



The Gonadal Length-Weight Relationships of Hilsa Shad (*Tenualosa ilisha*) in Relation to Fecundity, Total Length and Body Weight

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJFAR/2023/v25i2659

Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://www.sdiarticle5.com/review-history/105795>

Original Research Article

Received: 26/06/2023

Accepted: 29/08/2023

Published: 06/09/2023

ABSTRACT

The current study was carried out to estimate the range and average number of ova (eggs) released by a female Hilsa shad (*Tenualosa ilisha*) individual during the breeding season, as well as to establish a relationship between Fecundity (F) and Total Length (TL), Total Weight (TW),

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Gonadal Length (GL) and Gonadal Weight (GW). The fecundity of *T. ilisha* was determined by studying the ovaries of 20 individuals with TL ranging from 37.60 cm to 49.90 cm. In this study, only ovaries bearing nearly ripe eggs were considered for the data collection. For each specimen, the total number of ova was computed by multiplying the estimated number of ova in the sample by the ratio of total ovary weight to sample weight. The largest specimen (TL 499 mm and TW 1252 g) was found to have 2272864 eggs, while the smallest (TL 376 mm and TW 617 g) had 835461 eggs. The association between Fecundity and TL, TW, GL, and GW were found to be significant at the 5% level ($p < 0.05$) of significance. It was also discovered that for significant 't' values, Fecundity increases linearly with Total Length, Total Weight, and Gonadal Weight.

Keywords: *Hilsa shad (Tenualosa ilisha)*; fecundity; gonadal length-weight.

1. INTRODUCTION

According to studies, the length-weight relationship is one of the most essential biological factors for fish. The most crucial biological parameter that gives data to help understand population dynamics, such as morphological features, life history, distribution, and stock function [1]. In field research, length-weight relationships provide for greater flexibility in calculating specimen weight. Because direct weight measurement is time-consuming and labor-intensive, the length-weight relationship is critical [2,3]. Various studies have reported that biological aspects including fecundity, gonadosomatic index, and length at sex maturity are important indicators to understand the reproduction of a particular fish species as they give an idea of spawning maturity and activity. Fecundity refers to the total number of oocytes of a broodstock during its breeding period. Fecundity data can be important information in fisheries to predict the reproductive ability of different fish stocks.

The assessment of fecundity in fish is a crucial aspect in understanding the commercial prospects of their population, as well as their life history, practical cultivation, and effective fishery management [4]. The concept of "fecundity" refers to the quantity of eggs found within the ovary, which varies among different species and is not consistently fixed, but rather fluctuates within specific ranges. Fecundity refers to the quantity of eggs present within the ovary of a fish. Fecundity, a crucial component of fish biology, plays a pivotal role in comprehending population dynamics and devising strategies to enhance harvest yields. To effectively evaluate the population dynamics of a species, it is crucial to obtain precise estimations of its fecundity. Fecundity, in the context of fish reproductive biology, refers to the potential number of ova that a fish is expected to release during its spawning

seasons. Based on the findings of [5], the observed quantity refers to the count of eggs present within the female organism shortly before the process of spawning occurs.

Fecundity, a crucial component of reproductive biology, provides valuable insights into the quantity of eggs present in the ovary prior to the subsequent spawning season [5]. Research on the fecundity of fish species is crucial and valuable for conservation biology, particularly in the context of understanding population dynamics and estimating overall reproductive output. Fecundity serves as a crucial metric in the field of conservation biology, as it provides valuable insights into the reproductive capacity and abundance estimation of a given population. The fecundity of hilsa has been subject to limited research thus far. The study conducted by Saifullah et al. in 2004 [6] focused on examining the fecundity of Hilsa fish in the water bodies of Bangladesh. Their findings revealed that body weight serves as the most reliable indicator of fecundity in this species. The spawning activity of female Hilsa (*T. ilisha*) exhibited a notable increase during the month of October, as indicated by a Gonadosomatic Index (GSI) value of 10.2. However, in the month of April, the spawning activity of female Hilsa experienced a decline, with a GSI value of 6.77. In the female Hilsa population, the fecundity ranged from 87267 to 614482 individuals within the length size group of 210 mm to 350 mm. The geometric mean fecundity of the Hilsa fish species was documented as 587919 as reported by references [7,8].

