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Ferdous Ahamed
Department of Fisheries Management, Patuakhali Science and Technology University, Patuakhali, Bangladesh

Newton Saha
Department of Fisheries Management, Patuakhali Science and Technology University, Patuakhali, Bangladesh

Zoarder Faruque Ahmed
Department of Fisheries Management, Bangladesh Agricultural University, Mymensingh, Bangladesh

Md. Yeamin Hossain
Department of Fisheries, Faculty of Agriculture, University of Rajshahi, Rajshahi, Bangladesh

Correspondence
Ferdous Ahamed
Department of Fisheries Management, Patuakhali Science and Technology University, Patuakhali, Bangladesh

Morphometric relationships between length-weight and length-length of *Apocryptes bato* (Gobiidae) in the Payra River, southern Bangladesh

Ferdous Ahamed, Newton Saha, Zoarder Faruque Ahmed and Md. Yeamin Hossain

Abstract
Length-weight relationships (LWRs) and length-length relationships (LLRs) of *Apocryptes bato* were studied in the Payra River, southern Bangladesh. Monthly samples were collected from the small-scale fishers of set bag net fishery in the Payra River during May 2016 to April 2017. All specimens were separated on the basis of sex and standard length (SL), total length (TL), anal length (AL) and body weight (BW) were measured. The allometric coefficient 'b' of the LWRs indicated negative allometric growth in males, females and unsexed. The allometric coefficient 'b' of the LLRs between SL vs. TL indicated positive allometric growth, while TL vs. AL and SL vs. AL indicated negative allometric growth in males, females and unsexed individuals respectively. These results will be useful for fishery managers to impose adequate regulations for sustainable fishery management not only in the Payra River of but also in the surrounding water bodies of Bangladesh.

Keywords: length-weight relationships, length-length relationships, Payra River, *Apocryptes bato*

1. Introduction
The gobioid fish *Apocryptes bato* (Hamilton, 1822), is one of the common coastal fishes of Bangladesh and is found throughout the year, mostly in dry season [1]. This species is a demersal and amphidromous [2] which is found in mudflats of estuaries and the freshwater tidal zone of rivers [3]. This species is widely distributed in the coastal shallow water of the Bay of Bengal from the east coast of India to Myanmar and the Malay Archipelago [3-5]. This small indigenous fish species of Bangladesh has a high nutritional value in terms of protein, micronutrients, vitamins and minerals, and is considered as a crucial source to prevent malnutrition particularly for women and children [6]. It is one of the dominant fish species in the Payra River (southern Bangladesh) and is an important target species for small-scale fishers due to their delicacy among the people in southern Bangladesh
Length–weight relationships (LWRs) are useful in fishery management for both applied and basic use [7] to: (i) estimate weight from length observations; (ii) calculate production and biomass of a fish population; and/or (iii) provide information on stocks or organism condition at the corporal level. Length–length relationships (LLRs) are also important in fisheries management for comparative growth studies **[8]**. Although LWR and LLR are readily available for most European and North American freshwater and marine fishes **[9, 10, 11, 12, 13, 14, 15]**, adequate local information is still scarce for most tropical and subtropical fish species **[16, 17, 18]**.
The Payra River is considered as an important spawning and feeding ground for coastal riverine fishes of Bangladesh and a large number of these species including *A. bato* are fished by both small and large-scale fishers throughout the year. However, to the best of our knowledge, very few information on the LWR and LLR of *A. bato* are available [19, 20, 21] in the literature from different water bodies and no studies from the Payra River hampering the formulation of sound management strategies for this important fishery. Therefore, this paper describes the LWRs and LLRs of *A. bato* in the Payra River, southern Bangladesh.

2. Materials and methods
The present study was conducted in the Payra River running through Patuakhali, a southern district of Bangladesh (straddling 22º 35´ N and 90º 26´ E).

The river originated from the Tetulia River via the Karkhana River and finally falls into the Bay of Bengal by the name of Burishwar River.

