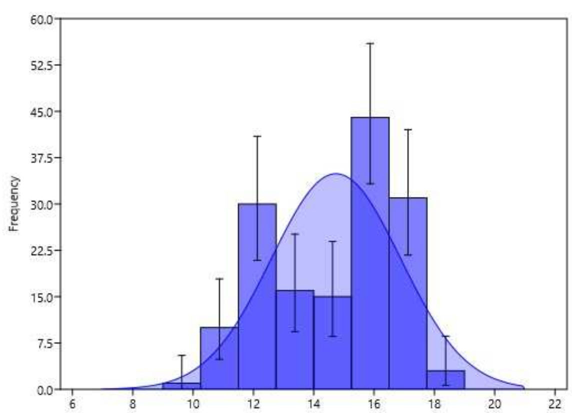

Fig. 2. Length-frequency distribution of *L. parsia* in the Passur River, Bangladesh.

Length-weight relationships (LWRs) and length-length relationships (LLRs)

The computed b value from LWR (TL vs. BW, FL vs. BW, and SLvs.BW) of *L. parsia* shows a negative allometric growth trend (Table II and Fig. 3 a, b, c). Furthermore, as shown in Fig. (3d, and e) the b value of LLR (SL vs. TL and FL vs.TL) demonstrated the similar growth pattern (b< 1). With all r^2 values more than 0.900, both connections (LWR and LLR) were found to be significant ($p < 0.05$).

Table II. Descriptive data of length–weight and length–length associations of *L. parsia* in Passur River

Formula	n	Regression Parameters		a (±95% CI)	b (±95% CI)	r^2	t_s	GP
		a	b					
BW = a x TL^b	150	0.0334	2.6174	0.0254 – 0.0441	2.5144 – 2.7203	0.9446	50.240	A-
BW = a x FL^b		0.0487	2.5301	0.0375 – 0.0633	2.4304 – 2.6298	0.9444	50.156	A-
BW = a x SL^b		0.0885	2.4199	0.0652 – 0.0441	2.5144 – 2.7203	0.9121	39.168	A-
TL = a + B x FL		0.7410	1.0047	0.3192 – 1.1632	0.9742 – 1.0341	0.9846	66.216	A-
TL = a + B x SL		1.1473	1.1064	0.6641 – 1.6293	1.0681 – 1.1452	0.9554	56.338	A-

Abbreviations: n, sample size; CI, Confidence interval for mean values; TL, total length; BW, body weight; SL, standard length; a, intercept; b, slope; r^2, co-efficient of determination, t_s, sample t-test value; GP, growth pattern; A-, Negative allometry.

