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Length-weight relationship and condition factor of *Sardinella fimbriata* (Valenciennes, 1847) and *Sardinella lemuru* (Bleeker, 1853) from the Bay of Bengal, Bangladesh

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Abstract
The current study primarily describes the length-weight relationship as well as condition factor of economically lucrative marine fish species; *Sardinella fimbriata* Valenciennes, 1847 and *Sardinella lemuru* Bleeker, 1853 of Clupeidae family from the Bay of Bengal, Bangladesh. In total 42 individuals were collected from a fishing vessel on 7th September, 2022. A scale and an electronic balance were used to measure the length and weight. The slopes, b-values of these species were 2.7135 and 2.6745 respectively, indicating the growth was negative allometric. The intercept, a-values were 0.0197 and 0.0248. Moreover, the relative condition factors were 1.0011 and 1.0032, indicating the general well-being. The relative weights were 100.1065 and 100.3205, indicating the availability of foods and habitats. The current study offered the initial information on the length-weight association as well as the condition factor for the effective management of these species.

Keywords: *Sardinella fimbriata*, relative condition factor, *Sardinella lemuru*, length-weight relationship, Bay of Bengal, relative weight

1. Introduction
The Bay of Bengal is one of the principal reservoirs of marine resources in Bangladesh. The production of marine fisheries provides 14.74% to the national fish production where sardines contribute 3.07% (34519 metric ton) to the total marine fisheries production of Bangladesh [8] and *S. fimbriata* and *S. lemuru* are also included to this total production due to their economic importance such as; demand, availability and export facilities. These species also provide nutritive values required by the human body. Therefore, it is essential to comprehend the biological parameters including the relationships between length and weight and condition factor for evaluating the sustainability of these species and necessity of assessing stock.
The length–weight relationship is a vital biological parameter for assessing fish stock and estimating the population dynamics [24, 21, 14, 13]. This relationship is used to estimate the growth pattern or age and the data are useful for scientifically monitoring the condition of a population health [9]. The growth pattern in the fish body is negative allometric while b is lower than 3, positive allometric while it is greater than 3, and isometric while it is equal to 3[3, 17]. Through this relationship, suitability of environment, development of gonad, feeding intensity and mating frequency are also estimated [4]. The association between length–weight and condition factor are considered as main factors used in fishery research and closely related to each other [11]. The condition factor acts to differentiate the fatness, health, or condition of fish in fisheries science [7]. It provides information to comprehend the phases of life of fish by comparing two populations in various conditions and it keeps a significant contribution to eligible management of fish [33]. The relative condition factor designated as 'Kn' indicates the well-being and the physiological state of fish. The value of this factor is influenced by spawning, availability of foods and gonadal maturity within the water [19].
Only a few studies had investigated globally on the relationship between length-weight and condition factor of *S. fimbriata* and *S. lemuru* [20, 27, 12, 28, 35].

But the study on length-weight relationships of these particular species is scarce in Bangladesh, despite the fact that they are significant for stock management and conservation. In light of the above, the current investigation aimed to estimate the length-weight relationship and condition factor of *S. fimbriata* and *S. lemuru* to evaluate the growth type, well-being and physiological condition, presence of prey and predator and the availability of habitats and foods at the specific community in the Bay of Bengal.

2. Materials and methods

2.1 Sample collection

There are four major fishing grounds in Bangladesh and this study was conducted on the middle ground which is located at 90.20'E to 91.30'E and 20.25'S to 21.20'S of the Bay of Bengal, Bangladesh [29].

In total 42 individuals were collected from a fishing vessel, F.V. Momyaon on 7th September, 2022. The samples were quickly sent to the laboratory after being collected and chilled. The number of specimens for research work was decided according to the sample collection (Fig. 1, 2).

Fig 1: Collection of *S. fimbriata*

Fig 2: Collection of *S. lemuru*

2.2 Laboratory procedure

Before being weighed, the fish samples were wiped on tissue paper to eliminate any surplus water from their entire body and assure accuracy. Each sample's total length was determined by measuring in centimeters (cm), starting at the tip of the snout (mouth closed) and ending at the last point of the caudal fin (Fig.3, 4) and the weight (g) was measured by using an electric weighing machine, respectively [11] (Fig.5, 6).

