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Study of the spawning season of Hilsa, *Tenualosa ilisha* in Bangladesh

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Abstract. An experiment was carried out on the reproductive biology of riverine populations of *Tenualosa ilisha* in Bangladesh to identify peak breeding season using gonadal biology and gonadosomatic index (GSI) information, reproductive and fry production potentiality, which will finally lead to development strategies for conservation of Hilsa fish species. Total 480 Samples were collected from Meghna River, Chandpur, from July 2012 to June 2013 and Tentulia River, Barisal from June 2013 to June 2014. Both Total length (TL) and Gonad length (GL) were measured using a measuring scale, and both Body weight (BW) and Gonad weight (GW) were taken using an electric balance. To detect the peak spawning activity of hilsa of the Meghna River and Tentulia River, the GSI and Dobriyal index (DI) were calculated. The mean GSI value for both female and male hilsa of the Meghna River was found to be varied from 4.84±0.63 to 15.31±1.17 and 0.32±0.04 to 1.04±0.08, respectively, with the highest value in October. In the case of the Tentulia River, the mean GSI value for female and male hilsa was found to be varied from 6.33±0.39 to 15.03±0.37 and 0.32±0.03 to 1.00±0.06, respectively, with the peak in October. Mean DI of female and male hilsa of Meghna River, Chandpur was found to be ranged from 3.31±0.23 to 5.15±0.17 and 1.18±0.04 to 1.71±0.03 respectively, and October was the highest. Mean DI value of female and male hilsa of Tentulia River, Barisal varied from 3.63±0.15 to 5.00±0.12 and 1.18±0.04 to 1.70±0.03 respectively, with the peak in October. Both the GSI and DI results of the present study suggested that hilsa has a prolonged spawning season, but major spawning takes place in October–November, with a distinct peak in October, indicating the peak spawning season for hilsa in Bangladesh.
Keywords: Hilsa, *Tenualosa ilisha*, Gonadosomatic Index, Dobriyal index

Introduction

The Hilsa shad, *Tenualosa ilisha* (Hamilton 1822) is an anadromous clupeid that migrates from the Bay of Bengal towards freshwater rivers for spawning. In Bangladesh, hilsa occurs in inland, marine, and coastal waters and is harvested throughout the year. In Bangladesh, the hilsa fishery has had a glorious past. Hilsa was abundantly caught in more than 100 rivers of Bangladesh. However, from the 1970s, the hilsa fishery began to decline gradually, with outputs reaching a low point of 0.19 million tonnes in 2001–2002 (BOBLME 2012). This situation was attributed to a combination of the closure of migratory routes, river siltation, over-fishing, and indiscriminate harvesting of brood stocks and juveniles (locally known as *jatka*) (Mohammed and Wahab 2013). Due to a low discharge of water from the river Ganges and consequently heavy siltation in most of the rivers, the feeding, spawning, nursery, and migratory areas of hilsa have been restricted to the downstream area. In addition, the gradual growth of industries, growing urbanization, and indiscriminate use of fertilizers, agrochemicals, pesticides, and the discharge of municipal waste are continuously polluting the river system. This may become endemic and widespread in the near future and will severely affect the hilsa fishery, unless proper management measures are developed and implemented. Since its declining production, considerable research has been conducted on reproduction biology and management aspects. Research on different parameters of

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the reproductive biology of hilsa shad could help to take management measures to enhance the productivity of hilsa.

A variety of methods are available to assess reproductive conditions in fishes, including microscopic gonadal staging, macroscopic gonadal staging, oocyte size–frequency distributions, sex steroid measurement and gonadal indices like gonadosomatic index (GSI), Dobriyal index (DI, Lowerre-Barbieri *et al.* 2011, West 1990). Histological gonadal staging provides a direct snapshot of developmental stages of individual gametes within the gonads, while the relationship between other metrics and gonadal gamete stage(s) may depend on the pattern of gonadal development. However, histological staging is time intensive and impractical in many cases, thus proxies are useful if they can be properly validated (Lowerre-Barbieri *et al.* 2011, West 1990). The GSI is a common metric of reproductive allocation and reproductive condition in fisheries biology. However, GSI may be an imprecise proxy for the gonadal stage because it assumes isometry between somatic mass and gonad mass as well as a tight correspondence between total gonad mass and gonad developmental stage (DeVlaming *et al.* 1982, Packard and Boardman 1988).