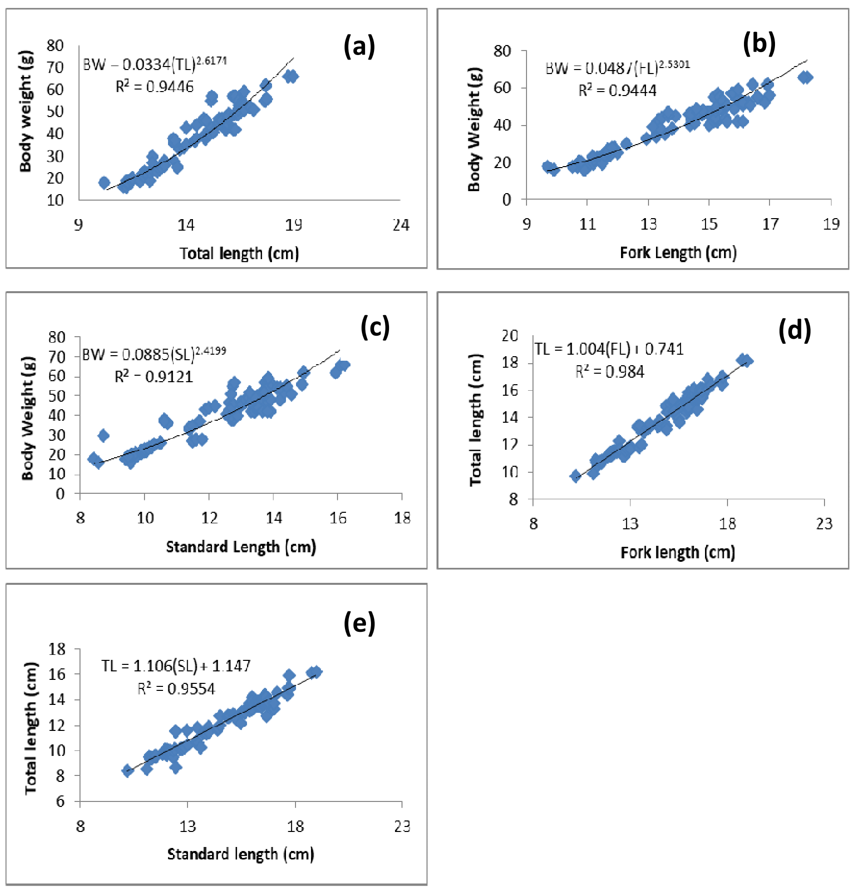

Fig. 3. Associations between total length, fork length and standard length and body weight of *L. parsia* (a, b and c) and between fork, standard and total length of *L. parsia* (d and e) in the Passur River.

Condition factors

In Table III, four types of condition indices (K_A, K_F, K_R and W_R) have been tabulated along with descriptive data. The condition factor (K_F), extremely showed significant (p < 0.05) correlation with TL, FL, SL, and BW, according to the Spearman rank correlation test (Table IV). The W_R for *L. parsia* displayed no substantial alterations from 100 (p> 0.05) according to a Wilcoxon sign-ranked test study. Table IV also shows the connections of the four condition indices with three lengths (TL, FL, and SL) and body weight (BW), whereas Figure 4shows the association between TL and WR.

Table III. Descriptive data on condition indices of *L. parsia* in Passur River

Condition indices	Minimum	Maximum	Mean ± SD	$CI_{95\%}$ (Lower-Upper)
K_A	0.0265	0.0461	0.0335 ± 0.0033	0.0330-0.0341
K_F	0.9622	1.6961	1.2067 ± 0.1396	1.1841-1.2292
K_R	0.7951	1.3788	1.0054 ± 0.1005	0.9892-1.0216
W_R	79.5138	137.8856	100.5403 ± 10.0411	98.9202-102.1603

Abbreviations: Condition factors (K_A, Allometric; K_F, Fulton's; K_R, Relative; W_R, Relative weight); and CI, confidence interval.

Table IV. Assessment of correlations for condition indices with different lengths and body weight of *Liza parsia* in the Passur River, Bangladesh

	TL	FL	SL	BW	K_A	K_F	K_R	W_S	W_R
TL	1.000								
FL	0.975*	1.000							
SL	0.945*	0.935**	1.000						
BW	0.946*	.937**	0.923**	1.000					
K_A	-0.008	0.002	0.047	0.216	1.000				
K_F	-0.615*	-0.580*	-0.554*	-0.390*	0.722*	1.000			
K_R	-0.019	-0.010	0.036	0.206*	0.997*	0.733*	1.000		
W_S	1.000*	0.975*	0.945*	0.947*	-0.008	-0.616*	-0.019	1.000	
W_R	-0.019	-0.010	0.036	0.206*	0.997*	0.733*	1.000*	-0.019	1.000

Abbreviations: r_S, coefficient of Spearman correlation test values. *Correlation is significant at the 0.05 level (2-tailed).

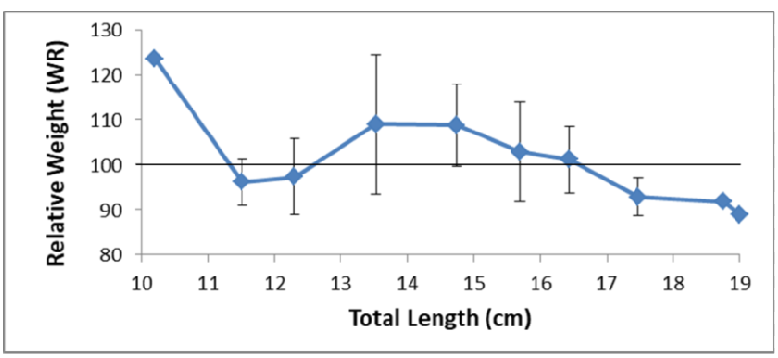

Fig. 4. Association between total length and relative weight of *L. parsia* in the Passur River.

Form factor
The estimated value of $a_{3.0}$ for *L. parsia* in the Passur River was 0.010, indicating that this fish has a fusiform body form.

Length at first sexual maturity (L_m)
During the current study, the $L_m$of *L. parsia* in the Passur River, Bangladesh, was calculated to be 11.201 cm.

Natural mortality (M_W)
The M_w of *L. parsia* in the Passur River during the current study was calculated to be 0.763/year. Furthermore, individuals with a TL less than 15.0 cm TL had a very high M_w value, whereas greater body sizes had a lower M_w value (Fig. 5).

