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ESTIMATION OF POPULATION STRUCTURE, GROWTH AND CONDITION OF *LATES CALCARIFER* (BLOCH, 1790) IN THE BAY OF BENGAL

Nur-E-Farjana Ilah, Md. Joynal Abedin, Md. Ashekur Rahman, Md. Abul Kalam Azad, Most. Taslima Khatun, Md. Asadujjaman, Md. Abdus Samad, Kazi Ahsan Habib, Md. Nowsher Ali and Most. Shakila Sarmin

Department of Fisheries, University of Rajshahi, Rajshahi 6205, Bangladesh (NEFI, MAR, MAKA, MSS); Department of Zoology, Carmichael College, National University, Bangladesh (MJA); Department of Soil Science, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh (MTK); Department of Aquaculture, Khulna Agricultural University, Khulna 9100, Bangladesh (MA); Department of Fisheries and Marine Bioscience, Jashore University of Science and Technology, Jashore 7408, Bangladesh (MAS); Department of Fisheries Biology and Genetics, Sher-e-Bangla Agricultural University, Dhaka 1207, Bangladesh (KAH); Department of Fisheries, MatshyaBhaban, Dhaka 1000, Bangladesh (MNA)

email: shakilasarmin13@gmail.com

ABSTRACT: The current study illustrates the life-history traits; including length frequency distribution (LFD), length-weight and length-length relationship (LWR and LLR), condition factors (allometric, K_A; Fulton's, K_F; relative condition, K_R; relative weight, W_R), and natural mortality (M_w) of *Lates calcarifer* from the Bay of Bengal, Bangladesh. A total of 103 individuals were randomly collected from January to December 2021 using traditional fishing gear including Koral net and gill net. For each individual, total length (TL), standard length (SL), and total body weight (BW) were measured with measuring scale to 0.1 cm and digital balance to 0.1 g precision, respectively. The TL size class 84.0 cm was a numerically dominant group in the population. The *b* value of LWR (TL *vs.* BW) indicated positive allometric growth (*b*=3.28) pattern in the Bay of Bengal. Likewise, the *b* value of LLR indicated also the same growth pattern. Among the four types of condition factors, K_F is the best-suited tool for evaluating the well-being of *L. calcarifer*. Additionally, W_R exhibited significant divergence from 100 ($P< 0.0001$), defining an imbalanced habitat. The calculated M_w was 0.23 year^{-1} for *L. calcarifer*. Therefore, these findings would be used in the future for the improved management of this species in the Bay of Bengal as well as for connecting ecosystems.

KEYWORDS: Bay of Bengal, conditions, growth, *Lates calcarifer*, natural mortality

INTRODUCTION

Fish is a source of high-quality protein and it fulfills the demand for protein by more than one billion people in the world. Barramundi or seabass, *Lates Calcarifer* (Bloch, 1790) is an economically important fish that is widely distributed in the Indo-West Pacific, spanning the water of the Middle East, South Asia, Southeast Asia, East Asia and Oceania / eastern edge of the Persian Gulf to China, Taiwan and Southern Japan,

Bangladesh, India, Myanmar, Sri-Lanka, Malaysia, Southward to Southern Papua New Guinea and Northern Australia (Froese and Pauly, 2022). This species is a highly commercial fish due to its higher growth rate, giant size, excellent taste and higher market demand. It is locally known as Bhetki or Koral and is available around the year in the estuarine and coastal regions of Bangladesh. They are ray-finned fishes, and demersal catadromous fish (Siddik *et al*., 2016). The distribution of seabass does not extend to the deep sea and is limited to 40-60 nautical miles from the shore. In Bangladesh, Koral fish is available in the coastal water of Coxs Bazar, Chattagram, Feni, Sondwip, Hatia, Bhola, Barisal, Patuakhali, Khulna, Bagerhat and Satkhira (Karmaker and Das, 2001; Kamruzzaman *et al*., 2013; Haque *et al*., 2019). The average length of Barramundi generally varies between 29-60 cm and the weight ranges up to 60.0 kg (Ilham *et al*., 2016). Huda *et al*., (2003) found a maximum length of up to 200 cm. This species is commonly available in marine, freshwater, and brackish coastal environments with depth range between 10-40 m (Froese and Pauly, 2022).

