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Length-weight relationship, relative condition factor and morphological studies of *Arius arius* (Hamilton, 1822) in Hooghly-Matlah estuary, West Bengal

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The present study deals with the length-weight relationship, relative condition factor, and morphometric and meristic characters of Threadfin sea catfish, *Arius arius* (Hamilton, 1822) from Hooghly-Matlah estuarine system, West Bengal, India. A total of 391 samples (243 females and 148 males) with the size ranging from 52 to 254 mm total length (TL) and weight ranging from 1.62 to 176.75 g were analyzed for a period of one year (April 2017 to March 2018). The 'b' value was estimated as 3.065, 3.127, and 3.104 for male, female, and pooled samples, respectively exhibiting positive allometric growth. The monthly mean relative condition factor (Kn) values ranged from 0.923 to 1.309 for males and 1.003 to 1.085 for females, respectively showing the good condition of the species. Fourteen morphometric characters analyzed revealed that the total length exhibited a highly significant correlation ($p < 0.05$) with most of the morphometric parameters. The analysis of meristic characters of *A. arius* found that the first dorsal fin bears 1 spine and 7 soft rays, pelvic fin is with 6 soft rays, pectoral fin bear 1 spine and 8-11 soft rays, anal fin bears 14-17 soft fin rays and the caudal fin is with 16-23 soft rays.

[**Keywords**: *Arius arius*, Hooghly-Matlah estuary, Length-weight relationship, Meristic counts, Morphometric characters, Relative condition factor]

Introduction

The knowledge of length-weight relationships (LWRs) of fish is vital in fisheries as it is useful to establish the mathematical relationship between two variables *i.e.*, length and weight, and is also used for comparison of an individual with and between different populations[1]. To understand survival, growth, maturity, reproduction, and general well-being, the mathematical relationship between length and weight of fishes is a practical suitable index and it is often used to characterize life history and make morphological comparisons between different fish species or populations[2]. In recent years, several types of research have been undertaken to study the LWRs of finfishes in freshwater and estuarine habitats of West Bengal[3-8].

In fisheries science to compare the condition, fatness, or wellbeing of fish the condition factor is being used. The heavier fish of a particular length is in a better physiological condition than lower weight fish, based on the general theorem[9,10]. The estimated values of the ponderal index (K) and relative condition factor (Kn) gives details on the general wellbeing of the fish and its development process. The knowledge of fish condition indices provides comparative measures of fish freshness and plumpness. Studies about fish condition parameters are useful, inexpensive, and easy measurement tool to know the fecundity, reproduction, growth and mortality rates of fishes[3-6], fat monitoring in the body, gonadal development[11] and to study the reproductive status of the fish.

Arius arius (Hamilton, 1822) (Fig. 1) commonly known as 'threadfin sea catfish' of the family Ariidae (order Siluriformes) constitutes a commercially important species in the West Bengal state of India. The production of sea catfish (*Arius* spp.) was 20,375 t against the total marine production of 1, 73,771 t during the year 2015-16[(ref. 12)] in the state of West Bengal. The estimated annual average catch of marine catfishes is around 80,559 t in India[13]. Family Ariidae comprises 153 species under 27 genera of tropical and sub-tropical marine catfishes[14]. Jayaram[15] reported 197 catfishes found in the Indian waters and a total of 86 catfish species were reported from West Bengal[16]. Along the east coast of India, among marine catfishes, the engraved catfish *A. arius* contributed major share in terms of its landing[17]. It is distributed in the Indo-West Pacific belt: India through neighboring coastal nations (Pakistan, Bangladesh, and Myanmar) to

