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RESEARCH ARTICLE

Morphological characteristics of smoothbelly sardinella, *Amblygaster leiogaster* (Val.) in the Bay of Bengal

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Abstract. Species identification, classification, and the genetic studies of fishes rely principally on meristic counts and morphometric characteristics. The current study was designed to provide the first comprehensive, instructive description of the meristic counts and morphometric relationships (length-weight relationship [LWR] and length-length relationship [LLR]) of *Amblygaster leiogaster* (Val.) from Bangladesh waters. Using various traditional fishing gears, 250 individuals were collected from the Bay of Bengal, Bangladesh between December 2019 and November 2020. A magnifying glass was used for the meristic counts, including several fin rays. Nine lengths were measured to the nearest 0.1 cm using a measurement board, and body weight (BW) was determined to the nearest 0.01 g with a digital electronic balance. The fin formula was: D. 17–18 (2/15–16); P. 15–16 (1/14–15); Pv. 8 (1/7); A. 18–20; C. 19–20 (2/17–18). Total length (TL) range was 13.3–20.0 cm, and BW range was 25.72–79.69 g. All LWRs demonstrated a high level of significance (P < 0.0001) with r^2 values ≥ 0.946. The best fitted models were BW vs TL in LWRs, and TL vs FL in LLRs, as shown by the highest r^2 values. This study serves as a baseline for identifying this species that will help fisheries scientists in further research.

Keywords: *Amblygaster leiogaster*, Bay of Bengal, meristic counts, morphometric, morphological characteristics, Sardine

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Introduction

The Bay of Bengal is a partially contained body of water in the northeastern Indian Ocean, serving as the primary habitat for marine fish species in Bangladesh. Its borders are formed by eight neighboring countries – Bangladesh, Myanmar, Sri Lanka, India, The Maldives, Thailand, Malaysia, and Indonesia (Hussain and Hoq 2010). In the 2018–2019 fiscal year, around 681,239 MT (14.74% of total production) of fish were harvested from the Bay of Bengal (DoF 2022). Bangladesh is ranked third in Asia for aquatic biodiversity, with 475 species of marine and coastal fishes (Hussain and Mazid 2010); however, a recent study found that 740 species of marine and coastal fishes inhabit the Bay of Bengal (Habib and Islam 2020).

The smoothbelly sardinella, *Amblygaster leiogaster* (Val.), is a marine, pelagic-neritic fish of the family Clupeiformes and is a commercially significant edible fish in Bangladesh (Hossain et al. 2020). It is known locally as *rash* or *takia* in Bangladesh and *tamban* in Malaysia and the Philippines (Froese and Pauly 2025). *A. leiogaster* is distributed in the coastal and shallow waters of the Indo-Pacific (coast of Africa east to Okinawa, Japan and south to western Australia) (Munroe et al. 1999) and is reported from 23 countries including Bangladesh, Sri Lanka, India, Taiwan, Myanmar, Thailand, etc. Given its main habitat is in coastal and shallow marine waters and its diet consists of acates, copepods, euphausiids, and other zooplankton, understanding the morphological characteristics of *A. leiogaster* is crucial (Allen 1993, Hossain et al. 2020).

Morphological or phenotypic variations include meristic and morphometric features that are used widely to determine differences among populations of the same species and frequently for identifying the fish stocks of various exploited species (Turan 2004, Tanjin et al. 2020, Ben Labidi et al. 2021). Meristic characters are precisely defined, sequential, repetitive, quantifiable structures that are determined – although in unknown proportions – by heredity and environmental influences. They are used to identify fish populations and to provide evidence to improve stocks (Liasko et al. 2012, Jawad et al. 2018). These characters are generated during the ontogenetic development of the larval stage and remain constant across the fish lifespan, which means they reflect the ecological consequences for the fish during just a few weeks of larval development (Jawad et al. 2017). Morphometric characteristics, on the other hand, are continual quantitative characteristics that describe body form and size attributes. Several morphometric features, like ecophenotypic variation, are utilized frequently in biometric investigations. Morphometric relationships are applied to estimate the minimal allowed sizes in fisheries management in several developed countries (Azad et al. 2018). Additionally, they perform a dynamic role in fisheries research in that they are used for the purpose of studying life histories, analyzing population structure, and assessing fishery stocks (Bolger and Connolly 1989, Kochzius 1997, Sabbir et al. 2021). They are also used to investigate the health status and reproductive features of fishes in the same habitat (Turan 1999, Waldman 2005, Ben Labidi et al. 2021). Studies of morphological characteristics are more practical, faster, and less expensive than molecular studies, as they can be conducted in the field (Ibañez et al. 2007).