Length-weight relationship (LWR), Length-length relationship (LLR), and condition factors are key parameters for designing a sustainable management plan for any fish population or species (King, 2007). Both LWR and LLR are also significant in fisheries management to compare the growth of fish in several habitats and to measure the fish stock size for its judicious exploitation (Le Cren, 1951; Froese, 2006; Hossain *et al*., 2006). The condition factor provides important knowledge on the well-being state of the fish species and its community to manage and conserve the natural population (Le Cren, 1951; Tesch, 1968; Faradonbe *et al*., 2015). Besides, relative weight (W_R) is also a biometric tool that is used for assessing the condition of fish (Rypel and Richter, 2008).

Moreover, *L. calcarifer* is well distributed in the Bay of Bengal. A few studies on the population structure, growth, and condition of this species were performed in several parts of the world. However, the objective of the current study is to define the different biological parameters (LFD, LWR, LLR, condition factor, and relative weight, and natural mortality) of *L. calcarifer* which are important to conserve and manage for the sustainability of this fish in their natural habitat.

MATERIALS AND METHODS

Study region and sampling: Fish sample were collected from the Bay of Bengal. A number of 103 individuals of *L. calcarifer* were collected over a period from January to December 2021, through several traditional fishing gears namely – gill net, and Koral net (mesh size:15-22 cm). Fish samples were chilled with ice on the spot immediately after sampling and then stored in refrigerator in the laboratory. A measuring scale was used to measure the total length (TL) and standard length (SL) for each specimen to 0.1 cm accuracy and a digital balance was used to measure body weight (BW) to 0.1 g accuracy.

Length frequency distribution (LFD): The length frequency distribution is necessary to figure out the age and growth of fish. Length frequency distributions (LFD) for the population of *L. calcarifer* were revealed through 2.0 cm class intervals of TL.

Length-weight and length-length relationship (LWR and LLR): The following term was used to describe the relationship between length and weight: $W = a*L^b$ (Le Cren, 1951), where W is the total weight (g), L is the total length (cm), and the regression

parameters are *a* and *b*. Regression variables *a* and *b* of the LWR were assessed by linear regression analysis: ln(W) = ln(*a*) + *b*ln(L) (Froese, 2006). As stated by Froese (2006), the extreme deviation was avoided from the regression analyses. A significant deviation of *b* from the theoretical isometric value specifies that allometric growth is either positive (*b*> isometric value) or negative (*b*< isometric value). Besides, the length-length relationship (TL *vs*. SL) was estimated using a linear regression model (Hossain *et al*., 2006).

Condition factors: Tesch (1971) suggested the following expression for calculating the allometric condition factor as $K_A = W/L^b$, where W is the body weight (BW, g), L is the total length (TL, cm), and regression slope (*b*) obtained from LWR. Fulton's condition factor (K_F) was assessed by the following equation, suggested by Fulton (1904): $K_F = 100\ (W/L^3)$, where W is the body weight in g and L is the TL in cm. A scaling factor of 100 was applied to acquire K_F close to the unit (Froese, 2006). Additionally, the relative condition factor (K_R) was assessed through the proposed formula of Le Cren (1951): $K_R = W/(a \times L^b)$. The method of Froese (2006) was used to calculate relative weight: $W_R = (W/W_s)*100$, where W_s is the expected normal weight as intended by the following equation, $W_s = a \times TL^b$.

Natural mortality (M_w): During this study, the M_w of *L. calcarifer* was assessed through the model offered by Peterson and Wroblewski (1984): $M_w = 1.92\ year^{-1} *(W)^{-0.25}$; where M_w = Natural mortality (at mass W); and $W = a*TL^b$; where *a* and *b* values were obtained from LWR (TL vs. BW).

Statistical analysis: Data processing and statistical analyses were performed by using Microsoft Excel and Graph Pad Prism 8 software. The Spearman rank-correlation test was applied to evaluate the association of condition factors with TL and BW. We used Wilcoxon sign-ranked test to compare the average relative weight (W_R) with 100 (Anderson and Neumann, 1996). At 5% (P< 0.05) significant level, all statistical analysis was performed.

