Distribution, Biology and Ontogeny of Indian River Shad (*Tenualosa ilisha*)

Abstract

The distribution, biology and ontogenic development of the Indian River Shad (*Tenualosa ilisha*) compared with some other fishes compile in this review. The distribution in the inland waters of Bangladesh, stock/race, movement and migration pattern, size and sex ratio, age of reproduction, maturity and fecundity and ontogenic development of the mouth, digestive tract and accessory gland of *T. ilisha* discussed in this article. The life cycle of a fish starts after fertilization, but the mouth and digestive tract development start after hatching. Just after hatching, there is a straight, nonfunctional, tube-like digestive tract that lies on the dorsal end of the yolk sack with a close anus. The mouth openings develop after 1-3 days of hatching. After developing the mouth opening, different parts of the digestive tract start to develop. Before mouth opening, fish collect nutrients from yolk sacks for survival. After developing the mouth opening, fish start feeding from the environment. The feed size and types change with the development of the digestive tract. Development of the digestive tract is complete at the juvenile stage.

Key Words: Habitat; Breeding biology; Ontogenic development; Digestive System; Morpho meristic characteristics.

Introduction

The largest single fishery, the Hilsa shad, *Tenualosa ilisha* (Hamilton), often known as Ilish, the national fish, employs around 2.5 million people and generates US$ 1.3 billion annually in revenue (DoF, 2021). Anadromous species like Hilsa migrate from the ocean to freshwater riverine habitats to spawn. It is dispersed across 9390 km2 of rivers, tributaries, and canals as well as the 118 813 km2 region of Bangladesh's northern Bay of Bengal (Hasan et al. 2013). With an annual harvest of over 0.55 million tonnes and a capture rate of more than 60% from marine waters, the hilsa fishery alone accounts for 12% of the national total (DoF 2021). Nearly half of all marine catches are made up of it, along with 12 percent of all fish production and 1.0 percent of GDP. The average yearly output of hilsa is 0.25 million tons, valued at 50 billion taka (200 taka per kilogram). Additionally, it adds to the country's annual foreign exchange revenues of Tk. 500–1000 million (DoF, 2015). A large peak occurs from September to October, while a smaller peak occurs from February to March during the peak fishing season, which runs from June to March (Islam, 1989). This is a traditional non-mechanized and mechanized wooden boat fishery that mostly uses drift and set gill nets (Islam, 1989). Hilsa fishing directly employs over 460,000 fishermen from 148 Upazilas, while the entire hilsa sector indirectly employs about 2.5 million people (trading, processing, etc.). As a result, the fishing industry contributes significantly to the country's employment, foreign exchange profits, and elimination of poverty (DoF, 2014). Currently, Bangladesh seas account for 50–60% of the world's hilsa catch, followed by Myanmar (20–25%), India (15–20%), and other nations (5–10%) (such as Iraq, Kuwait, Malaysia, Thailand, and Pakistan) (BOBLME, 2010). Bangladesh, India, and Myanmar control the majority (about 90%) of Hilsa (Bhaumik, 2015)

Comment [WU1]: Should be arranged in several paragraphs

Distribution of habitat in inland waters

In the past, *T. ilisha* was adaptable in Bangladeshi waters. According to Ahmed (1954), all other areas of Bangladesh saw significant hailfall at various times of the year, with the exception of the districts of Rangpur, Dinajpur, Bogra, and the Chittagong Hill Tracts, which were not inundated by major rivers. Almost all of the important rivers, including the Padma, Meghna, Jamuna, Rupsa, Shibsa, Bishkhali, Pyra, and Ilisha, have it available (Ahsanullah, 1964). Along with these rivers, hilsa were also common in the Karnafuly, Feni, and Muhuri rivers as well as in the majority of the Padma (Ganges), Brahmaputra, and its branches and tributaries (Haldar et al. 1992). Raja (1985) claims that the hilsa's migration range was in the Brahmaputra up to Tezpur.