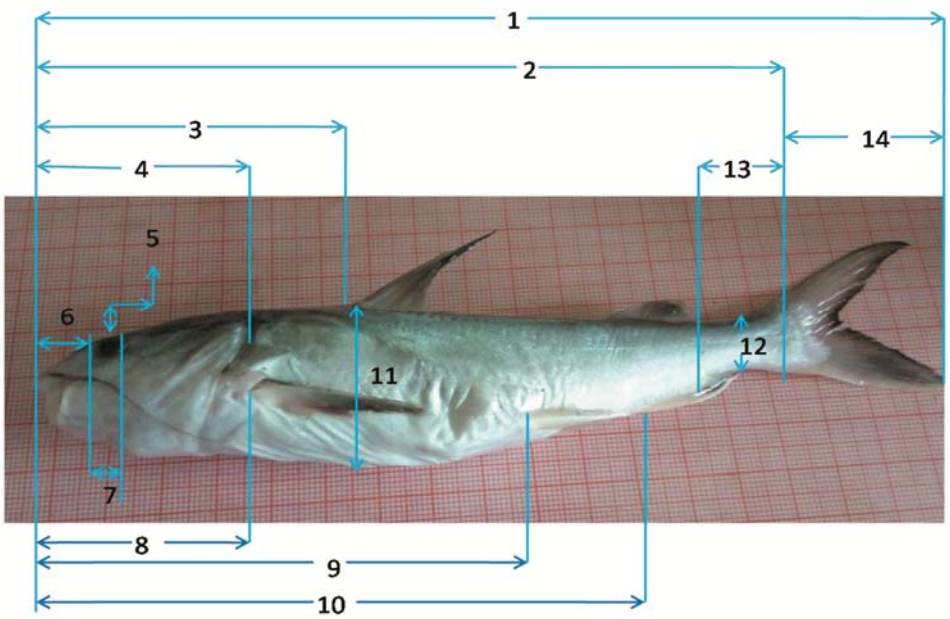

Fig. 1 — Morphometric characters of *A. arius*: 1) Total length, 2) Standard length, 3) Pre-dorsal length, 4) Head length, 5) Inter orbital length, 6) Snout length, 7) Eye diameter, 8) Pre-pectoral length, 9) Pre-pelvic length, 10) Pre-anal length, 11) Mid body depth, 12) Caudal depth, 13) Caudal peduncle length, and 14) Caudal length

Singapore, South China Sea. This species feeds mostly on invertebrates. *A. arius* is a bottom-dwelling catfish, widely distributed in estuaries and freshwater environments of the west and east coasts of India.

Numerous reports are available on the LWRs of marine catfishes in different parts of the World[18-23] and few in the Indian context[24-28]. But no work has been reported regarding studies of biological parameters of *A. arius* occurring in Hooghly-Matlah estuary of West Bengal. The present paper deals with the LWRs, Kn values and morphological characters of *A. arius* from Hooghly-Matlah estuary which will be helpful to promote management measures of the species in the region.

Materials and Methods

Specimens of *A. arius* were collected from Godakhali (latitude 22°10’182” N; longitude 88°12’034” E) and Diamond Harbour (latitude 22°24’284” N; longitude 88°08’548” E) fish landing centers of 24 South Paraganas district under the Hooghly-Matlah estuarine system. Fishes were caught mostly by stationary bagnet (locally called beenjal, behundi jal), a non-selective multispecies small-meshed net (10-25 mm mesh size) and by drift gill nets (30-60 mm mesh size). A total of 391 samples of *Arius arius* with a size ranged from 50 mm to 255 mm was considered for the present study (April 2017 to March 2018).

Fish specimens were collected from selected landing centers in fresh conditions and were transported in a plastic insulated box containing ice and brought to the laboratory. By using a measuring board, the total length (TL) of the fish specimens were measured from the tip of the anterior-most part of the body to the tip of the caudal fin to the nearest 0.1 mm and weighed using an electronic balance to the nearest 0.01 g accuracy. The LWRs for both male and female specimen was calculated separately following the method of Ricker[29] using the formula $W = aL^b$. Isometric and allometric growth was tested by employing Fisher ‘*t*’ test.

The *‘Kn’ value* can also be used to compare the general well-being, fatness, or the state of development of gonads. The ‘Kn’ was calculated by using the formula: $Kn = W_0/W_c$, where W_o = observed weight and W_c = calculated weight. Monthly mean values of ‘Kn’ were calculated for individual samples and the average value was estimated accordingly.