RESULTS AND DISCUSSION

Information on the life-history traits of *L. calcarifer* is quite scant in literature from Bangladesh but few studies were available worldwide (Table 1). Hence, the current study focus on the life-history traits of *L. calcarifer* including LFD, LWR, LLR, condition factors (K_A, K_F, K_R, and W_R), and M_w using specimens of various sizes over a year from the Bay of Bengal. A number of 103 fish specimens were randomly collected occasionally from the fishermen of the Bay of Bengal. During the study period, TL varied from 67.5 to 99.5 cm whereas, BW ranged from 3440 to 13000 g (Table 2). The LFD showed that the 84.0 cm TL size group was 19.42% of the total population and was numerically prominent in the Bay of Bengal (Fig. 1).

During the study, we could not sample individuals of *L. calcarifer* less than 67.5 cm TL, owing to the fishers did not go where the smaller fish were or possibly due to the small individual's non-appearance on the fishing grounds (Hossain *et al*., 2017; Khatun *et al*., 2019; Sarmin *et al*., 2021a). Besides, the highest length of *L. calcarifer* was 99.5 cm which is lower than the highest recorded estimation of 200.0 cm (Huda *et al*., 2003; Froese and Pauly, 2022). The dissimilarity may be due to the selectivity of fishing gear (Hossen *et al*., 2019; Islam *et al*., 2021; Sabbir *et al*., 2020). Generally, for the estimation

of the asymptotic length (L_∞) and fish growth coefficient, information on the maximum length is very crucial and is often useful for the better planning and management of the wild fish population.

Table 1. Available literature on *L. calcarifer* from worldwide water bodies.

Aspects	Water body	References
Length-weight relationship and condition factor	Meghna River estuary of Bangladesh	Rakib *et al*. (2021)
Length-weight relationship and relationship condition factor	Chilika Lagoon, Odisha	Mohanty *et al*. (2014)
Growth analysis from tanks	East Java	Sari *et al*. (2020)
Growth pattern ,condition and prey-predator status	Arabian Sea (Baluchistan and Sindh), Pakistan	Hassan *et al*. (2020)
Length-weight relationship	Merbok estuary, Kedah	Isa *et al*. (2012)

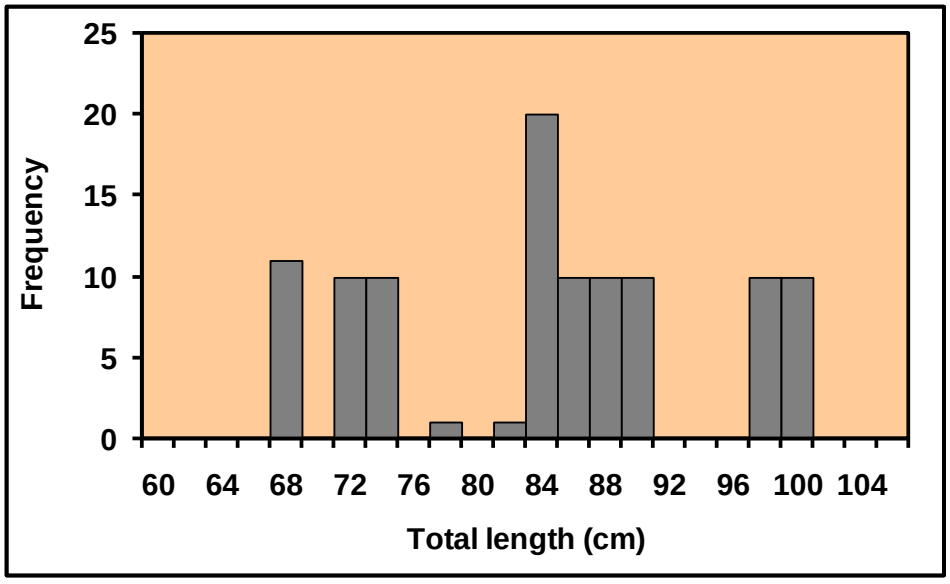

Fig. 1. Length-frequency distribution of *L. calcarifer* in the Bay of Bengal.