Morphological diversity within populations is still significant in stock identification as persistent variations in morphology among subgroups of fishes might show different growth rates, mortality, or reproduction relevant to stock delineation (Cadrin 2000). Variations in morphological features triggered by environmental influences may be valuable for stock identification, particularly where timeframes are minimal for determining substantial genetic difference in stocks, as might occur in partially segregated populations (Ben Labidi et al. 2021). There is currently no information on the stock structure or other aspects of *A. leiogaster* in the Bay of Bengal except for the study Rafail (1972) conducted in the Red Sea, Egypt. Thus, the present study aimed to investigate the morphological characteristics of *A. leiogaster* in the Bay of Bengal based on an inspection morphometric characteristics and meristic characters.

Materials and methods

Study area and sampling

The current study was conducted in the in the Bay of Bengal (22°66.78' N, 89°53.26'E), Bangladesh (Figure 1). A total of 250 individuals of *A. leiogaster* were obtained from catches made by fishers using various traditional fishing gears between December 2019 and November 2020. The fresh samples were preserved immediately with ice after collection and subsequently stored at a temperature of -20°C until they were transported to the laboratory.

Meristic counts and morphometric characteristics

Frozen samples were stored in a freezer in the laboratory and defrosted just before starting measurements. Six meristic characters and 10 morphometric