A total of five meristic and fourteen morphometric characters were studied following the standard procedure of Grant & Spain[30]. For the analysis of morphometric characters, a linear regression equation was fitted using the least square method described by Snedecor & Cochran[31]. Meristic characters included the number of spines and rays on pectoral, dorsal, anal, pelvic, and caudal fins. Relationships

between certain body measurements to the total length and head length have been calculated.

Results

Length-weight relationships (LWRs)

The LWRs of catfish *A. arius* was estimated based on 391 samples (243 females and 148 males) with the size varied from 52 to 254 mm and weight ranging between 1.62 to 176.75 g. The log transformation of the linear regression of LWR of *A. arius* and its corresponding exponent is depicted in Figure 2. It was observed that the fish exhibited positive allometric growth as the 'b' value differed significantly ($p < 0.01$) from 3. The 'b' values found were 3.065, 3.127 and 3.104 for male, female, and pooled samples, respectively. The corresponding '*r*' value of 0.939, 0.924, and 0.924 indicated a significant correlation ($p < 0.01$) with the length and weight of the fish. The regression equation for the LWRs, with corresponding 'r' values, is presented in Table 1.

Relative condition factor (Kn)

The monthly mean 'Kn' was calculated for different months and is presented in Figure 3. In the case of male, the monthly mean values of 'Kn' varied from 0.923 to 1.309 and that of females from 1.003 to 1.085. In the case of males, the monthly mean 'Kn' values were maximum in June (1.309) and minimum during August (0.923). The average value gradually increased from September (1.121) to March (1.194) with the highest of 1.309 in June. In the case of female, it was gradually increased from May (1.003) to March (1.085).

Morphometric and meristic characters

The present study considered 5 meristic and 14 morphometric characteristics of the fish. The morphometric characters of *A. arius* showed a proportional positive increase with the increase in total length of the fish. Morphometric characteristics were estimated using regression analysis for both male and female fish to find out the growth pattern in relation to total length and other body parameters *i.e.*, standard length, pre-anal length, pre-dorsal length, pre-pectoral length, pre-pelvic length, head length, mid-body depth, caudal depth, caudal length, snout length, pre-orbital length, inter-orbital length, and eye diameter**.** The range values of different morphological characters with mean and standard error are given in Table 2.

