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Research Article

Length-Weight Relationships (LWRs) of Four Loach Species of the Cobitidae Family from the Surma River, Bangladesh

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Four loaches, namely, *Lepidocephalichthys guntea* (Hamilton, 1822), *Lepidocephalichthys annandalei* (Chaudhuri, 1912), *Lepidocephalichthys thermalis* (Valenciennes, 1846), and *Lepidocephalichthys berdmorei* (Blyth, 1860) from the Cobitidae family, were collected from the Surma River, Bangladesh. Of the total 376 speciminia, 193 males (51.32%) and 183 females (48.67%) in number; were collected with the support of local fishermen using a variety of nets at 15-day intervals from November 2022 to April 2023. The length-weight relationship (LWR) parameters were analyzed using the equation $W = aL^b$. *L. annandalei* displayed a notable isometric growth pattern, with a condition factor (K) ranging from 0.725 to 0.734. In addition, *L. thermalis* exhibited isometric growth among males, while females showcased positive allometric growth with a condition factor (K) varying between 0.697 and 0.714. *L. guntea* exhibited a consistent positive allometric growth pattern across all aspects, with a condition factor (K) ranging from 0.729 to 0.738. In contrast, *L. berdmorei* demonstrated positive allometric growth, but males and females both exhibited a negative allometric growth pattern. The condition factor (K) for *L. berdmorei* ranged from 0.699 to 0.702. This suggests a complex growth pattern influenced by both length and weight in every experimental loach. The research underscores the importance of recognizing gender-specific variations in growth patterns within species.

1. Introduction

Loaches are small indigenous species (SIS) that offer both aesthetic appeal and dietary benefits. Many people prefer to consume a variety of SIS, usually under (<25) cm [1]. These loach species are typically found in hill streams, and some can also thrive in rivers and swampy environments [2–4].

The Cobitidae family, which is known as a family of true loaches, encompasses over 200 known species, with the majority being indigenous to central and southern Asia [5]. Several areas in Bangladesh, particularly the larger Sylhet, Mymensingh, Dinajpur, Rangpur, and Chittagong Hill Tracts, are habitats for loaches [4, 6]. Sylhet, Bangladesh, is known for its rich aquatic biodiversity, including various fish species. Sylhet appears to be a particularly favorable habitat for loaches, as it has been reported to have the highest number of loach species within the Cobitidae family, with a total of six species [7]. However, despite the rich biodiversity of loaches in Bangladesh, there has been limited research on various aspects of loaches [8]. Hossain et al. [9] identified 293 fish species in Bangladesh in 2011, which included 9 genera and 3 loach families, emphasizing the importance of species identification for conservation reasons [10]. This highlights the ecological significance of the region and its importance for conservation efforts aimed at preserving the diversity of fish species.

The length-weight relationship (LWR) holds significant importance in fishery assessment [11, 12]. The LWR offers insights into a species' size and weight characteristics, and it can reveal differences among similar species in various

locations around the world [13–15]. Understanding the life cycle patterns of loach species, including their age, reproduction, longevity, and available nutrition in aquatic environments, is essential for managing these populations [16, 17]. Assessing the condition factors of different fish species is essential for maintaining ecosystem balance [18]. It enables comparisons between groups inhabiting similar environments, determines growth and reproduction cycles, and helps monitor a species' feeding habits [19, 20]. Proper management and conservation efforts depend on a comprehensive understanding of loach physiology and their ecological roles.

The main objective of this research effort was to determine the length-weight relationships (LWRs) of the identified loaches from the Cobitidae family in their current state. The outcomes of this study should provide important data for assessing the effective management of these organisms, preventing the potential loss of their natural populations.

2. Materials and Methods

2.1. Study Area. From November 2022 to April 2023, an investigation was conducted in the hill stream regions adjacent to the Surma River in northeastern Bangladesh. The Surma River originates from the southern slopes of the Naga-Manipur watershed; the average depth of the river is 282 feet (86 m) and the maximum depth is 550 feet (170 m), serving as the northern branch of the Barak River. It initially flows west and then southwest, passing through Sylhet town [21]. Afterwards, it continues its course in a northwest and west direction until it reaches Sunamganj town [22]. The geomorphological characteristics of the river encompass erosional and depositional processes, including the shape of the channel, riverbed dynamics, sedimentation, and more [23].