Fig 3: Measuring the length of *S. fimbriata*

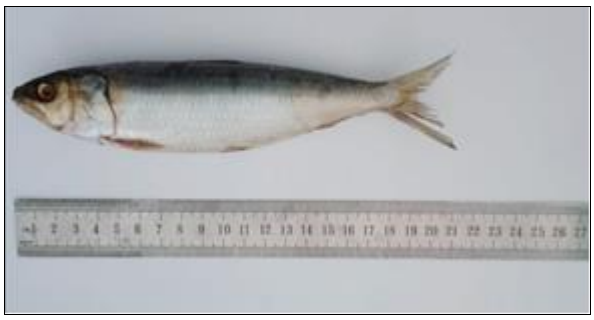

Fig 4: Measuring the length of *S. lemuru*

Fig 5: Measuring the weight of *S. fimbriata*

Fig 6: Measuring the weight of *S.lemuru*

The identification of the samples was based on [20, 27, 35, 28, 6] and the scientific name was verified according to the procedure of [36, 12].

2.3 Estimation of length-weight relationship

Linear regression serves to determine the association between fish length-weight. The following length-weight formula was used to obtain the relationship between fish length-weight [25]:

$$W = aL^b$$

Where, W = Total weight of fish in gram; L = Total length of fish in centimeter; a = Intercept and b = Slope.

The following formula was used to calculate the logarithm conversion for the values of intercept (a) and slope (b) [25]:

$$\log W = \log a + b \log L$$

Where, Log W = Logarithm of body weight in gram; Log a = Intersection points of straight in the axis W; b = Angular coefficient of regression; Log L = Logarithm of total length in centimeter.

The intercept (a) was estimated with the formula:

$$a = \left[\frac{\sum y}{n} - \frac{(b\sum x)}{n}\right]$$

The slope (b) was estimated with the formula:

$$b = \left[\frac{n\sum xy}{n\sum x^2} - \frac{(\sum x)(\sum y)}{(\sum x^2)}\right]$$

Where, n = Number of fish; x = Fish's length; y = Fish's weight

Confidence limits for intercept (a) and slope (b) [32] were estimated by the formula:

$$a = [a - sa \times t_{n-2}, a + sa \times t_{n-2}]$$

$$b = [b - sb \times t_{n-2}, b + sb \times t_{n-2}]$$

Where, sa = Deviation of a; sb = Deviation of b; tn = Fractiles in the "t-distribution"

The co-efficient correlation (r) was determined by using the formula [34, 23]:

$$r = \sqrt{R^2}$$

$$R^2 = \frac{(\sum xy - (\sum x)(\sum y)^2)}{(\sum x^2 - (\sum x)^2(\sum y^2) - (\sum y)^2)}$$

Where, n = Number of fish; x = Fish's length; y = Fish's weight

2.4 Estimation of condition factor

The following formula was used to compute the relative condition factor (Kn) [19]:

$$K_n = \frac{W}{aL^b}$$

Where, Kn = Relative condition factor; L= Total length of fish in centimeter and W = Body weight of fish in gram.

The following formula was used to calculate the relative weight [31]:

$$W_r = \frac{W}{W_s} \times 100$$

Where, Wr = Relative weight; Ws = Predicted weight of fish (aL^b) and W = Weight of fish.

2.5 Data analysis

The relationships among the variables were identified using the regression analysis. A t-test was applied to identify significant variations in the length-weight relationship. All statistical tests were accomplished with Microsoft® Excel® 2019 and the significance level was set at 5% (p<0.05).

3. Results and discussion

3.1 Length-weight relationship of *S. fimbriata* and *S. lemuru*

In total, 42 specimens of two distinct species were collected to study the length-weight relationship, growth type, and length-weight parameters as presented in Table 1, 2.