The current study aimed to examine the reproductive capacity of *T. ilisha*, a species of interest in the field of conservation biology. Our objective was to determine the potential number of eggs produced by individual female fish during the breeding season, and to establish a mathematical correlation between Fecundity (F)

and various factors including Total Length (TL), Total Weight (TW), Gonadal Length (GL), and Gonadal Weight (GW).

2. MATERIALS AND METHODS

2.1 Sampling of Fish

Hilsa fish samples were systematically collected from two distinct ecological regions within Bangladesh i.e., the upper Meghna River in Chandpur and the Tentulia River in the Barisal district. The sampling efforts were carried out from July 2012 to June 2013 in the Meghna River, followed by a subsequent period from July 2013 to June 2014 in the Tentulia River. A monthly sampling was implemented, during which a total of 20 fully mature female Hilsa specimens were collected. The Hilsa (*T. ilisha*) were captured in the river during nocturnal hours utilizing gill nets as the primary fishing method. All specimens were carefully preserved using crushed ice in specialized containers designed to maintain optimal temperature conditions. These containers, commonly referred to as cool fish boxes, were utilized to ensure the specimens remained in a cool environment during transportation. The primary objective was to minimize any potential degradation or alteration of the physical and biological characteristics of the specimens.

2.2 Measurement of Total Length and Body Weight

All collected samples were rinsed with tap water and the excess water was blotted with tissue paper. Total length (TL) and standard length (SL) were measured to the nearest 0.01 cm using a measuring scale. The standard length was determined by measuring from the point of the snout to the last vertebra where tail folding causes a crease. The body mass index (BMI) was determined using an electric scale to the nearest 0.01g. All the information was maintained in a data document.

2.3 Calculation of Length-Weight Relationships

Length-Weight relationship is generally calculated from the following equation:
 $W=aL^b$

Where, W is body weight of fish,
a is multiplicative factor
L is a linear measure of the fish length and
b is an exponent.

2.4 Gonado-somatic Index (GSI)

The gonado-somatic index (GSI) can be used to determine the reproductive cycle of a species at monthly or biweekly intervals year-round. It is a highly effective method for indicating the reproductive season of a species at the level of the field. GSI implies that the size of the gonad grows proportionally to the ratio of the Weight of Gonad (GW) to the Body Weight (BW) of the species. The gonado-somatic index of each fish was computed using the formula outlined below:

$$GSI = (GW/BW) \times 100$$

2.5 Collection of Gonad and Sex Determination

The body cavity of fish was delicately cut and opened with scissors, and the gonads were collected with forceps. Other constitutional elements, such as muscles, fatty tissues, digestive organs, and blood veins, were removed appropriately. Total Weight (TW) and Gonad Weight (GW; both left and right gonads) were measured to within 0.001 g. Additionally, the Total Length (TL) and Gonad Length (GL) were measured to the nearest 0.01cm. After being weighed, gonads were placed in small containers containing 10% formalin for further study.

2.6 Observation of Ovarian External Features

During sample collection and preservation, *T. ilisha* female gonads were examined for their general characteristics and structure, as well as their size, shape, and color by month. In both length and breadth, the left gonad was larger than the right in Hilsa. On the basis of external observations of both ovaries with the unaided eye and under magnification, the various stages of ovarian maturity were classified (Fig. 1).