In Table 3, sample size (n), regression variables of LWR with 95% CI, and the coefficient of determination (r^2) of *L. calcarifer* are specified. The calculated b value of LWR (TL *vs.* BW) indicated the positive allometric growth pattern for this species (Fig. 2). In addition, the b value of LLR (SL *vs.* TL) indicated the same growth pattern and it is represented in Figure 3. Furthermore, both relationships (LWR and LLR) were highly

significant ($P< 0.0001$) with all r^2 values being ≥ 0.991. The current study stated that the allometric coefficient *b* value of LWR (TL *vs.* BW) was 3.28 for *L. calcarifer* which was found to be accordant with the expected range (2.0-4.0) proposed by Tesch (1971) and the range 2.5-3.5was stated by Froese (2006). Based on the *b* value of LWR, *L. calcarifer* exhibited the positive allometric growth pattern ($b> 3$) in the Bay of Bengal which indicates faster growth in body weight than length dimension. Dissimilar negative allometric growth patterns were reported $b= 2.88$ from the Merbok estuary, Kedah, Malaysia (Isa *et al*., 2012); and $b= 2.89$ from Chilika Lagoon, Odisha, India, (Mohanty *et al*., 2014); $b= 2.51$ from Arabian Sea, Pakistan (Hassan *et al*., 2020); $b= 1.48$ from Meghna River estuary, Bangladesh (Rakib *et al*., 2021) for *L. calcarifer*. These variances in the value of *b* might be attributed to distinction in observed length class, sample preservation methods, degree of stomach completeness, gonad ripeness, sex, diet, physiology, seasonal effect, or geographical position (Hossain *et al*., 2017; Hossen*et al*., 2019; Khatun *et al*., 2019; Sarmin *et al*., 2021b; Sarmin *et al*., 2022a, b) that were not predicted in the current research.

Table 2. Explanatory statistics on length (cm) and weight (g) measurements with their 95% confidence interval of *L. calcarifer* in the Bay of Bengal.

Measurement	*n*	Min	Max	Mean±SD	$CI_{95\%}$
Total length (cm)	103	67.5	99.5	83.56±10.30	81.55-85.58
Standard length (cm)		58	89	74.34±10.11	72.36-76.32
Body depth (cm)		20	32	26.55±3.47	25.88-27.23
Body weight (g)		3440	13000	7348.25±2904.62	6780.58-7915.93

Abbreviations: *n*, sample size; Min, minimum; Max, maximum; CI, confidence interval for mean values.

Table 3. Descriptive statistics of length-weight and length-length relationships (LWR and LLR) of *L. calcarifer* in the Bay of Bengal.

Formula	*n*	Regression variables		*a* (±95% CI)	*b* (±95% CI)	r^2
		a	*b*			
$BW = a \times TL^b$	103	0.0034	3.28	0.0026 to 0.0045	3.22 to 3.35	0.991
$SL = a + b \times TL$		-7.39	0.98	-8.81 to -5.97	0.96 to 0.99	0.992

Abbreviations: *n*, sample size; TL, total length; BW, body weight; SL, standard length; *a*, intercept; *b*, slope; CI, confidence interval; r^2, coefficient of determination.

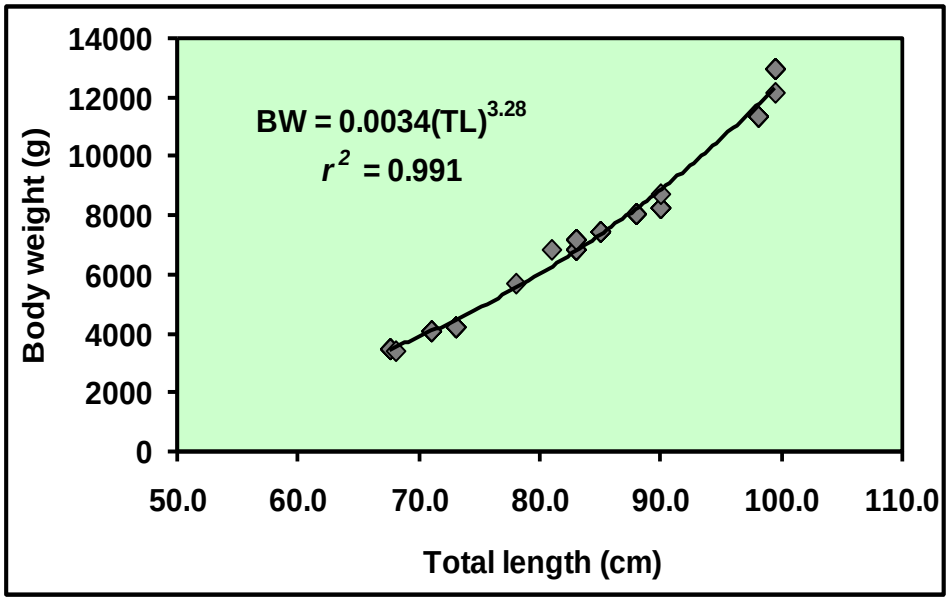

Fig. 2. Relationship between total length (cm) and body weight (g) of *L. calcarifer* in the Bay of Bengal.