2.2. Fish Sampling. All specimens were collected from four different sites using a variety of equipment and nets (cast net, push net, drag net) with the help of fishermen (Figure 1). Approximately 30 loaches were collected and subsequently placed in each polybag. During transportation, oxygen was filled in two-thirds of the bags to ensure their survival. At each sampling site, field data such as latitude and longitude were recorded using a global positioning system (GPS). Furthermore, the biodiversity status and fish value of four freshwater loaches were documented.

2.3. Morphometric Analysis. To conduct taxonomic and morphometric analyses, all collected loaches were identified using morphometric examination and morphological traits. Slide calipers and measuring tapes were used to measure the length. The identification of the collected fish genera and species was based on the references provided by Siddiqui et al. [6] and Conway et al. [24]. To ensure accuracy and cross-reference of the collected data, reports from other researchers and employees who had examined the same or related taxa were consulted. In addition, Fishbase, an online database of fish species information, was used as a pictorial resource for identification. The IUCN 2015 red list status has been checked in accordance with Bangladesh for these experimental loaches and is documented in Table 1.

The standard length (SL) and total length (TL) of each loach were measured in centimeters (cm) using a digital slide caliper, and the body weight was determined in grams (g). We used MS 222 (10 mg/l) to anesthetize the loaches during length-weight data collection. After documenting the length-weight data, we preserved 50% of the samples in a 100% ethanol solution for future molecular studies and released the remaining fish into the open waterbody from which we had sampled.

2.4. Sex Determination. Fishes were visually inspected for external morphological differences between males and females. These differences included size, coloration, and the presence of reproductive organs [26].

2.5. Length-Weight Relationship. The (LWRs) were analyzed using the following equation: [27]

$$W = aL^b, \tag{1}$$

where W = weight of fish in g; L = length of fish in cm. a = intercept; b = weight at unit length (slope); $b = 3$ (isometric growth); and $b \neq 3$ (allometric growth) [28].

2.6. Condition Factors. The degree of well-being of fish in their habitat, also known as the condition factor, was calculated using the following equation [29]:

$$K = \frac{100W}{L^b}, \tag{2}$$

where K = condition factor; W = fish weight (g); L = fish length (cm); and b = weight at unit length (slope).

2.7. Relative Condition Factors. Le Cren's [27] formula was used to compute the relative condition factor (Kn).

$$\mathrm{Kn} = \frac{W}{W'}, \tag{3}$$

where Kn = relative condition factor; W = weight of fish in g (observed weight); and $W' = aL^b$ (calculated weight).

A t-test analysis at a significance level of $p < 0.05$ was performed on the length-weight ratio (LWR).

The collected data were analyzed statistically using MS Excel Spreadsheet 2021 and Student's t-test was conducted in the Microsoft Excel 2021 software.

3. Results

Our study specifically focused on loaches belonging to the Cobitidae family (Figure 2). Four river loaches, including *L. annandalei* (Chaudhuri, 1912),*L. thermalis* (Valenciennes, 1846), *L. guntea* (Hamilton, 1822), and *L. berdmorei* (Blyth, 1860), were meticulously documented, with specimen