2.7 Determination of the Fecundity of Hilsa

The ovaries of 20 species ranging in length from 37.60 cm to 49.90 cm were examined to determine the fertility of Hilsa. This investigation utilized only ovaries containing nearly mature eggs. All feasible precautions were taken to omit spoiled or immature fish. Before approximating the number of ova in each ovary, the ovaries were fixed in formaldehyde at a concentration of 5% for at least a week. Only ova that were visible



Fig. 1. Observation of external features of egg

to the unaided eye were tallied. After removing the surface moisture, ovaries were weighed using a chemical balance to the milligram. A small sample of approximately 2.0 gm was extracted from the center and weighed to the nearest mg. The ova in the sample were extracted from the follicle, and counts were taken of all the ova visible to the unaided eye that comprised the mature growth. For each specimen, the total number of ova was determined by multiplying the calculated number of ova in the sample by the ratio of the total weight of the ovary to the weight of the sample. Compared to the standard, the maturation level of female gonads is classified as immature (grey to reddish in color), early maturing (reddish in color with capillaries), late maturing (ovaries with a reddish orange hue), ripe, or spawned [9].

2.8 Statistical Analysis of Data

The statistical analysis and graphical representation were done using the Microsoft Excel 2017 software.

3. RESULTS

3.1 External Features of Hilsa Ovaries

Female *T. ilisha* ovary is bilobed, elongated, and located within the body cavity. In accordance with the degree of maturation of the oocytes, the ovary changes in size, shape, and hue; the embryonic ovary is small, reddish, and translucent, while the mature ovary is yellowish. The immature ova are microscopic, transparent, and devoid of yolk; however, as the phases progress, the ova become large and opaque. At

maturity, the ova are yellowish and acquire their maximum size.

3.2 Fecundity of Hilsa

The individual fecundity of fish ranged from 835461 eggs (for the smallest sized fish with a Total Length of 379 mm and a Total Weight of 836 g) to 2272864 eggs (for a fish with a Total Length of 499 mm and a Total Weight of 1252 g) based on an examination of 20 female fish ovaries. The mean Fecundity of 20 females was 1484103 ± 97822 eggs, with a mean Total Length of 41.10 ± 0.94 mm and a mean Total Weight of $818.4041.60$ g (Table 1).

The highest GSI value was 17.65 with Gonad Length 13.90 cm and Gonad Weight 109.07 g, while the lowest GSI value was 12.11 with Gonad Length 13.90 cm and Gonad Weight 86 g (Table 1). The Adjusted R^2 value was observed 0.313 for the Summary Model of F/TL, F/TW, F/GL and F/GW relationships of *T. ilisha* (Table 2). The t value is -0.929 at 0.368 significance level, 1.967 at 0.068 significance level, 0.795 at 0.455 significance level, -0.255 at 0.803 significance level, 0.795 at 0.439 significance level (Table 3).

At the 5% level of significance (0.619), a correlation between the fecundity of Hilsa and Gonad Weight (GW) was found. At the 5% level of significance, Total Length was found to be significantly correlated with Fecundity and Gonad Weight (0.444, 0.713). The correlation between Total Weight and Total Length was found to be significant at the 5% level of significance (0.536) (Table 4).

Table 1. Total Length, Total Weight, Gonadal Length, Gonadal Weight, Gonado-somatic Index and estimated Fecundity of 20 gravid females of *T. ilisha*

Sl. No.	Total Length (TL) (cm)	Total Weight (TW) (g)	Gonadal Length (GL) (cm)	Gonadal Weight (GW) (g)	Gonado Somatic Index (GSI)	No. of Ova (Fecundity)
1	37.70	710.00	13.90	86.00	12.11	899732
2	38.50	736.00	14.80	126.00	17.12	1831284
3	39.60	744.00	15.80	114.00	15.32	1574796
4	49.90	874.00	13.70	144.00	16.48	1218096
5	39.80	790.00	13.40	126.00	15.95	1459962
6	39.20	672.00	12.70	102.00	15.18	941868
7	49.90	1175.00	13.70	193.60	16.48	2272864
8	37.80	618.00	14.00	102.00	16.50	1346094
9	39.60	778.00	14.70	112.00	14.58	1342208
10	44.50	1220.00	15.50	195.91	16.06	1834109
11	37.90	836.00	13.90	87.00	10.41	835461
12	39.20	730.00	14.80	125.00	17.12	1193750
13	39.60	810.00	15.80	117.00	14.44	1341054
14	49.90	874.00	13.70	149.00	17.05	2165566
15	40.20	790.00	13.40	121.00	15.32	1671494
16	39.20	672.00	12.70	107.00	15.92	958613
17	44.60	1252.00	17.00	200.00	15.97	2117400
18	37.80	617.00	13.90	109.07	17.65	1007152
19	39.60	768.00	14.60	125.00	16.28	1792500
20	37.60	702.00	14.50	112.00	15.95	1478064
Mean	41.105 ±0.94	818.4 ±41.61	14.32 ±0.24	127.69 ±7.48	15.59 ±0.38	1484103 ±97822