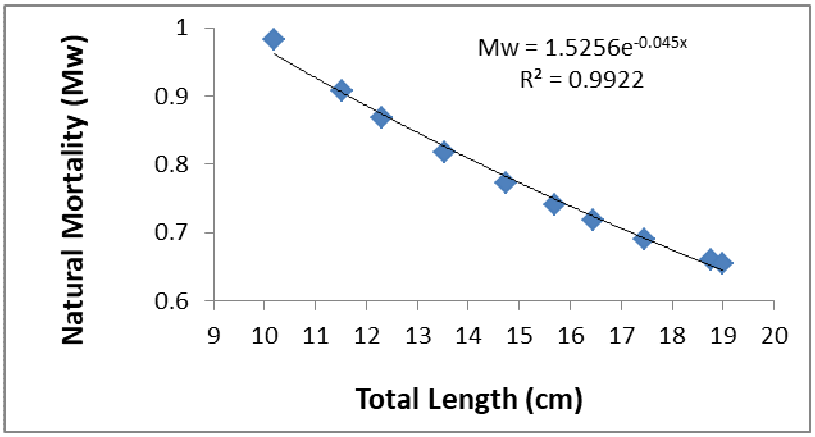

Fig. 5. Natural mortality of *L. parsia* in Passur River.

Optimum catchable length (L_{opt})
The projected optimum catchable length (L_{opt}) for *L. parsia* was 12.636 cm in TL in the Passur River (Fig. 6).

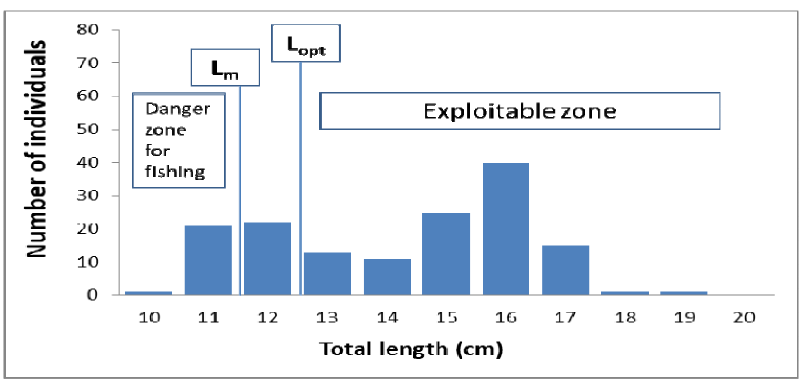

Fig. 6. Optimum catchable length of *L. parsia* in Passur River.

Discussion

The present study concentrated on a full explanation of *L. parsia* life-history traits, such as LFD, LWR, LLR, multi-approach condition factors (K_A, K_F, K_R and W_R), $a_{3.0}$, L_m, $M_{w,}$ and L_{opt}, based on analysis of specimen of different sizes from the Passur River, Bangladesh. Individuals of *L. parsia* less than 10.2 cm in TL were not harvested in this study due to several factors such as comprising a one-sided collection of fishing gear, the fishers' failure to move to specific niches where smaller fish were available, a lack of such individuals in the ecosystem, or possibly the fishers' discarded of such smaller fish(Islam et al., 2021).In addition, the maximum length of *L. parsia* found in the Passur River was 19.00 cm, which is lower than the maximum estimate of 31.0cm (Froese and Pauly 2021). This disparity could be due to the usage of fishing gear or the fact that fishermen did not catch the perfect niches in the Passur River (Islam *et al.* 2021). As a matter of policy, maximum length information is fundamental for assessing asymptotic length (L_∞) and fish growth coefficient, and is extensively employed for effective planning and management of wild fish stocks. The results of this investigation revealed that the allometric coefficient of b value based on LWR (TL vs. BW) for *L. parsia* was 2.6174, which was determined to be consistent with method of Tesch (1968), where predicted ranges were 2.0 to 4.0. In the Passur River, *L. parsia* showed a negative growth pattern ($b < 3$) based on the b value of LWR, indicating reduced body weight growth relative to increasing length dimension. Renjini and Nandan (2011) observed that the b value of *L. parsia* were 3.1545 for males, 3.0094 for females, and 3.1938 for the combined sex from Champakkara area of the Cochin estuary, India, indicating that the species' growth was better. Sujatha *et al.* (2010) investigated the length-weight relationship of *L. parsia* in response to pollution in Visakhapatnam, India, and discovered a b value of 2.49 for polluted waters and 2.52 for non-polluted waters. These differences in the value b could be due to differences in the perceived length classes, sample preservation procedures, the degree of stomach fullness, gonad maturity, sex, food, physiology, seasonal impacts, or geographic location, which were not predicted in the current study (Samad *et al.* 2021). Various factors contribute to an individual's weight gain, and these elements can be intrinsic, extrinsic, or both, and have favored changes in growth metrics such as length and weight in fish (Townsend *et al.* 2003). If the fish maintains the same shape throughout its life, its specific gravity remains constant, it grows isometrically, and the 'b' exponent is approximately 3.00 (Wootton 1998).