Throughout the investigation, 21 specimens of *S. fimbriata* in total were studied. The maximum and minimum lengths of *S. fimbriata* were 17.3 cm and 14 cm. The maximum and minimum weights were 44.7 g and 26.5 g (Table 1). According to [12], the maximum length of this species was 19cm and the length at first maturity was 12cm. In current study, the logarithmic conversion of length-weight relationship of *S. fimbriata* was log BW=0.0227 log (TL)+2.7135 (Table 1). The logarithmic conversion of length-weight relationship with linear regression is shown in Figure 7. The estimated b value of *S. fimbriata* was 2.7135 (Table 2), so the growth type was negative allometric (b<3). The parameters of the length-weight relationship amongst fish vary depending on various factors including food, salinity, temperature, sex, and phases of maturation [30, 26]. The values of b < 2.5 or >3.5 frequently obtain with slender body from the samples [5]. According to [27], the b value of this species was 2.44 which showed negative allometric growth. [20] Also found negative allometric growth in *S. fimbriata*. So far it seems that there is limited study on the relationship between length-weight and condition factor of *S. fimbriata* observed in Bangladesh. However, [22] reported that *S. fimbriata* spawned sometimes in October, but generally they spawned from August to September in the North Bay of Bengal. In this study, the species was caught in September and its negative allometric growth was probably because of spawning stress. The coefficient of correlation, r was 0.9483 (Table 2) which means there was a significant correlation (r<1, nearly 1) between length and weight of this species and coefficient of determination, R^2 was 0.8993 (Table 2). It indicates the data were compatible with the model that was used for the analysis [18]. Besides, there was a strong significance in the regressions (p< 0.01). This showed that by using total lengths, it was possible to calculate the body weight with high accuracy [10, 1].

In total 21 specimens of *S. lemuru* were studied during the investigation. *S. lemuru* was estimated at a maximum of 21.7 cm and a minimum of 18.7 cm in length and weights ranged from 99 g to 53.5 g, respectively. 23 cm and 14.3 cm were the maximum length and maturity length of this species [12] log BW = 0.0248 log (TL) + 2.6745 is the logarithmic conversion of length-weight relationship of *S. lemuru* (Table 1). The

logarithmic conversion of length-weight relationship with linear regression is shown in Figure 8. In this study, the estimated b value of *S. lemuru* was 2.6745 (Table 2), so the growth type was observed to be negative allometric. So far, there appears to be no research on this topic in Bangladesh. But some countries did some researches on this species. Previous researches stated that isometric growth type (b=3.22) exist in *S. lemuru* [28, 12] reported that the b value is 3.09, indicating an isometric growth. This b value is influenced by the physiological state, such as the availability of foods and development of gonads [15]. However, according to [35], though the spawning season of this species was generally from September to February, it reached its highest point in December to January. Thus, this indicated that the growth pattern of this species was probably influenced by the spawning stress. The co-efficient of correlation, r was 0.8258 (Table 2), indicating a significant correlation between length and weight. The co-efficient of determination, R^2 was 0.6819 (Table 2), indicating the data were consistent with the model. Moreover, there was a strong significance in the regressions ($p< 0.01$).

Table 1: Length-weight relationship of *S. fimbriata* and *S. lemuru*

Species	Sample size	Total length (cm)		Body weight (g)		Logarithmic transformation
		Max	Min	Max	Min	
S. fimbriata	21	17.3	14	44.7	26.5	log BW = 0.0227 log (TL)+ 2.7135
S. lemuru	21	21.7	18.7	99	53.5	log BW = 0.0248 log (TL)+ 2.6745

*Max = Maximum; Min = Minimum; TL=Total length; BW=Body weight.

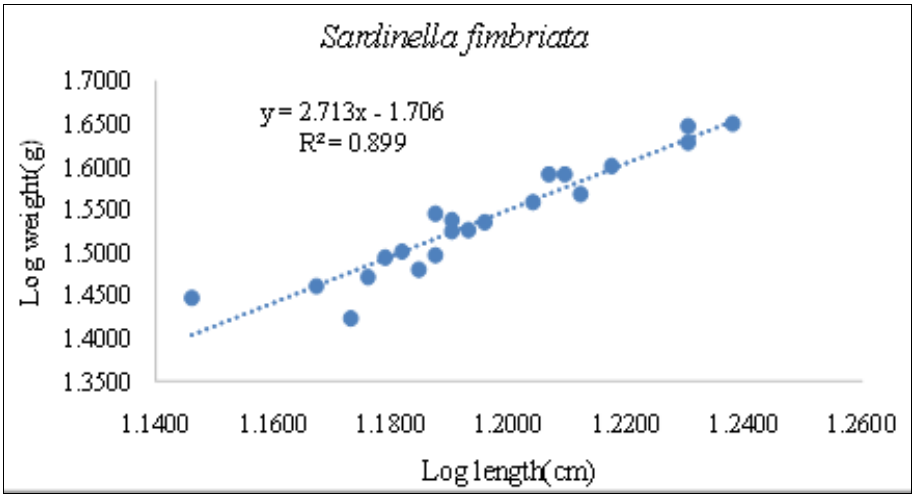

Fig 7: Length-weight relationship of *S. fimbriata* in the Bay of Bengal, Bangladesh