Table 2. Summary Model of F/TL, F/TW, F/GL and F/GW relationships of *T. ilisha*

Model	R	R ²	Adjusted R ²	Std. Error
1	0.677 ^a	0.458	0.313	3.18712E5

a. Predictors: (Constant), Body weight (g), Gonad length (cm), Gonad weight (g), Total body length (cm)

Table 3. Regression co-efficient (b), intercepts (a), in the F/TL, F/TW, F/GL and F/GW relationships of *T. ilisha*

Un-standardized Coefficients		Standardized Coefficients	t-Value	Significance level
B	Std. Error	Beta		
-1.681	1.810		-0.929	0.368
13784.057	7008.150	0.642	1.967	0.068
79289.927	103284.297	0.170	0.768	0.455
-11006.776	43152.114	-0.101	-0.255	0.802
978.187	1231.117	0.212	0.795	0.439

a. Dependent Variable: No of ova (Fecundity)

Table 4. Correlation matrix between Fecundity and various body parameters of *T. ilisha*

		No of ova (Fecundity)	Gonad Weight (g)	Gonad Length (cm)	Total Length (cm)	Total Weight (g)
No of ova (Fecundity)	Pearson Correlation	1				
	Sig. (2-tailed)					
	N					
Gonad Weight (g)	Pearson Correlation	.619**	1			
	Sig. (2-tailed)	0.004				
	N	20	20			
Gonad Length (cm)	Pearson Correlation	0.272	0.094	1		
	Sig. (2-tailed)	0.247	0.692			
	N	20	20	20		
Total Length (cm)	Pearson Correlation	.444*	.713**	-0.158	1	
	Sig. (2-tailed)		0	0.507		
	N	20	20	20	20	
Total Weight (g)	Pearson Correlation	0.278	0.154	0.12	.536*	1
	Sig. (2-tailed)	0.236	0.517	0.614	0.015	
	N	20	20	20	20	20

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed)

4. DISCUSSION

The maturation of gonads can serve as an indicator of the timing of spawning events and play a significant role in determining the seeding of juvenile fish. Fish devote the preponderance of their dietary intake to physiological processes associated with the production and maturation of reproductive materials. On the basis of extant scholarly sources, it has been observed that the weight of fish gonads increases as the fish approaches the spawning phase, eventually reaching a maximum. Typically, following the spawning procedure, the weight of the gonads will decrease. Following the spawning procedure, there is a subsequent weight reduction.

Variation in fecundity is a common occurrence among fish species [10]. Several parameters, including size, age, condition, and species type of the population, influence the number of embryos produced by a female fish [11]. Multiple studies indicate that within populations of the same fish species, latitude differences exceeding five degrees result in discernible differences in both the size and age at which individuals attain sexual maturity. Moreover, the observed size differences can be attributed to differences in aquatic biological conditions.

Breeding studies revealed that the reproductive potential of a species varies in response to factors such as the availability of space and sustenance [12]. It was discovered that the largest specimen, measuring 499 mm in length and weighing 1252 g, contained a total of 2272864 eggs. The smaller specimen, which measured 376 mm in length and weighed 617 g, was discovered to contain 835461 eggs. It was observed that the fecundity of fish of equal length varied. One fish of 441 mm Total Length and 1018g Total Weight, including a gonadal weight of 79.78g, produced a total of 924436 ova. Comparatively, another fish with the same Total Length produced a marginally greater quantity of eggs, 948840. In addition, specimens of fish measuring 540 mm in length also exhibited this phenomenon.