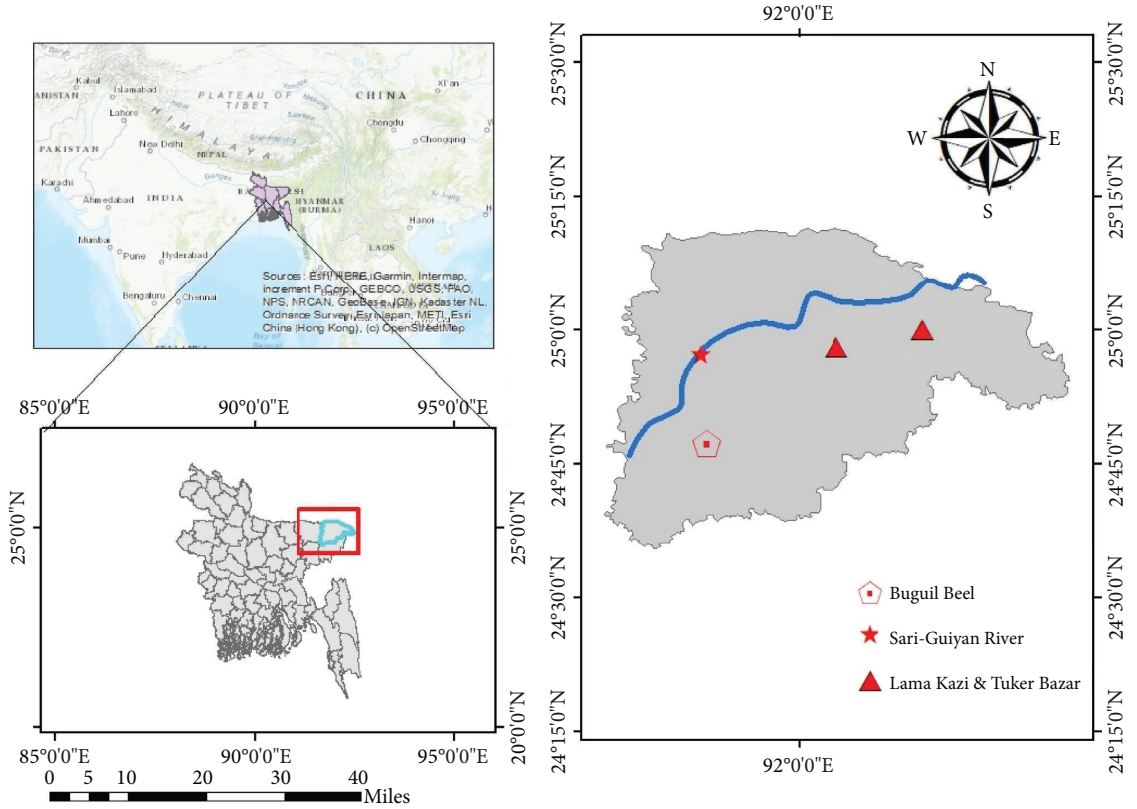

Figure 1: Study area; (1) Buguil beel; (2) Sari Guiyan River; (3) Lama Kazi Bazar; (4) Tuker Bazar. (Source: Arc-GIS, 10.8 mapping software).

numbers of 59, 95, 137, and 85, respectively (Table 2). *L. annandalei* showed an isometric growth pattern, indicating proportional growth in both length and weight. Both males and females exhibit similar trends in size and weight. *L. thermalis* follow an isometric growth pattern, maintaining proportional development in length and weight. However, females exhibit a positive allometric growth pattern, suggesting that as they grow in length, their weight increases at a faster rate. *L. guntea* demonstrates a positive allometric growth pattern for both males and females, implying that as the fish grow longer, their weight increases at a faster rate than expected proportionally. *L. berdmorei* exhibited a positive allometric growth pattern, indicating a faster weight increase relative to length. In contrast, females display a negative allometric growth pattern, suggesting a slower weight increase compared to length (Table 2). Condition factors (K) for the species range between 0.697 and 0.738, indicating variations in the general well-being of the fish populations. Relative condition factors (Kn) also show variability, ranging from 0.938 to 1.033, providing insights into the overall health and condition of the fish. R^2 values, representing the goodness of fit in the growth models, range from 0.677 to 0.940. Higher R^2 values suggest a better fit of the observed data to the growth models.

In summary, each species exhibits unique growth patterns, and the variations in condition factors and R^2 values offer a comprehensive picture of their development. These findings are crucial for fisheries management, helping to understand and potentially address factors influencing the growth and health of these fish populations.

Furthermore, we documented the biodiversity status and economic value of four freshwater loaches, all of which are valuable as food or ornamental fish. According to the red list of Bangladesh in 2015 (IUCN), *L. guntea* (Hamilton, 1822) and *L. annandalei* (Chaudhuri, 1912) were classified as "Least Concern" (LC). However, *L. thermalis* (Valenciennes, 1846) was categorized as "Data Deficient" (DD), and *L. berdmorei* (Blyth, 1860) was classified as "Endangered" (EN), emphasizing the urgent need for conservation measures to prevent its extinction.