Estimation of GSI of a fish is essential for evaluating the commercial potentialities of its stock, life history, practical culture and actual management of the fishery (Rahimibashar *et al*. 2012). GSI, which is an index of gonad size relative to fish size, is a good indicator of gonadal development in fish (Dadzie and Wangila 1980). The percentage of body weight of fish that is used for the production of eggs is determined by the GSI. The study of GSI is very essential for a better understanding of the reproductive biology of fish. It is an efficient indicator of the functional state of the gonads (Vazzoler 1996). GSI also determines the period of greatest reproductive intensity, evidence of the reproductive strategy of each species. These vary within a species, and even within a sex, and may occur in most taxa (Gross 1996). On the other hand, DI, the cube root of the average gonad weight in grams, is used as a measure of reproductive capacity, determination of spawning season, sexual maturity and frequency of spawning (Dobriyal *et al*. 1999). Unlike the GSI, DI does not involve body weight which is dependent on feeding intensity, food availability and environmental and physiological stress. In the present study, GSI and DI of hilsa shad were calculated to determine the spawning season in Bangladesh.

Materials and Methods

Sampling of fish: The experiment was conducted for 24 months from July 2012 to June 2014. Hilsa fish samples were collected from two different locations of Bangladesh *i.e.*, upper Meghna River at Chandpur district and Tentulia River at Barisal district of Bangladesh. Sampling was conducted during July 2012 to June 2013 in the Meghna River and July 2013 to June 2014 in the Tentulia River. Samples were collected once a month and 20 mature hilsa samples (10 female and 10 male) were collected at each sampling day. Hilsa were caught in the river during the night using gill nets primarily. All specimens were preserved with crushed ice in cool fish boxes and brought to the laboratory as soon as possible. A total of 480 mature fishes (240 samples from each site; 240 female and 240 male) covering various size groups were collected from both sampling sites.

Gonad collection and sex determination: The body cavity of the fish was opened carefully by scissors and gonads were collected with forceps carefully. Other constitutional units such as muscles, fat tissues, digestive organs and blood veins etc. were taken away properly. Body weight (BW) and Gonad weight (GW; both left and right gonads) were measured to the nearest 0.001 g. Total length (TL) and gonad length (GL) were also measured to the nearest 0.01 cm. After weighing, gonads were preserved with 10% formalin in small vials for further investigation.

Calculation of GSI: The reproductive cycle of a species for the year-round fortnightly or monthly intervals may be determined by GSI. It is a very useful method to indicate the spawning season of a species at the field level. GSI assumes that a gonad increases in size with increasing development compared with the weight of the gonad (GW) to the total weight of the animal (BW). The GSI of each fish was calculated by the using following formula as described by Nikolsky, 1963:

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

Calculation of DI: To examine the monthly changes in the gonads as a means for estimating the spawning season of fish, the DI was also used, which was calculated by the following formula as described by Dobriyal *et al.,* 1999

$$DI = \sqrt[3]{GW}$$

Where, GW is the average gonad weight.

Statistical analysis of data: The statistical analysis and graphical representation were done using the Microsoft Excel 2013 software.

Results

Determination of spawning season using GSI

Month-wise GSI of female Hilsa of Meghna River, Chandpur: The GSI value for female Hilsa of Meghna was observed to be varied from 4.84±0.63 to 15.31±1.17 (Table I). Specimens that were collected in May showed the lowest mean GSI value (4.84±0.63) and the highest mean GSI value (15.31±1.17) was found in the month of October. Higher GSI values were also observed in the month of September (9.30±.42), November (13.21±1.17) and December (8.56±0.63). As the highest mean GSI of female hilsa was observed in the month of October, we can primarily consider October as the peak spawning month of *T. ilisha*.