Monthly samples were collected from the small-scale fishers of set bag net fishery in the Payra River during May, 2016 - April, 2017. All collected specimens were preserved in 10% formalin and transferred to the laboratory for analysis. For each individual, standard length (SL), total length (TL) and anal length (AL) was measured to the nearest 0.01 cm using a measuring scale, while the body weight (BW) was recorded using a digital balance (AND, FSH, Korea) to 0.01 g accuracy. Sex determination was done by incision of the abdomen of each individual and visual inspection of the gonad by naked eye.

The LWR was estimated by linear regression analysis based on natural logarithms: ln (W) = ln (a) + b ln (L), where W is the body weight (BW g) and L the standard length (SL cm), total length (TL cm) or anal length (AL cm). Additionally, 95% confidence limits of a and b, and the coefficient of determination r^2 were estimated. According to Froese [22], all extreme outliers were excluded from the analyses. Furthermore, SL vs. TL, SL vs. AL and TL vs. AL were estimated by linear regression separately for male, female and unsexed specimens. A t-test was applied to determine significant differences from the isometric value (b= 3.0 for length-weight relationship and b = 1.0 for length-length relationship) [23]. Deviation of the b value from the theoretical isometric value indicates either positive (b > isometric value) or negative (b < isometric value) allometric growth. Analysis of covariance (ANCOVA) [24] was used to test for significant differences in slopes and intercepts among the relationships.

3. Results

A total of 1068 specimens of *A. bato* were collected during this study, with 248 (23.22%) males, 665 (62.27%) females and 155 (14.51%) unsexed individuals. The SL ranged from 4.3 to 10.7 cm in males, from 4.4 to 9.1 cm in females and from 3.7 to 7.8 cm in unsexed whereas BW ranged from 1.82 to 16.07 g, from 1.74 to 10.60 g and from 0.68 to 6.20 g for male, female and unsexed individuals respectively.

The LWRs between SL vs. BW, TL vs. BW and AL vs. BW indicated negative allometric growth for male, female and unsexed individuals (Table 1) as the allometric coefficient b values were significantly different (<3.0) from the expected isometric value of 3 (t-test, $p<0.05$). Extremely significant differences in both slope (b) and intercept (a) were observed among the relationships (ANCOVA; $p<0.0001$). The positive values of the coefficient of determination for male, female and unsexed indicated that body weight increase with the increase of length.

Table 1: Descriptive statistics and estimated parameters of length–weight relationships for male, female and unsex of *Apocryptes bato* in the Payra River, southern Bangladesh from May 2016 to April 2017.

Sex	n	Equation	Regression parameters		95% confidence level of a	95% confidence level of b	r^2
			a	b			
Male	248	ln (BW) = ln (a) + b ln (SL)	- 2.959	2.340	-3.144 to -2.773	2.243 to 2.435	0.909
		ln (BW) = ln (a) + b ln (TL)	- 3.188	2.100	-3.438 to -2.937	1.989 to 2.211	0.949
		ln (BW) = ln (a) + b ln (AL)	- 1.384	2.460	-1.511 to -1.256	2.353 to 2.567	0.904
Female	665	ln (BW) = ln (a) + b ln (SL)	- 3.049	2.436	-3.145 to -2.952	2.384 to 2.487	0.931
		ln (BW) = ln (a) + b ln (TL)	- 3.540	2.309	-3.662 to -3.412	2.253 to 2.365	0.908
		ln (BW) = ln (a) + b ln (AL)	- 1.042	2.199	-1.116 to -0.968	2.135 to 2.264	0.924
Unsex	155	ln (BW) = ln (a) + b ln (SL)	- 3.626	2.707	-3.904 to -3.346	2.539 to 2.873	0.909
		ln (BW) = ln (a) + b ln (TL)	- 4.672	2.795	-4.997 to -4.347	2.630 to 2.959	0.914
		ln (BW) = ln (a) + b ln (AL)	- 1.556	2.562	-1.727 to -1.384	2.381 to 2.743	0.938

n, number of individuals; a, intercept; b, slope; Cl, confidence limits; r^2, coefficient of determination.