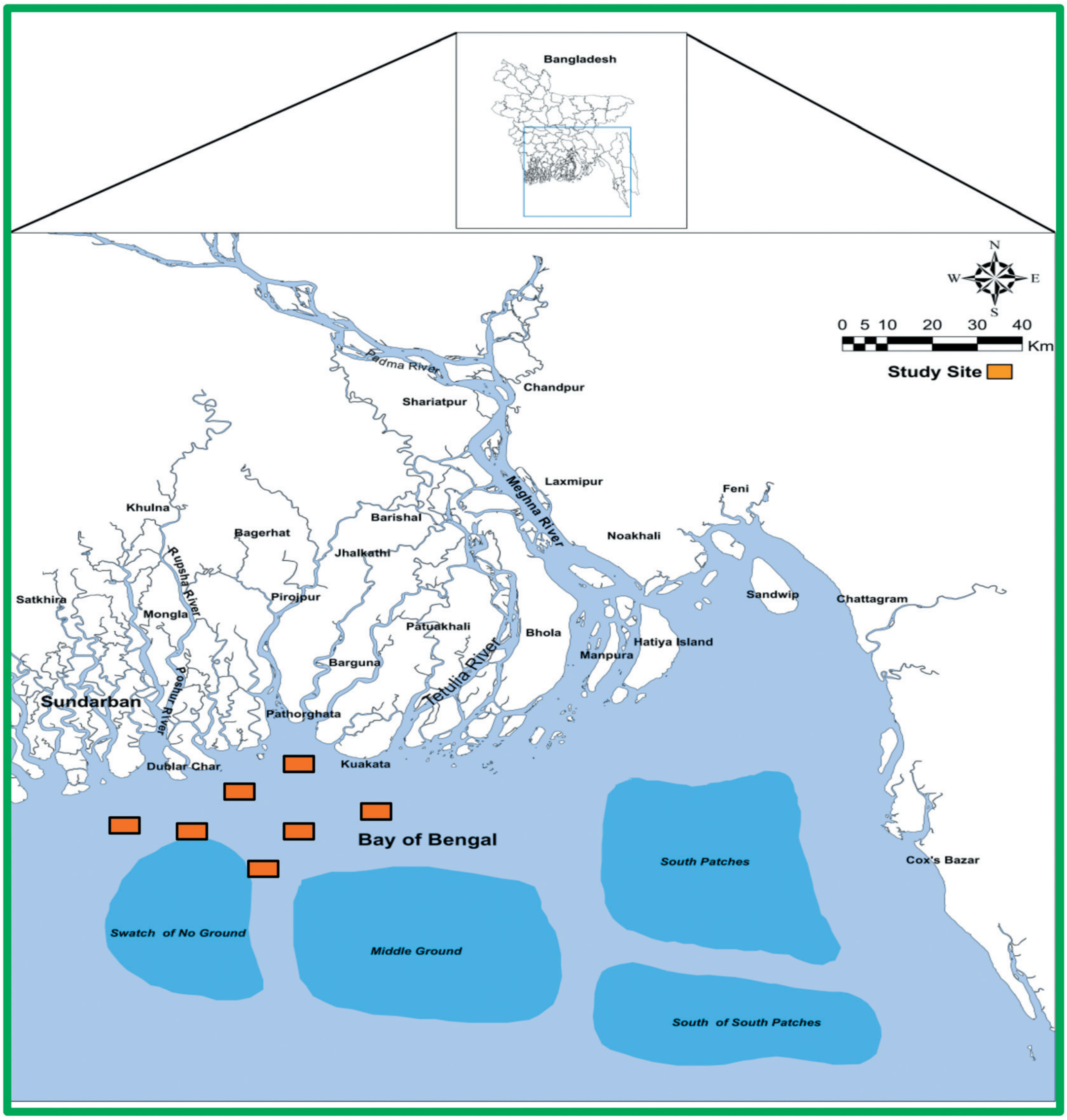

Figure 1. Map of sampling sites (indicated by rectangular shapes) in the Bay of Bengal, Bangladesh.

characteristics of *A. leiogaster* were included in this study. To determine the fin formula, different fin rays (branched – top half of the fin split into many rays; unbranched – solitary fin ray) were counted using a magnifying glass in the laboratory. Two soft rays at the end of an array were regarded to be separate rays (Kottelat and Freyhof 2007). The total number of pored scales in the lateral line was determined by counting from the shoulder girdle to the end of the caudal peduncle. Belly scutes were also counted using a magnifying glass. The BW of each specimen was determined on an electric balance to the nearest 0.01 g. Additionally, linear dimensions, specifically body lengths (Table 1), were measured for each specimen to the nearest 0.01 cm. LWR was calculated with the Le Cren equation (1951) – BW= $a \times L^b$; here L is a different body length. Additionally, linear regression analysis was utilized to establish length-length correlations (LLRs). The regression parameters (a and b) were estimated through natural logarithm transfer ($\ln(W) = \ln(a) + b \ln(L)$). Furthermore, the confidence limit (95%) of the regression parameters and the coefficient of determination (r^2) were evaluated.

Table 1
Description of different morphometric measurements of smoothbelly sardinella, *A. leiogaster* in the Bay of Bengal, Bangladesh

Morphometric measurements	Description
Total Length (TL)	From the tip of the snout to the end point of the caudal fin
Fork Length (FL)	From the tip of the snout to the deepest point of the caudal fin notch
Standard Length (SL)	From the tip of the snout to the base of the caudal fin
Head Length (HL)	From the tip of the snout to the end point of the bony opercular edge
Dorsal Length (DL)	From the tip of the snout to the anterior point of the dorsal fin base
Pectoral Length (PcL)	From the tip of the snout to the anterior point of the pectoral fin base
Pelvic Length (PvL)	From the tip of the snout to the anterior point of the pelvic fin base
Anus Length (AnsL)	From the tip of the snout to the anterior point of the anus
Anal Length (AnL)	From the tip of the snout to the end point of the anal fin base

Statistical analyses

The analysis excluded extreme value outliers based on Froese's (2006) criteria. In order to ensure that the *b* values evaluated in the linear regressions were not substantially different from the isometric value ($b = 3$), a t-test was conducted (Sokal and Rohlf 1987). The best model was selected depending on the highest value of r^2 from LWRs and LLRs. With a significance level of 5% ($P < 0.05$), all statistical analyses were conducted using GraphPad Prism 6.5 software.