Month-wise GSI of male Hilsa of Meghna River, Chandpur: In the present study, the GSI value for male hilsa of the Meghna River was observed to be varied from 0.32±0.04 to 1.04±0.08 (Table I and Fig. 1). Specimens that were collected on March showed the lowest mean GSI of 0.32±0.04 and highest mean GSI value 1.04±0.08 was found in the month of October. Higher GSI values were also observed in the month of February (0.59±0.08), September (0.60±0.06) and November (0.56±0.04). In case of male hilsa, the highest mean GSI value was also found in the month of October. Therefore, we can primarily consider October as the peak spawning month of *T. ilisha*.

Month-wise GSI of female Hilsa of Tentulia River, Barisal: In the present study, the GSI value for female Hilsa of Tentulia River was found to be varied from 6.33±0.39 to 15.03±0.37 (Table I). Specimens that were collected on December showed the lowest mean GSI value (6.33±0.39) and highest mean GSI value (15.03±0.73) was found in the month of October. It is important that higher GSI was also found in the month of July (10.30±0.73), September (11.32±0.98) and November (11.48±1.06). As the highest mean GSI value (15.03±0.73) was found in the month of October, therefore, we can primarily consider October as the peak spawning season of *T. ilisha.*

Table I. Monthly gonadosomatic index of female and male *T. ilisha* in the Meghna River at Chandpur district and Tentulia River at Barisal district, Bangladesh

Month	Female		Male	
	GSI range	Mean GSI (± SE)	GSI range	Mean GSI (± SE)
Meghna River, Chandpur				
July	6.52-10.60	8.05±0.42	0.33-0.71	0.52±0.04
August	5.79-10.00	7.58±0.53	0.25-0.68	0.44±0.04
September	5.82-15.40	9.30±0.90	0.22-0.89	0.60±0.06
October	8.59-20.66	15.31±1.17	0.68-1.64	1.04±0.08
November	6.89-17.99	13.21±1.17	0.38-0.81	0.56±0.04
December	5.94-11.49	8.56±0.63	0.25-0.75	0.49±0.05
January	5.93 -9.24	7.81±0.32	0.24-0.75	0.34±0.05
February	4.75-9.58	7.53±0.53	0.38-1.17	0.59±0.08
March	4.58-7.67	5.87±0.36	0.22-0.63	0.32±0.04
April	3.12-7.38	5.36±0.42	0.24-0.76	0.44±0.05
May	2.85-7.58	4.84±0.63	0.26-0.68	0.46±0.05
June	1.17-10.92	7.77±0.85	0.35-0.57	0.42±0.02
Tentulia River, Barisal				
July	6.43-13.28	10.30±0.73	0.32-0.70	0.49±0.04
August	5.40-11.32	8.54±0.64	0.39-0.72	0.51±0.03
September	5.79-15.97	11.32±0.98	0.40-0.59	0.75±0.04
October	9.98-17.12	15.03±0.73	0.71-1.38	1.00±0.06
November	7.30-15.63	11.48±1.06	0.40-0.65	0.50±0.03
December	5.12-8.40	6.33±0.39	0.37-0.64	0.47±0.03
January	4.52-11.93	7.73±0.78	0.23-0.82	0.34±0.05
February	4.27-12.20	8.66±0.88	0.33-0.74	0.52±0.04
March	4.22-13.80	8.25±0.94	0.22-0.63	0.32±0.04
April	5.68-12.78	8.30±0.71	0.23-0.50	0.32±0.03
May	4.96-12.17	8.45±0.78	0.25-0.68	0.40±0.04
June	4.23-11.32	6.36±0.69	0.31-0.57	0.41±0.03

Monthly GSI of male Hilsa of Tentulia River, Barisal: The GSI value for male hilsa of Tentulia River, Barisal was observed to be varied from 0.32±0.03 to 1.00±0.06 (Table I). Specimens that were collected on April showed lowest mean GSI value (0.32±0.03) and highest mean GSI value (1.00±0.06) was found in the month of October. Higher GSI value of 0.52±0.04, 0.51±0.03 and 0.75±0.04 were also observed in the month of February, August and September respectively. In case of male hilsa of Tentulia River, the highest mean GSI value (1.00±0.68) was found in the month of October. Therefore, primarily October could be considered as the peak spawning month of *T. ilisha*.