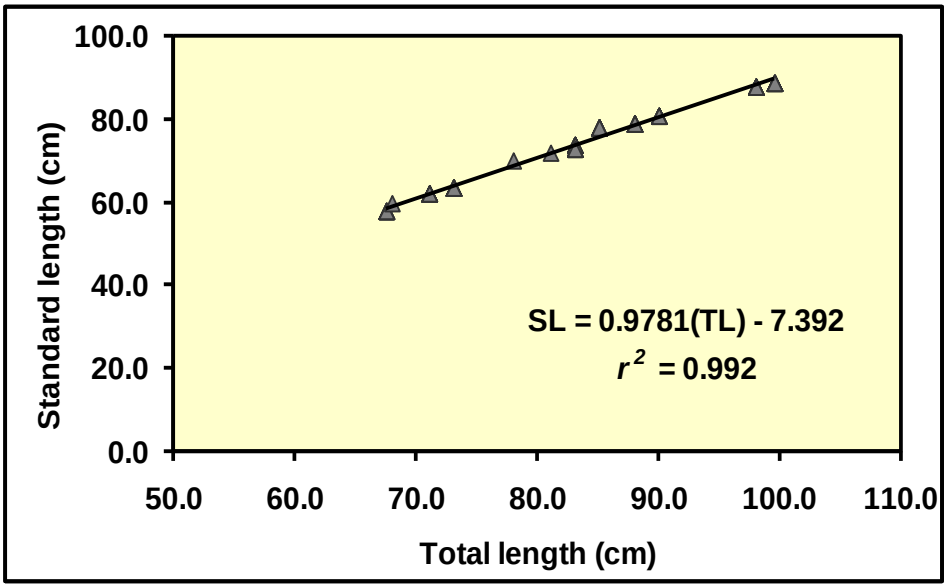

Fig. 3. Relationship between standard length (cm) and total length (cm) of *L. calcarifer* in the Bay of Bengal.

Table 4. Descriptive statistics on condition factors measurements and with their 95% CI of *L. calcarifer* in the Bay of Bengal.

Conditions	Minimum	Maximum	Mean±SD	$CI_{95\%}$
K_A	0.0031	0.0036	0.0033 ± 0.0001	0.0033-0.0034
K_F	1.0925	1.3197	1.9101± 0.0637	1.1776-1.2025
K_R	0.9426	1.1098	1.0142 ± 0.0401	1.0064-1.0221
W_R	94.26	110.98	101.42 ± 4.014	100.64-102.21

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

Table 5. Estimation of correlation for condition factors with total length (TL, cm) and body weight (BW, g) of *L. calcarifer* in the Bay of Bengal.

Relationships	r_s values	$CI_{95\%}$ of r_s	*P* values	Degree of significance
TL *vs.* K_A	-0.1694	-0.3565 to 0.0308	0.0872	*ns*
BW *vs.* K_A	-0.1440	-0.3336 to 0.0568	0.1468	*ns*
TL *vs.* K_F	0.5101	0.3461 to 0.6438	<0.0001	***
BW *vs.* K_F	0.5319	0.3722 to 0.6610	<0.0001	***
TL *vs.* K_R	-0.0946	-0.2883 to 0.1066	0.3420	*ns*
BW *vs.* K_R	-0.0719	-0.2672 to 0.1291	0.4707	*ns*
TL *vs.* W_R	-0.1008	-0.2940 to 0.1004	0.3110	*ns*
BW *vs.* W_R	-0.0701	-0.2655 to 0.1309	0.4817	*ns*

Abbreviations: Condition factors (K_A, Allometric; K_F, Fulton's; K_R, Relative; W_R, Relative weight); r_s, coefficient of spearman rank correlation test values; CI, confidence interval; *P*, exhibitions the intensity of significance; *ns*, notsignificant and ***extremely significant.