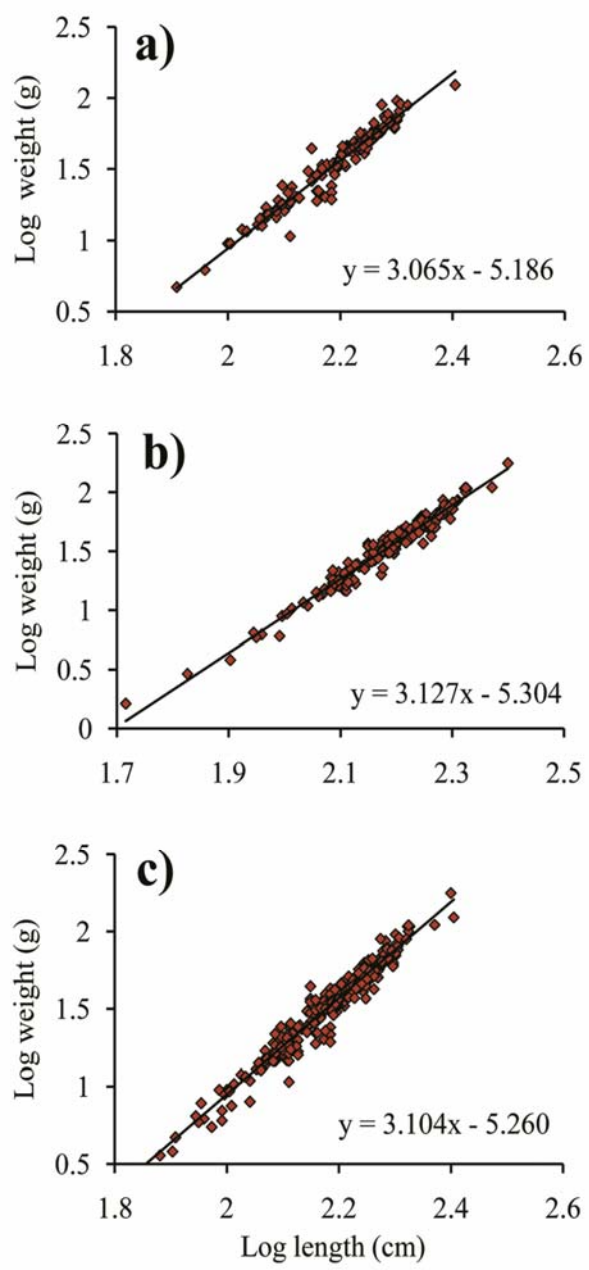

Fig. 2 — Logarithmic length-weight relationship of *A. arius* (a. Male, b. Female, and c. Pooled)

Table 1 — Length-weight relationship of *A. arius*

Group	No. of Samples	a	b	Logarithmic Equation	Linear equation	'r'
Male	148	0.000007	3.065	- 5.186 + 3.065 L	$W = 0.000007L^{3.065}$	0.939
Female	243	0.000005	3.127	- 5.304 + 3.127L	$W = 0.000005L^{3.127}$	0.924
Pooled	391	0.000005	3.104	- 5.260 + 3.104 L	$W = 0.000005L^{3.104}$	0.924

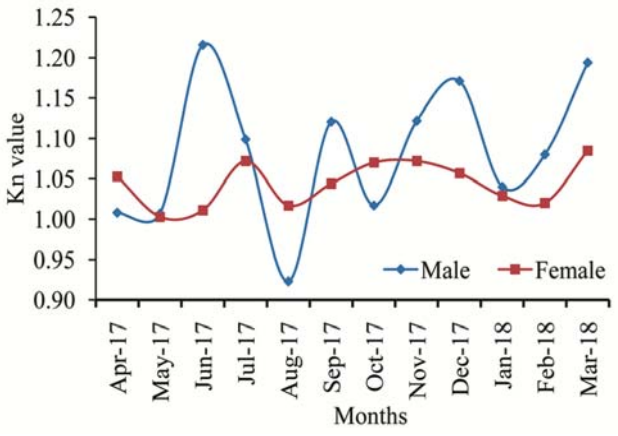

Fig. 3 — Monthly mean estimated 'Kn' value of male and female of *A. arius*

Table 2 — General morphometric analysis in percentage of total length of *A. arius*

Parameters (in mm)	Mean	SE	Range
Standard length	80.35	0.09	72.45 - 88.18
Head length	21.08	0.08	18.01 - 24.85
Pre-dorsal length	28.48	0.12	22.15 - 33.87
Pre-anal length	57.56	0.11	51.52 - 68.82
Pre-pelvic length	43.55	0.11	37.37 - 48.72
Pre-pectoral length	19.50	0.07	16.15 - 24.83
Least depth of caudal fin	6.01	0.03	5.04 - 8.91
Post- orbital length	8.65	0.09	6.25 - 11.94
Inter- orbital length	10.16	0.06	8.00 - 12.99
Snout length	7.45	0.04	6.12 - 9.92
Eye diameter	4.22	0.03	2.78 - 7.84
Caudal length	21.09	0.07	18.03 - 24.84
Mid body depth	18.07	0.09	15.08 - 22.73

The regression coefficient of different variable characters on the total length was significant ($p < 0.05$) and highest ($r = 0.993$) in the case of standard length. The total length exhibited a highly significant correlation ($p < 0.05$) with most of the morphometric parameters (Table 3). Among the selected meristic characters, it was found that the first dorsal fin is having 1 spine with 7 soft rays, pelvic fin has 6 soft rays, pectoral fin with 1 spine and 8-11 soft rays, anal fin with 14-17 soft fin rays and the caudal fin was having 16-23 soft rays**.**

Discussion

Length-weight relationships (LWRs)

The LWRs change with various biological processes like metamorphosis, growth, and maturity. This relationship was generally used to obtain information on the condition, and the growth of fish and to find out whether the somatic growth is isometric or allometric[11]. The variation in exponent 'b' values could be ascribed to environmental factors, food availability and physiological factors including sex and life stages[11]. It's value usually lies between 2.5 to 4.0[(ref. 32)].