The result of GSI of both female and male *T. ilisha* in both the experimental site which peaked in October was significantly different from other months. This indicated that the GSI was highest in September and November for both sexes of *T. ilisha*, suggesting that spawning occurs in these months. Furthermore, the higher GSI in different months of the year suggested the prolonged spawning season the hilsa.

Determination of spawning season using DI

DI of male and female hilsa of Meghna River, Chandpur: Mean DI of female and male hilsa of Meghna River, Chandpur was found to be varied from 3.31±0.23 to 5.15±0.17 and 1.18±0.04 to

1.71±0.03, respectively (Table 2). In female, the highest DI was found in the month of October and lowest in May; however, in male, the highest mean DI was found in the month of October and lowest in March. Higher mean DI values of 4.18±0.13, 4.11±0.16, 4.43±0.20 and 4.64±0.79 were also found in the month of July, August, September, and November in female hilsa and mean DI values of 1.41±0.02, 1.53±0.07, 1.47±0.04, 1.42±0.06 were found in the month of July, September, November and February in male hilsa.

Table II. Month-wise Dobriyal index (DI) of female and male *T. ilisha* in the Meghna River at Chandpur district and Tentulia River at Barisal district, Bangladesh

Month	Mean Dobriyal Index (DI)			
	Meghna River, Chandpur		Tentulia River, Barisal	
	Female	Male	Female	Male
July	4.18±0.13	1.41±0.02	4.27±0.17	1.39±0.02
August	4.11±0.16	1.36±0.04	3.87±0.15	1.40±0.07
September	4.43±0.20	1.53±0.07	4.71±0.27	1.64±0.02
October	5.15±0.17	1.71±0.03	5.00±0.12	1.70±0.03
November	4.64±0.79	1.47±0.04	4.42±0.23	1.43±0.09
December	3.93±0.15	1.29±0.05	3.63±0.15	1.26±0.03
January	3.99±0.14	1.20±0.06	3.71±0.20	1.24±0.07
February	3.95±0.11	1.42±0.06	4.00±0.18	1.40±0.05
March	3.99±0.13	1.18±0.04	3.91±0.16	1.18±0.04
April	3.55±0.10	1.29±0.06	3.99±0.21	1.20±0.02
May	3.31±0.23	1.28±0.04	3.95±0.13	1.27±0.05
June	3.83±0.23	1.31±0.04	4.23±0.18	1.32±0.04

DI of male and female hilsa of Tentulia river, Barisal: Mean DI value of female and male hilsa of Tentulia River, Barisal varied from 3.63±0.15 to 5.00±0.12 and 1.18±0.04 to 1.70±0.03, respectively (Table 2). In female, the highest DI value was found in the month of October and lowest in December; however, in male, the highest DI value was found in the month of October and lowest in March. Besides the highest DI value in October, higher mean DI values of 4.27±0.17, 4.71±0.27 and 4.42±0.23 were also found in the month of July, September, and November in females, respectively and a mean DI value of 1.40±0.07, 1.40±0.05, 1.64±0.02 and 1.43±0.09 were found in the month of August and February, September, and November in male hilsa, respectively. The highest DI of both female and male in both the experimental sites in October suggested that the peak breading season of hilsa is the month of October. Also, the higher DI values in different month indicated the prolonged spawning season of the hilsa.

Discussion

The values of GSI increase with the maturation of fish, being maximum during the period of peak maturity and declining abruptly thereafter when fish become spent (LeCren 1951). The monthly changes in GSI reflect the ovarian activity of fish and it must be noticed that GSI is a reliable tool to determine peak spawning season (Vladimir 2000).