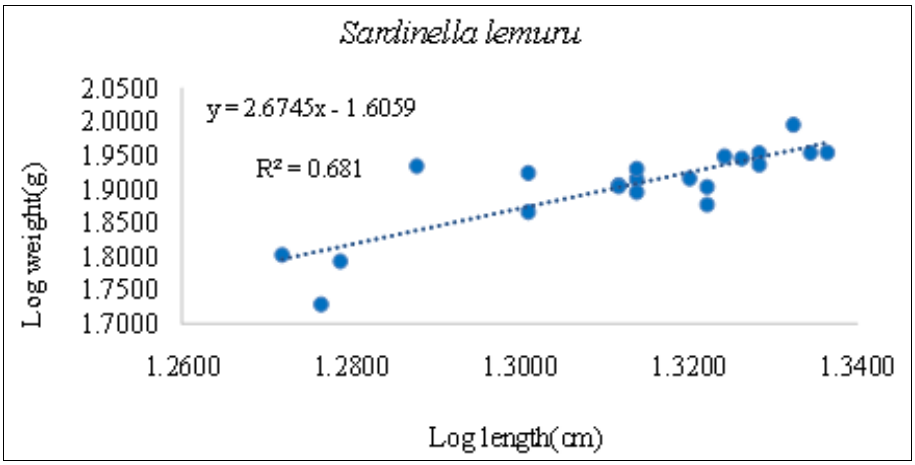

Fig 8: Length-weight relationship of *S. lemuru* in the Bay of Bengal, Bangladesh

Table 2: Growth type and length-weight parameters of *S. fimbriata* and *S. lemuru*

Species	Intercept (a)	Slope (b)	95% Confidence limits of intercept		95% Confidence limits of slope		Co-efficient of correlation	Co-efficient of determination	Growth type	p-value
			Max	Min	Max	Min	r	R^2		
S. fimbriata	0.0197	2.7135	0.5410	-0.5017	3.1495	2.2775	0.9483	0.8993	Negative allometric	<0.01
S. lemuru	0.0248	2.6745	1.1759	-1.1263	3.5515	1.7975	0.8258	0.6819	Negative allometric	<0.01

3.3 Condition factors

A relative condition factor, Kn provides information about the physiological status and overall health of fish. It is used in order to compare an individual's weight with the average

weight for the specified length determined by the length-weight relationship of the relevant sample and the value of Kn> 1 implies a healthy and stable physiological state [19]. The calculated values of relative condition factor (Kn) of *S. fimbriata* ranged from 0.8834 to 1.1054 and mean value was 1.0011±0.05, for *S. lemuru* ranged from 0.8325 to 1.2465 and the mean value of relative condition factor was 1.0032±0.08 (Table 3) which indicates the good physiological condition and well-being of these two species. The values of relative weight of *S. fimbriata* ranged from 88.3433 to 110.5372. The mean value of relative weight (Wr) was 100.1065±4.71. According to [27], the relative weight (Wr) of *S. fimbriata* was 100.14. Moreover, *S. lemuru* ranged from 83.2464 to 124.6453 and mean value of relative weight was 100.3205±8.35 (Table 3) which tended to be 100. This is the indication of a stabilized existence of prey and predator in specific community [2] for both *S. fimbriata* and *S. lemuru*. Additionally, it demonstrated that the habitats and food availability were in adequate condition [16] for both species in the middle ground of the Bay of Bengal.

Table 3: Condition factors of *S. fimbriata* and *S. lemuru*

Species	Relative Condition Factor (Kn)		Mean±SD	Relative Weight (Wr)		Mean±SD
	Maximum	Minimum		Maximum	Minimum	
S. fimbriata	1.1054	0.8834	1.0011±0.05	110.5372	88.3433	100.1065±4.71
S. lemuru	1.2465	0.8325	1.0032±0.08	124.6453	83.2464	100.3205±8.35

4. Conclusion

The outcomes of this study will create valuable database for establishing further future research on these fish species. Moreover, the result of this study will be helpful to the researchers to give attention to the basic reasons for negative allometric growth and condition. In addition, it is necessary to minimize fishing activities during spawning periods. Thus, it is also important to do more research on the relationship between length-weight of several marine fish species to get more helpful information.

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