Results

Meristic counts

A. leiogaster has a body shape that is sub cylindrical and moderately slender. The mouth is small and the upper jaw extends to the front edge of the eye. The opercle is smooth without a bony strait. The shoulder girdle margin has two outgrowths. The belly is somewhat rounded. Even though the scutes are not always prominent, there are 17–18 prepelvic and 13–15 post pelvic scutes, as shown in Table 2. The dorsal fin starts approximately at the middle of the body. The anal fin is fairly short and is posterior to the base of the dorsal fin. The pectoral fin is positioned at a lower point on the body and has longer rays. The pelvic fin is abdominal and does not reach the anal fin base. The caudal fin is deeply forked. The last two anal fin rays are enlarged. The body color is blue-green on the dorsal side and silvery the ventral side without blackish spots on the trunk, and the dorsal fin base is blackish in color (Figure 2). The fin formula was: D. 17–18 (2/15–16); P. 15–16 (1/14–15); Pv. 8 (1/7); A. 18–20; C. 19– 20 (2/17–18).

Morphometric characteristics

In this study, the TL range was 13.3–20.0 cm (mean ± SD = 17.27 ± 1.05), and the BW range was 25.72–79.68 g (mean ± SD = 52.53 ± 8.45). All morphometric measurements are presented in Table 3. The regression parameters (a and b) for length-weight relationships (LWR) of *A. leiogaster*, their 95% CL, and r^2 are provided in Table 4. All LWR values exhibited a high level of significance ($P < 0.0001$) with r^2 values equal to or greater than 0.851. The LWR by BW vs TL models showed the highest level of fit among nine equations, as indicated by the r^2 value. Table 5 presents all LLRs that showed a strong correlation with r^2 values ≥ 0.812. Based on the r^2 value, the LLR by TL vs FL model was found to be the most accurate among eight equations.

Discussion

The study of meristic counts and morphometric characteristics is one of the simplest and most

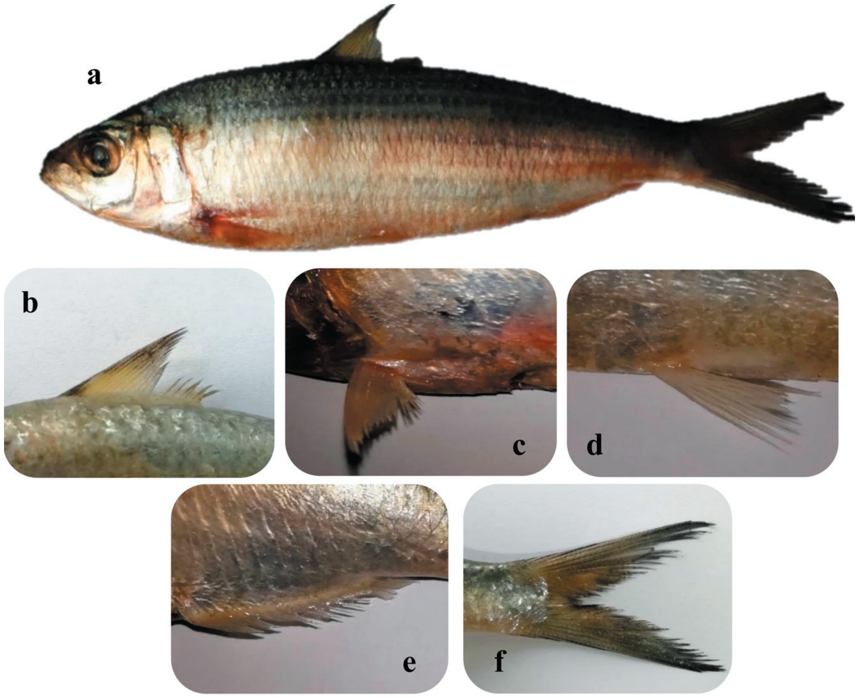

Figure 2. (a) *Amblygaster leiogaster* specimen collected from the Bay of Bengal, Bangladesh during sampling showing the (b) dorsal (c) pectoral, (d) pelvic, (e) anal, and (f) caudal fins.