In general, the value of exponent 'b' is considered either more than 3 (b > 3) or less than 3 (b < 3) which indicates that fish become heavier and lighter, respectively for a certain length as its increases in size[32]. The 'b' value of *A. subrostraus* was reported as 2.6224, 3.0914 and 2.8067 for male, female and for combined specimens, respectively[27]. Sawant & Raje[26] observed that *A. caelatus* and *A. thalassinus* were having positive allometric growth (b > 3) in both

Table 3 — Relationship between different morphometric characters of *A. arius*

Sl. No.	Morphometric characters	Y = a + bx	'r' value
1	Standard length on Total length	Y = 0.803x - 0.063	0.993*
2	Pre-anal length on Total length	Y = 0.596x – 3.243	0.544*
3	Pre-dorsal length on Total length	Y = 0.300x – 2.415	0.524*
4	Pre-pectoral length on Total length	Y = 0.204x – 1.404	0.923*
5	Pre-pelvic length on Total length	Y = 0.447x – 1.822	0.949*
6	Head length on Total length	Y = 0.207x + 0.522	0.919*
7	Mid body depth on Total length	Y = 0.187x – 1.007	-0.088
8	Caudal depth on Total length	Y = 0.053x + 0.955	-0.041
9	Caudal length on Total length	Y = 0.196x + 2.141	0.929*
10	Snout length on Total length	Y = 0.075x – 0.143	0.873*
11	Pre-orbital length on Total length	Y = 0.108x – 0974	-0.015
12	Inter orbital length on Total length	Y = 0.075x – 0.358	-0.015
13	Eye diameter on Total length	Y = 0.024x + 2.675	0.783*

* Significant at the 0.05 level.

males and females along the west coast and east coast, respectively. Raje *et al*.[25] recorded 'b' value of *T. jella* as 3.305 (r = 0.960), 3.3050 (r = 0.970) and 3.443 (r = 0.960) for male, female, and pooled sample, respectively with positive allometric growth. The LWRs gives some ideas on the condition and growth patterns of fish. The changes in 'b' values depend mainly on the fatness and shape of the species and it is also influenced by other aspects such as food, salinity, sex, temperature, time of the year and stages of maturity[9,10].

Farooq *et al*.[33] had computed the 'b' values for three species of catfish, namely *Arius gagora*, *Plotosus lineatus* and *Osteogeneiosus militaris* along the Arabian Sea of Pakistan and the values were 3.013 (r = 0.898); 3.742 (r = 0.991) and 3.350 (r = 0.980) showing positive allometric growth. While the values of 'b' for *O. militaris* was 2.940 (r = 0.995) and found as negative allometric along the West Bengal coast[34]. The length-weight relationship of *Arius maculatus* and *Arius tenuispinis* has been done by Arshad *et al*.[35] and the 'b' values reported displayed were negative allometric (2.624 and 2.08, respectively). Comparative LWRs of marine catfishes done by other researchers is provided in Table S1.

The 'b' value in the present study was observed more than 3 for the male, female and pooled samples indicating positive allometric growth which is concurrent with earlier studies on *A. arius* in different regions by other researchers[36-37].

Relative condition factor (Kn)

The condition of a fish usually fluctuates by interaction, amount of food consumed, parasitic infections and by physiological factors, and it reflects the current physical and biological circumstances of the fish[11]. The LWRs and 'K' values are used directly for fishery assessment and future comparisons between populations of the same species at different locations[38]. The variation in length against weight is not due to changes in specific gravity but due to changes in volume since the fish always maintain the same density as that of the surrounding water. These changes are analyzed by the condition factor or coefficient of condition or ponderal index[1,38].

In general, condition factors in fishes are influenced by various factors such as availability and types of food, physicochemical parameters, age and sex of the individual, spawning, onset of maturity, breeding, feeding, etc.[6,7]. In the present study, the 'Kn' values were found to be high in smaller size fishes which agree with the earlier workers such as Bhakta *et al*.[3] and Das *et al*.[39]. Das *et al*.[39] observed the mean 'K' and 'Kn' values for *Arius tenuispinis* and found the values as 1.0755 (K) and 1.0144 (Kn) for males as well as 1.0307 (K) and 1.0025 (Kn) for female fish, respectively. Hossain *et al*.[40] reported the 'K' value of the Asian striped catfish *Mystus vittatus* (Siluriformes: Bagridae) as 0.972 to 3.188 for males and 1.564 to 3.186 for females from the Mathabhanga river of south-western Bangladesh. The female specimens were in better condition compared to males and it was correlated with the spawning season of the species.