Here, we have focused on several types of condition factors (K_A, K_F, K_R, and W_R) to assess the physical and ecological status of *L. calcarifer* in the Bay of Bengal. The values of condition factors are displayed in Table 4. According to the Spearman rank correlation test, there were very highly significant (P<0.0001) co-relationships of K_F with TL and BW compared to other condition variables (Table 5). As a consequence, it is reasonable to assume that K_F is the best for evaluating the well-being of *L. calcarifer* in the Bay of Bengal as well as the adjoining ecosystem. As specified by Rypel and Richter (2008), W_R can be used to judge the general physical status and wellness together with ecosystem disruptions the population level. Based on Wilcoxon sign-ranked test analysis, the W_R demonstrated significant differences from 100 (P< 0.0001) for *L. calcarifer* in the Bay of Bengal predicting an imbalance territory with the presence of predators (Anderson and

Neumann, 1996; Rahman *et al*., 2020). The relationships of condition factors (K_A, K_F, K_R, and W_R) with total length (TL) and body weight (BW) are presented in Table 5. Different populations of the same species have different condition factors, which may reveal details about food availability, breeding timing, and length of spawning (Weatherly, 1972; Hossain *et al*., 2021).

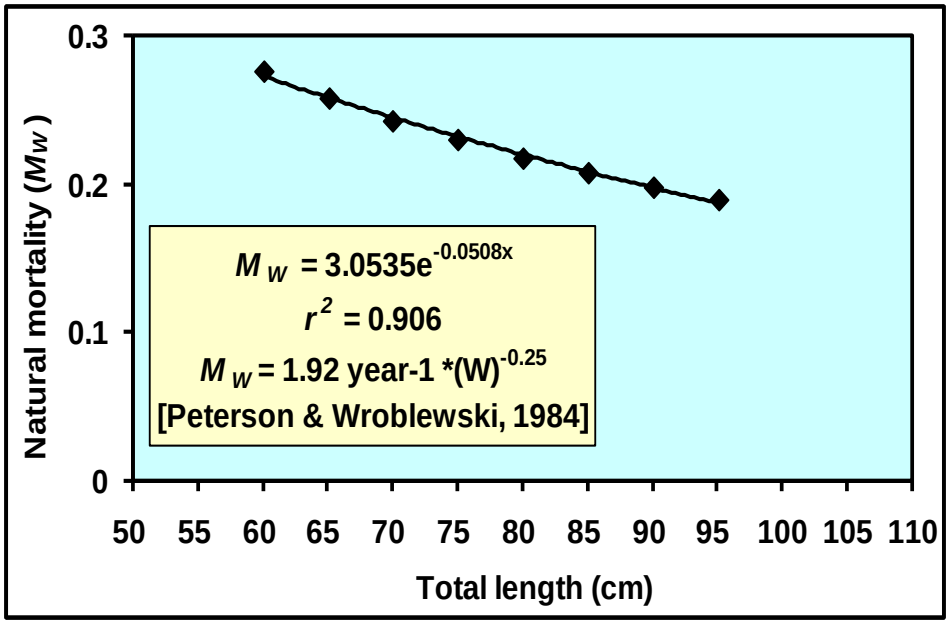

Fig. 4. Natural mortality of *L. calcarifer* in the Bay of Bengal.

In addition, the M_w of *L. calcarifer* was computed as 0.23 year^{-1} in the Bay of Bengal, also the first global estimate for this fish species. Moreover, the M_w value was very high for individuals when the species was less than 65.0 cm TL; on the contrary, it was decreased with larger body sizes (Fig. 4). Since this is the first work on this biological aspect, no comparison can be made.

CONCLUSION

The present study describes the life-history traits, including population structure (length frequency distribution), growth (length–weight and length–length relationship), condition factors, and natural mortality of *L. calcarifer* from the Bay of Bengal in Bangladesh. The growth pattern of this fish species was positive allometric. K_F was the preeminent fitted tool for evaluating the conditions. The natural mortality value was high with comparing to the smaller sizes. This research finding would be valuable evidence for future research to assess the stock of *L. calcarifer* in the Bay of Bengal and adjoining aquatic ecosystems.

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