Table 2
Meristic counts of smoothbelly sardinella, *A. leiogaster* in the Bay of Bengal, Bangladesh

Meristic data	Numbers	Unbranched	Branched
Dorsal fin rays (D)	17 – 18	2	15 – 16
Pectoral fin rays (P)	15 – 16	1	14 – 15
Pelvic fin rays (Pv)	7	1	6
Anal fin rays (A)	18 – 20	-	18 – 20
Caudal fin rays (C)	19 – 20	2	17 – 18
Scutes	17–18 prepelvic; 13–15 post pelvic		

Unbranched, single fin ray; Branched, upper portion of fin divides into several rays

Table 3
Descriptive statistics on different measurements with 95% confidence limits of smoothbelly sardinella, *A. leiogaster* in the Bay of Bengal, Bangladesh

Measurements	Min (cm)	Max (cm)	Mode (cm)	Mean ± SD	95% CL	% TL
Total length (TL)	13.3	20.0	17.4	17.27 ± 1.05	17.14–17.40	100.00
Fork length (FL)	11.2	17.2	15.0	14.81 ± 0.89	14.70–14.92	86.00
Standard length (SL)	10.5	15.6	13.8	13.39 ± 0.83	13.28–13.49	78.00
Head length (HL)	2.2	4.0	3.2	3.30 ± 0.31	3.26–3.34	20.00
Dorsal length (DL)	4.4	7.1	5.8	5.86 ± 0.41	5.81–5.91	35.50
Pectoral length (PcL)	2.3	3.9	3.2	3.17 ± 0.26	3.14–3.20	19.50
Pelvic length (PvL)	5.1	7.8	6.7	6.53 ± 0.42	6.48–6.58	39.00
Anus length (AnsL)	7.8	11.6	9.3	9.92 ± 0.67	9.84–10.01	58.00
Anal length (AnL)	8.0	11.8	10.3	10.10 ± 0.65	10.02–10.18	59.00
Body weight (BW)*	25.72	79.68	48.10	52.53 ± 8.45	51.48–53.58	-

SD, standard deviation; CL, confidence limit; *, measured in grams

Table 4

Descriptive statistics and estimated parameters of different length-weight relationships of smoothbelly sardinella, *A. leiogaster* in the Bay of Bengal, Bangladesh

Equation	*a*	*b*	95% CL of *a*	95% CL of *b*	r^2
BW = $a \times TL^b$	0.0298	2.621	0.0239–0.0373	2.542–2.669	0.946
BW = $a \times FL^b$	0.0436	2.629	0.0345–0.0550	2.543–2.716	0.935
BW = $a \times SL^b$	0.0766	2.514	0.0595–0.0986	2.417–2.611	0.913
BW = $a \times HL^b$	1.2470	2.603	0.9997–1.4811	2.523–2.684	0.861
BW = $a \times DL^b$	1.0519	2.208	0.8846–1.2508	2.110–2.306	0.888
BW = $a \times PcL^b$	1.3869	2.767	0.9868–1.6939	2.715–2.812	0.851
BW = $a \times PvL^b$	0.5758	2.401	0.4603–0.7202	2.281–2.520	0.864
BW = $a \times AnsL^b$	0.2494	2.327	0.2030–0.3063	2.238–2.417	0.913
BW = $a \times AnL^b$	0.2148	2.374	0.1683–0.2741	2.269–2.480	0.888

See Table 3 for abbreviations; *a* and *b*, regression parameters; r^2, co-efficient of determination

Table 5

Descriptive statistics and estimated parameters of different length-length relationships (Y = a +*b* × X) of smoothbelly sardinella, *A. leiogaster* in the Bay of Bengal, Bangladesh

Equation	*a*	*b*	95% CL of *a*	95% CL of *b*	r^2
TL = $a+b\times$FL	0.2296	1.151	-0.0280–0.6672	1.121–1.180	0.960
TL = $a+b\times$SL	1.0567	1.211	0.5121–1.6013	1.170–1.252	0.933
TL = $a+b\times$HL	1.6860	3.209	1.1720–2.1999	3.053–3.364	0.870
TL = $a+b\times$DL	2.8629	2.458	2.3008–3.4251	2.362–2.553	0.912
TL = $a+b\times$PcL	1.2656	3.628	1.0707–1.4607	3.409–3.846	0.812
TL = $a+b\times$PvL	1.9422	2.347	1.1870–2.6974	2.231–2.462	0.866
TL = $a+b\times$AnsL	2.2452	1.514	1.7874–2.7030	1.468–1.560	0.944
TL = $a+b\times$AnL	1.6464	1.547	1.0714–2.2215	1.490–1.604	0.921