Several studies have demonstrated that differences in length and weight between species are influenced by a number of parameters, including age, life span, food availability, dietary intensity, metabolic activity, gonad development, and gonad weight, among other ecological factors. Previous investigations [13] and [14] conducted by the same authors on the identical

species also documented similar patterns of variation. At 5% level of significance ($p < 0.05$), the statistical analysis revealed a significant association between Fecundity and the variables TL, TW, GL, and GW. The data analysis produced significant 't' values, implying a positive linear relationship between fecundity and total length, total weight, and gonadal weight. The correlation coefficients between fecundity and other parameters indicate a strong relationship between fecundity and body weight in fish, implying that changes in fecundity are primarily attributable to variations in body weight. Similar significant linear correlations have been found between fecundity and total length (TL), total weight (TW), and gonad weight (GW) in previous studies [10,15,16] of the same fish species. A high R^2 value indicates a strong association and high correlation between two variables, whereas a low R^2 value indicates a feeble relationship [17]. Fertility is not inherently greater in large fish.

The range of variation for the Gonadosomatic Index (GSI) score was between 10.41 and 17.65. This study revealed a significant relationship between the fecundity of *T. ilisha* from the Tentulia River near Chandramohan in Barisal and the total length (TL), total weight (TW), and gonad weight (GW) of the fish. TW displayed the strongest correlation with the fecundity of *T. ilisha*, whereas fecundity demonstrated a strong correlation with GW. In an experiment conducted by [2], the fecundity of *T. ilisha* specimens collected from the Padma River was investigated. The range of these specimens' fecundity (F) was 558700 to 1867000, with a mean value of 1239360.35 ± 405068.97 . This investigation was conducted on fish ranging in length from 350 to 557 mm, with a mean length of 455.25 ± 59.94 mm. In addition, the total body weight of the specimens ranged from 600 to 1775g, with a mean weight of 1181.85 ± 356.12 g. The research conducted by [5,18] revealed that the fecundity (F) of fish measuring between 39 and 51 cm in total length (TL) ranged from 1030951 to 1940620, with a mean of 1377884 ± 290145 . It was determined that the average total length of these specimens was 44.083.84 cm.

Several previous studies [19, 20] have documented the effect of increased fishing pressure on the reproductive capacity of this species. According to previous research [21, 22], the fecundity of Hilsa demonstrates a positive correlation with both age and size. An adult female hilsa fish with a body length between 27

and 40 cm is estimated to produce between 44002 and 1554894 ova. Other factors such as size/age at sexual maturity, absolute and relative fecundity, sex ratio, and abundance also influence reproductive potential in fish populations, despite the fact that the proportion of females capable of reproduction is the primary focus in evaluating reproductive potential. Identifying and conserving size/age groups with the maximum reproductive potential is the most important step in managing excessive fish growth and recruitment. Existing information regarding the developmental phases of tropical fish relies heavily on difficult distinctions and quantification of these stages.

5. CONCLUSION

The specimen with the greatest dimensions, measuring a total length of 499 mm and weighing 1252g, was discovered to be carrying a remarkable quantity of 2272864 eggs. In contrast, the fish with the smallest dimensions, measuring a total length of 376 mm and weighing 617g, was found to be carrying a comparatively smaller quantity of 835461 eggs. However, there was observed diversity in the reproductive capacity of fish that were of the same length. One fish with a Total Length of 441mm, Total Weight of 1018g, and Gonadal Weight of 79.78g produced a total of 924436 eggs. In comparison, another fish with the same Total Length produced 948,840 eggs. The aforementioned difference was likewise observed in the fish specimen measuring a Total Length of 540 mm. The statistical study indicated that there was a significant link between fecundity and the variables TL, TW, GL, and GW, with a significance level of 5% ($p < 0.05$). The analysis of the data indicated that there is a positive linear relationship between fecundity and the variables of total length, total weight, and gonadal weight. This relationship was supported by the significant 't' values obtained from the statistical analysis. The correlation coefficients between fecundity and other parameters indicate a strong relationship between fecundity and the body weight of a fish, suggesting that changes in fecundity may be accurately explained by variations in body weight.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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