In the present study, the GSI values of female hilsa of Meghna River, Chandpur showed that the GSI value increased markedly from July (8.05±0.4) to November (13.21±1.17) in which it showed highest peak in October (15.31±1.17). This result suggested that the spawning season is prolonged from July to November, with a distinct spawning peak in the month of October. After November, the GSI value went down and reached at lowest in May (4.84±0.63). The GSI values

of female hilsa of Tentulia River, Barisal also showed the same trend of the Meghna River. However, the GSI reached at highest (15.03±0.73) peak in October and the lowest GSI was found in December (6.33±0.39) in the Tentulia River although it was found lowest in May in the Meghna River hilsa. On the other hand, the GSI value of male hilsa of both experimental sites showed same as that of female hilsa showed. In both the experimental sites, the GSI of male hilsa showed highest peak in the month of October (1.04±0.08 and 1.00±0.06, respectively). The same lowest GSI (0.32±0.04) of male hilsa was found in March in the Meghna River and in the Tentulia River it was lowest in March and April.

The GSI values of the present study suggested that *T. ilisha* spawn throughout the year and the spawning season is prolonged from July to November. However, the highest GSI value in October, both for female and males and also in both experimental sites indicated that the peak breeding season of hilsa shad in the Meghna and Tentulia River is in the month of October, and this result agreed with the previous studies. Hossain (1985) studied the GSI of female hilsa and found that GSI reached at the highest peak in October in case of hilsa of the Meghna River and August in case of hilsa sourced from the Bay of Bengal. Islam *et al.* (1987) also observed the peak GSI value of females in riverine and estuarine environments in October. Halder (2004) determined the peak breeding period of hilsa and they stated that the peak breeding period of hilsa is during the full moon in the month of October, which agrees with the findings of the present study. Flura *et al.* (2015) reported GSI values ranged 1.6-24 in females and in case of males, values ranged from 0.67-1.5 in Chandpur, more importantly, the highest in the month of October. However, the study of Quddus *et al.* (1948) showed a little dissimilar result to the present study, they determined the spawning period from the GSI study and found that the riverine hilsa of type A (broader type hilsa) breed from July to October with peak in September and type B hilsa (slender type hilsa) breed from January to March with a peak in February.

Almukhtar *et al.* (2016) observed the maximum values of GSI in April (9.5±2.4) for females and in February (2.5±1.4) for males in the Shatt Al Arab River and Southern Al Hammar Marsh, Basra, Iraq. They found two distinct peaks for both sexes. The first peak was during March-June and the second was in August-October. Al-Noor (1998) found that the spawning season of *T. ilisha* in Shatt al Arab was extended from March to October and Al-Uqaili (2001) observed larvae from March to September in the northern part of the Shatt al Arab River. In Iran, Roomiani *et al.* (2014) suggested that the spawning season of *T. ilisha* in the Khuzestan Province rivers occurred from May to August. These results of the spawning season of hilsa were somewhat different from the present study as these stocks of hilsa were from different stocks and different geographical locations.

DI is used as a measure of reproductive capacity, determination of spawning season, sexual maturity and frequency of spawning (Dobriyal *et al.* 1999). Unlike the GSI, DI does not involve body weight which is dependent on feeding intensity, food availability and environmental and physiological stress. The seasonal variation in DI also indicated the prolonged spawning season with a peak in the month of October. The highest DI was 5.15±0.17and 5.00±0.12 in female hilsa and 1.71±0.03 and 1.70±0.03 in male hilsa in the Meghna River and Tentulia River, respectively. These highest DI were observed in the month of October. The highest DI in October indicated that this month is the peak spawning season of the hilsa. Seasonal variation in DI was observed and these seasonal variations coincided with the seasonal variations in GSI which showed a prolonged spawning season with a peak in October. Almukhtar *et al.* (2016) observed the DI for hilsa in the Shatt Al Arab River and Southern Al Hammar Marsh, Basra, Iraq and found mean DI of 1.28 and 2.34 for males and females respectively with two distinct peaks. Like the present study, they also found seasonal variation in DI and concluded that hilsa has a prolonged spawning season.

Conclusions

To detect the size of maturity, subsequent spawning and the period of peak spawning activity, calculating the GSI and DI are the most important approaches and it is essential to observe throughout the year. In the present study, GSI and DI were studied to determine the peak spawning season of hilsa. Both the GSI and DI result of the present study suggested that hilsa has a prolonged spawning season with a distinct peak in the month of October, *i.e.*, October is the peak spawning season for hilsa.

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