Table 2: Length–length relationships between standard length (SL), total length (TL) and anal length (AL) of *Apocryptes bato* in the Payra River, southern Bangladesh from May 2016 to April 2017.

Sex	n	Equation	Regression parameters		95% confidence level of a	95% confidence level of b	r^2
			a	b			
Male	248	TL=a+ b×SL	- 0.656	1.484	-0.941 to -0.369	1.443 to 1.524	0.955
		AL=a +b×SL	0.290	0.438	0.173 to 0.406	0.421 to 0.454	0.918
		AL=a +b×TL	0.556	0.288	0.441 to 0.670	0.276 to 0.299	0.907
Female	665	TL=a+ b×SL	- 0.061	1.381	-0.189 to 0.063	1.362 to 1.400	0.968
		AL=a +b×SL	- 0.026	0.496	-0.094 to 0.043	0.485 to 0.506	0.929
		AL=a +b×TL	0.088	0.348	0.017 to 0.158	0.340 to 0.356	0.920
Unsex	155	TL=a+ b×SL	- 0.002	1.374	-0.259 to 0.254	1.326 to 1.421	0.955
		AL=a +b×SL	0.050	0.477	-0.073 to 0.172	0.454 to 0.499	0.917
		AL=a +b×TL	0.102	0.341	-0.029 to 0.234	0.323 to 0.359	0.906

n, number of individuals; a, intercept; b, slope; Cl, confidence limits; r^2, coefficient of determination.

The allometric coefficient 'b' of the LLRs between SL vs. TL indicated positive allometric growth while TL vs. AL and SL vs. AL indicated negative allometric growth in males, females and unsexed individuals as the allometric coefficient b values were significantly different from the expected isometric value of 1 (t test; $p<0.05$). All LLRs were highly significant (ANCOVA; $P < 0.0001$), with all coefficient of determination values being >0.900.

4. Discussion

Length-weight relationship (LWR) can be derived from length and weight measurements of the same fishes throughout their lives or from a sample of fish taken at a particular time [25]. The parameters of length-weight relationship are influenced by a series of factor including season, habitat, gonad maturity, sex, diet, stomach fullness, health of the individuals in their natural habitats as well as the treatment of specimens and preservation techniques after

sampling [9, 26]. The allometric coefficient (b) generally lies between 2.5 and 3.5 [22], but they can vary between 2.0 and 4.0 [9]. The values of a and b of LWRs for *A. bato* in this study were within the limits reported by Froese [22]. In the present study, the allometric coefficient (b) indicated negative allometric growth in LWR which was in accordance with the studies of Rahman *et al.*, 2016 [20] from the coast of Chittagong, and Hossain *et al.*, 2016 [19] from the Rupsha River, southwestern Bangladesh. However, Siddik *et al*., 2016 [21] reported isometric growth of *A. bato* from a southern coastal river of Bangladesh. The differences in b values can be attributed to the combination of one or more factors including habitat, area, season, stomach fullness, gonadal condition, sex, health, preservation methods and differences in the size of the specimens caught [27], which were not accounted in this study.

Due to the lack of references dealing with LLRs for *A. bato*, it was not possible for comparisons with the previous literature. However, the present study was compared with results from studies dealing with other species of the Gobiidae family. In the present study, the LLR between SL and TL indicated positive allometric growth for male, female and unsexed individuals. Similar results were observed by Baeck and Park [28] who also reported positive allometric growth between SL and TL relationship for two gobioid fish, *Periophthalmus modestus* and *Periophthalmus magnuspinnatus* for male, female and unsexed individuals from tidal flats of Korea. However, differences in LLRs might occur due to the differences in the ecological conditions of the habitats or variation in the physiology of the animals, or both [29]. The estimated length-length relationships of this species could provide valuable information for future research.

5. Conclusion

This study has provided basic information on the LWRs and LLRs that would be useful for fishery biologists/managers to impose adequate regulations for sustainable fishery management in the Payra River and surrounding water bodies of Bangladesh. However, further detailed studies are necessary for future assessment.

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