Ambily & Nandan[27] reported the 'Kn' of *Arius subrostratus* ranging from 0.75 to 1.07, 0.944 to 1.407 and 0.96 to 1.196 for male, female, and pooled groups, respectively. Kamukuru & Tamatamah[41] reported a peak in 'Kn' values of *A. thalassinus* in February for females and during March for males. There was a sharp decrease in 'Kn'values for both sexes during May and June, presumably when the fish had released their gametes. Trivedi *et al*.[42] studied the condition factor of important fin fishes from the lower Gangetic delta based on salinity gradient and found the 'K' values of *Tachysurus jella* (Family Ariidae) as 1.125 at Hooghly estuary and 0.733 from Matlah estuary. They opined that a higher level of 'K' value for ariids at Hooghly estuary was due to the hyposaline environment resulting in the discharge of freshwater water from Farakka barrage against the hypersaline environment of Matlah estuary.

In the present study highest 'Kn' value was observed in June for males and that of females in July which could be due to the spawning season of the species. There was a significant difference ($p < 0.05$) in 'Kn' values due to sex among males and females which might be due to the differential growth of gonads and feeding. Moreover, there was a significant difference ($p < 0.05$) in 'Kn' values due to the interaction of month and sex. Comparative analyses of 'Kn' values of marine catfishes done by other researchers are provided in Table S2.

Morphometric and meristic characters

The analysis of morphometrics helps in understanding the relationship between the body parts. The proportion of body parts with its total length was used for morphometric analysis. Studies of variation in morphological characters are essential to illuminate patterns observed in phenotype and genotypic variations among coastal fish population[43].

Further due to different environmental factors, selection and heredity, different growth patterns within species can lead to a variety of body shapes[36].

Many researchers observed variation between body parameters occurred due to the changes in biological (size, genetic factors) and environmental factors (temperature, turbidity, and depth of water). Velayudham *et al*.[44] studied the morphometrics of the *Istiophorus platypterus* at Parangipettai from the southeast coast of India and stated that the size of the body varies with the first dorsal fin.

The present study revealed the highest correlation of total length (X) on standard length (Y) with the value of '*r*' being 0.993. The lowest value of correlation was noticed in total length (X) on pre-dorsal length (Y) with '*r*' value of 0.524. A highly significant correlation ($p < 0.05$) with most of the morphometric parameters was observed. Sawant & Raje[26] reported that in *Arius caelatus* collected from Mumbai and Veraval waters, out of seven investigated characters in four characters, morphometrically significant differences were found between the sexes at the same locality, within the same sexes at different localities and between both sexes combined. For the populations of *Arius thalassinus* collected from Veraval and Vishakhapatnam, significant differences were noticed between and within the sexes at the same locality and when the sexes were combined, almost all the characters showed highly significant difference. Brian *et al*.[45] had observed geometric morphometric analysis in two species of catfishes *Arius manillensis* and *Arius dispar*, which looked similar externally, but by examining the tooth patch morphology on the palate both species can be distinguished. Among some of the locations, five morphometric characteristics describing the shape of the fish were significantly different. Significantly shorter pre-orbital length (8.3 % SL vs 9.2-10.7 % SL in the other populations) is a population-specific character from the specimens from Walawe estuary. Significant differences in other characteristics were found indicating heterogeneity in morphology.

Supplementary Data

Supplementary data associated with this article is available in the electronic form at http://nopr.niscair.res.in/jinfo/ijms/IJMS_50(01)60-66_SupplData.pdf

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Conflict of Interest

The authors declare that there is no conflict of interest.

Author Contributions

The first author (BBC) was involved in fish samples collection, morphological analysis, and manuscript writing; and the rest of the authors (SKD & DB) helped in manuscript reviewing and editing.

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