See Table 1 for abbreviations; *a*, intercept; *b*, slope; r^2, coefficient of determination

trustworthy approaches to identify any species of fish, and it also provides details on fish taxonomy (Nayman 1965, Ihssen et al. 1981). Typically, fishes exhibit a greater range of morphological features within species as well as among populations compared to other vertebrates. Morphological features are frequently used to distinguish between populations within species. There is very little information available in the literature regarding the morphological features of *A. leiogaster*. Thus, the present study aimed to fill this void.

Meristic characters

Waldman (2005) observed meristic variation in numerous fish species. However, the dorsal fin (17–18) of *A. leiogaster* in the current study was consistent with the findings of Weber and De Beaufort (1913) and Hossain et al. (2020), but they were lower than the findings of Losse (1968) from east African coastal waters. The pectoral fin is more or less similar to the earlier studies (16–17 pectoral fin rays by Hossain et al. (2020) and 16–18 by Weber and De Beaufort (1913)). The pelvic and anal fin rays resembled the findings of Weber and De Beaufort (1913), Losse (1968), and Hossain et al. (2020). The scutes observed (17–18 prepelvic and 13–15 post pelvic) were identical to those in Losse (1968) who observed them in east African coastal waters. Moreover, the pictorial form of meristic characters (Figure 2) is beneficial to recognize this species and identical to the present study (Tanjin et al. 2020).

Morphometric characteristics

In the Bay of Bengal, Bangladesh, the TL range of *A. leiogaster* was 13.30–20.0 cm. Nevertheless, the absence of fish measuring less than 13.3 cm TL in the study could be attributed to the choice of fishing gear, a relatively low market demand, or fishers avoiding areas inhabited by larger fish (Rahman et al. 2021). Hossain et al. (2020) documented that the species typically has a length range of 15.0–18.0 cm and a weight range of 50.0–60.0 g with a maximum of 80.0 g. However, Whitehead (1985) reported 18.0 cm (SL) as the common length for this species. The maximum TL of the present study was higher than their findings, but the BW was similar to them. Furthermore, Hossain et al. (2020) reported a maximum length of 20.0 cm, while Whitehead (1985) stated 23.0 cm (SL) and Losse (1968) observed 21.6 cm in east African coastal waters, all of which exceeded the current study in the Bay of Bengal.

Froese (2006) reported that the values of allometric co-efficient (b) varied between 2.5 and 3.5. Some LWRs of this study did not follow the range reported by Froese (2006). However, Carlander (1969) reported values between 2.0–4.0, and the b values of *A. leiogaster* from the Bay of Bengal, Bangladesh was within this range. Since $b < 3$, all LWRs indicated negative allometric growth (Tesch 1971). Nevertheless, Rafail (1972) observed positive allometric growth ($b = 3.143$) in the Red Sea, Egypt. However, b values within the same species can vary as a result of the interaction of one or more factors, such as disparities in physical growth, physiological status, gender, gonadal maturation, food accessibility, preservation methods, habitat, or variations in lengths among specimens (Dasgupta 1991, Hasan et al. 2020, Sidiq et al. 2021, Rahman et al. 2021) that were not considered in this study. Significant changes within stocks can emerge as a result of these characteristics, particularly within geographic subgroups or populations subjected to shifting ecological circumstances (Silva 2003). Because of minimal genetic diversity among genuine populations, environmental factors can frequently influence stock identification (Kinsey et al. 1994, Begg and Waldman 1999). Moreover, all of the LLRs exhibited significant correlations. Considering the limited availability of literature data, it is difficult to make direct comparisons with the current findings. Nevertheless, this study identified the most optimal model among many equations of varied lengths, based on the r^2, that will serve as a benchmark for future studies to make comparisons.

In conclusion, this study provides basic information on morphological characteristics of smoothbelly sardinella, *A. leiogaster* in the Bay of Bengal, Bangladesh that are pertinent for biologists and managers for sustainable management strategy initiatives.

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