In the Passur River, the evaluated $a_{3.0}$ for the population of *L. parsia* was between 0.0131–0.0140suggesting a fusiform fish body shape proposed by Froese (2006). However, it was impossible to conduct comparisons across water bodies due to the lack of comparable references about the shape aspect of this species. For calculating the physical and ecological standings of *L. parsia* in the Passur River, four types of condition indices (K_A, K_F, K_R, and W_R) were focused. Nonetheless, earlier studies focused on a single condition aspect. Only K_F has a very strong link with TL and BW, according to a Spearman rank correlation test, when associated to the other condition variables. As a consequence, it's plausible to infer that K_F is the most perfect measure for evaluating the health of *L. parsia* in the Passur River and the adjacent ecosystems. Furthermore, the Wilcoxon-signed rank test revealed that the mean W_R for *L. parsia* in the Passur River was significantly different from 100 ($p< 0.05$), demonstrating an unequal territory with availability proportional to the occurrence of predators (Bister *et al.* 2000).W_R can be used to evaluate over-all health standing and welfare, as well as environmental disruptions, at the population level, according to Rypel and Ritcher (2008).Nevertheless, there is no obtainable literature on the W_R of *L. parsia*, preventing a comparison with the findings of this investigation.

To regulate the reason(s) for size disparities at maturity, knowledge of fish size during sexual maturity are required (Templeman 1987). The L_m for mutual sexes of *L. parsia* was determined to be 11.201 cm TL in this study, which would be used as the minimum permitted capture size, and has specific implication in fish population supervision (Nurdin *et al.* 2016). Furthermore, in the Passur River, the calculated M_w of *L. parsia* was 0.763/year, which will be the first global calculation of this factor. The optimal catchable length (L_{opt}) is the length above which the greatest number of fish can be caught (Froese *et al.* 2018). L_{opt} aids in the selection of fishing gear mesh sizes and the avoidance of catching fish that are smaller than the harvestable size for the intended fishes (Samad *et al.* 2021). There are no comparisons possible because this is the first study on this biological topic. The current study, the calculated L_{opt} is 12.636 cm. Pollution, fishing pressure, environment deterioration, and destructive fishing with non-selective fishing gears are all severe risks to the ichthyo faunal resources of the Passur River, either individually or in combination (Islam *et al.* 2015). Suggestions based on the findings of this study include determining the cause(s) of a species' decrease, establishing suitable sanctuaries, and protecting mature individuals during the spawning seasons. In particular, for long-term conservation and management, the mesh size of fishing nets must be evaluated throughout the year, based on the length of the fish at initial maturity. As a consequence, fish with a total length of less than 11.201 cm should not be harvested. It's also critical to raise public awareness about these issues in order to ensure proper supervision of this species in the Passur River and other adjacent aquatic habitats.

These fish species are sharply decreasing in coastal rivers in Bangladesh due to anthropogenic and other activities. However, the present study was carried out in the Passur River in order to acquire relevant data and assist further research for ensuring the proper management and conservation. However, the Passur River is the most preferred breeding grounds of aquatic organisms like fishes in the mangrove areas of Sundarban regional area. As a consequence, investigating the life-history characteristics in the riverine water bodies can help with effective management plans and conservation of this species in Bangladesh. As a necessary consequence, appropriate management should be employed to assist the reappearance of its spawning route in the study river.

L. parsia has an extended body structure and a territorial discrepancy with higher predators in the Passur River. The K_F was found to be the most important criterion for assessing this species' environments. Furthermore, the projected length at first maturity was 11.201 cm in TL, which is the lowest capture size allowed. In contrast to the reduced sizes, the species' natural mortality was quite high. As a necessary consequence, the prevailing study provides useful evidence and records for the database (online), and a notable framework for future investigation of *L. parsia* in the Passur River and neighboring ecosystems.

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