4. Discussion

The genus *Lepidocephalichthys* within the family Cobitidae is known for its diverse group of loach species. There were 17 valid species recognized within the *Lepidocephalichthys* genus [30]. Present findings on LWRs calculated for all four species, namely *L. annandalei* (Chaudhuri, 1912), *L. thermalis* (Valenciennes, 1846), *L. guntea* (Hamilton, 1822), and *L. berdmorei* (Blyth, 1860), captured from different locations of the Surma River. Gender distribution varies significantly among the species. In *L. annandalei* and *L. thermalis*, females constitute a higher percentage. *L. guntea* shows a more balanced distribution, with a slight majority in male. *L. berdmorei* has a predominantly male population, with 78.82% males (Table 2). These differences could be due to various factors such as species-specific

Table 1: Habitat, family, biodiversity status, and fish value of the four species of loaches from the Cobitidae family in the Surma River, Bangladesh.

Family	Species	English name	Habitat	IUCN status (2015)	Fish value	Remarks
Cobitidae	*Lepidocephalichthys annandalei* (Chaudhuri, 1912)	Annadale loach	Freshwater	LC	Ornamental fish/ food fish	*L. thermalis*, commonly found in India and Sri Lanka, for the first time reported in Bangladesh
	Lepidocephalichthys thermalis (Valenciennes, 1846)	Spotted loach or common spiny loach	Freshwater	DD	Ornamental fish/ food fish	
	Lepidocephalichthys guntea (Hamilton, 1822)	Guntea loach	Freshwater	LC	Food fish	
	Lepidocephalichthys berdmorei (Blyth,1860)	Beardmore's stone loach	Freshwater	EN	Ornamental fish	

*LC = least concern, EN = endangered, DD = data deficient [25].

Figure 2: Loaches collected during this study. (a) *Lepidocephalichthys annandalei* Chaudhuri, 1912. (b) *Lepidocephalichthys thermalis* Valenciennes, 1846. (c) *Lepidocephalichthys guntea* Hamilton, 1822. (d) *Lepidocephalichthys berdmorei* Blyth, 1860.

reproductive strategies, ecological factors, or sample biases [31]. The available information on the biological aspects, including LWRs of loaches in the Surma River, is inadequate and insufficiently concise. This analysis accounted for more than 61% of the variability in the data (Table 2, $R^2 > 0.61$), indicating that length can predict more than 61% of the variance in weight of fish species in LWRs equation. The allometric coefficient b exhibited variation across the species, ranging from a minimum of 3.073 for *L. annandalei* to a maximum of 3.335 for *L. berdmorei*. The coefficient (b) values have proven to be a crucial parameter in the analysis of length-weight relationships (LWRs), serving as a significant indicator for predicting the overall growth status of species [32–35]. The spectrum of *b* values was within the typical limit of our existing experiments and supports findings similar to those of Pan et al. [33] and Hossain [35]. A multitude of geographical (temperature fluctuation, ecosystem type, spatial location) and ecological (population size, maturity of sex, developmental stage, nutritional requirements) variables might affect the LWR [36–38]. Several studies on LWRs have shown a connection between the logistic regression b value and changes in fish dimensions throughout maturation [13, 14, 32]. Condition factors (*K*) for the experimental loaches ranged between 0.697 and 0.738, indicating variations in different growth status. Among males of *L. thermalis*, the minimum condition factor (K) indicated an isometric growth pattern, while females displayed positive allometric growth ranging from 0.697 to 0.714. In contrast, *L. guntea* demonstrated a consistent positive allometric growth pattern across all aspects, with the maximum condition factor (*K*) ranging from 0.729 to 0.738. The condition factor (*K*) of *Tilapia zilli* was similar to our findings by Bala et al. [39]. Fafioye and Oluajo [40] similarly found that *Chrysichthys nigrodigitatus* in Epe Lagoon, Nigeria, exhibited a K-value below <1. According to the findings, relative condition factor (kn) values for *L. guntea* were 1.0322, *L. thermalis* (0.9536), *L. berdmorei* (0.9388), and *L. annandalei* were 1.008, indicating that the Surma river is a suitable habitat for loaches. Moreover, a comprehensive analysis was carried out on the length-weight relationships (LWRs) of five fish species in the Atrai River [41], as well as five endangered fish species in the Jamuna River of Bangladesh [31]. Consequently, the condition variables could differ among different types of fish in various habitats

Table 2: Summary statistics (mean ± 95% CI) of length-weight relationships ($W = aL^b$), condition factor (K), confidence interval (CI), and relative condition factors (Kn) for four species of loaches from the Cobitidae family in the Surma River, Bangladesh.

Species	*Lepidocephalichthys annandalei* (Chaudhuri, 1912)			*Lepidocephalichthys thermalis* (Valenciennes, 1846)			*Lepidocephalichthys guntea* (Hamilton, 1822)			*Lepidocephalichthys berdmorei* (Blyth, 1860)		
Size of sample (n)	Total 59	Male 23 (38.98%)	Female 36 (61.02%)	Total 95	Male 27 (28.42%)	Female 68 (71.58%)	Total 137	Male 76 (55.47%)	Female 61 (44.53%)	Total 85	Male 67 (78.82%)	Female 18 (21.18%)
Total length range (cm)	6.8–9.0	6.8–9.0	6.6–8.9	6.5–9.1	6.8–8.6	6.5–8.7	7.9–9.1	8.2–8.9	8.1–9.0	6.8–9.1	6.8–8.9	6.9–9.1
Total weight range (g)	2.1–5.8	2.2–5.3	2.1–5.2	1.6–5.0	1.8–5.0	2.6–4.8	3.0–6.1	3.4–6.0	3.1–5.9	2.0–5.8	2.1–5.8	2.0–5.2
Parameter (a)	0.006	0.007	0.007	0.006	0.00	0.003	0.005	0.005	0.008	0.004	0.030	0.036
Parameter (b)	3.073	2.992	3.061	3.296	3.27	3.148	3.261	3.236	3.208	3.335	2.417	2.438
95% CI of a	0.004–0.008	0.007–0.008	0.006–0.008	0.002–0.009	0.004–0.005	0.003–0.004	0.001–0.008	0.004–0.005	0.006–0.009	0.003–0.004	0.025–0.035	0.028–0.045
95% CI of b	2.957–3.190	2.958–3.027	2.995–3.127	2.878–3.715	3.171–3.369	3.319–3.518	3.018–3.505	3.170–3.302	3.070–3.346	3.236–3.435	2.324–2.511	2.316–2.560
t value	1.228	−0.454	1.812	1.386	5.345	2.915	2.101	7.008	2.954	6.599	−12.221	−9.029
Sig. p	0.222	0.652	0.074	0.167	<0.001	0.004	0.037	<0.001	0.004	<0.001	<0.001	<0.001
Growth pattern	Isometric	Isometric	Isometric	Isometric	Positive allometric	Positive allometric	Positive allometric	Positive allometric	Positive allometric	Positive allometric	Negative allometric	Negative allometric
Condition factor (K)	0.725	0.734	0.725	0.697	0.714	0.713	0.729	0.735	0.738	0.699	0.702	0.692
Relative condition factor (Kn)	1.008	1.019	1.021	0.953	1.016	1.013	1.032	1.025	1.033	0.938	1.007	1.011
Coefficient of determination (R^2)	0.899	0.880	0.889	0.807	0.807	0.940	0.677	0.619	0.640	0.919	0.734	0.687

[42]. A satisfactory amount of nutrition and suitable surroundings are indicated by a condition factor of 1 [17]. In addition, the R^2 values for *L. guntea* and *L. thermalis* were very low compared with the other two loaches which indicated low variance in weight is explained by length of fish species in our experiment, similar to the findings of Kasapoglu and Duzgunes [43]. Further research is needed to examine the relative impact of these variables on the fluctuation in the b-parameter. These research findings reveal useful insights into the LWRs, which is an effective tool for future studies on fisheries, sustainability, and the administration of the Surma River environment.

Data Availability

The data used in this study are available upon reasonable request to the corresponding author.

Ethical Approval

The Animal Ethics Committee of the Sylhet Agricultural University provided guidelines for the handling of fish in this study (Memo: SAU/AEC/FOF/FBG-501), which were strictly followed.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Authors' Contributions

Shamima Nasren conceptualized the study and proposed a methodology. MD Zobayer Rahman wrote the original draft. MD Shahinul Islam collected the data. Rasel Mia curated the data and was responsible for the Software. Sohel Mian performed validation. Md. Abdullah-Al Mamun wrote, reviewed, and edited the study.

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