Comment [WU2]: Please add other references about the distribution of this fish species. It can also be studied at fishbase.org

https://www.fishbase.se/Summary/SpeciesSummary.php?ID=1596&AT=Nga-tha-lauk

Stock/Race of hilsa

Data from otolith microchemistry and genetic analysis indicated that *T. ilisha* in the Bay of Bengal is a single stock, with fish taken in Bangladesh's coastal areas and those from India and Myanmar not significantly different from each other (Hussain et al. 1998). Before, there was debate over whether all Bangladeshi Hilsa stocks migrate. When it comes to their migratory patterns, some people believed that there are three different hilsa stocks. (1) A migratory (anadromous) stock that inhabits the Bay of Bengal's littoral and migrates significantly upwards into rivers to breed. (2) A stock that goes through all stages of development within the river system. It doesn't move toward the sea. (3) A sea animal that lives its entire existence.

Comment [WU3]: Is there no research on the population genetics of this fish yet? Please can you provide this information

Migration and movement patterns

The majority of freshwater-born hilsa move upstream for breeding and feeding as well as to live and grow in the sea. After spawning, the adults head back out to sea again. When the monsoon season begins, the young spend about 6-7 months living in rivers and streams (Haldar, 2005). He provides a graphic of the *T. ilisha* life cycle based on his study (Fig. 1).

Comment [WU4]: Please include other supporting references. Because this is a review article (non-research article) that needs a lot of supporting references

Fecundity

Fish species' fecundity, a crucial component of their reproductive cycle, tells us how many eggs are present in their ovaries before the next spawning season. Fecundity varies depending on a number of variables, including age, size, body and gonad weight, and the ecological state of the water body (Bagenal and Tesch, 1978). The fecundity of *T. ilisha* has undergone extensive change over time. The quantity of ova and egg diameter have been found to increase with fish age and fecundity, respectively, according to numerous research. According to Bhaumik et al. (2012), a gravid female weighing 4.250 kg that was retrieved from the river Tapti had the highest fecundity ever recorded in history at 29,49,750. Sharma and Bhaumik (2012) found that the number of eggs in mature *T. ilisha* ovaries varied from 44,002 (length 274 mm/weight 234.5 g) to 15, 54,894 (length 403 mm/weight 855 g). In fish measuring between 334 mm and 522 mm in length, (Amin et al., 2002) calculated egg counts ranging between 3,73,120 and 14,75,676. In the upper Ganga River system near Allahabad, Swarup (1961) and Mathur (1964) discovered that fish in the 315 to 506 mm and 310 to 436 mm size ranges, respectively, recorded fecundity values of 2,89,000 to 11,68,622 and 3,16,316 to 18,40,179. Fish measuring 253 to 481 mm in length from the Hooghly estuary were fecund in the range of 2, 50,000 to 16, 00,000. This information was gathered by Pillay in 1958.

In 2011, Panhwar et al. reported the size range and fecundity of *T. ilisha* specimens taken from the Indus River. The average number of eggs carried by specimens in the size classes 200–250 mm, 25–300 mm, and 30–350 mm was 1, 13, 483, 3, 82, 105, and 5, 72, 709–6, 14, 482.

Comment [WU5]: It is better if the comparison of fish fecundity based on different research data is compared and reviewed in the form of a table, so that it can be seen more clearly

According to Hassan (1999), Sbour in Iraq's Satt Al-Arab River can lay anywhere between 1,000 and 20,000,000 eggs per female. According to Coad (1997), *T. ilisha* in Iranian waters may be able to produce 1,616,560 eggs per fish that is 33.0-41.5 cm long. When researching the reproduction of *T. ilisha* in depth, Bhuiyan and Talbot (1968) discovered that the species from the Indus River has a fecundity range of 7,55,000 to 29,17,000. They also came to the conclusion that there is no direct correlation between Hilsa from the Indus' fertility and length or weight. The quantity of eggs fluctuated between 80,000 and 2,000,000, according to Qureshi (1968a), who was researching the fecundity of *T. ilisha* from the Indus River. However, the size range was also stated.

Spawning

All freshwater reaches of the rivers are where Hilsa spawns (Hora, 1938, Malhotra et al. 1973, Chandra 1962). From May to July, Rao and Pathak (1972) observed the peak Hilsa spawning in the Brahmaputra River. During the monsoon, marine fish that spawn in areas with salinities between one and twenty-six percent stay there for a few months before returning to the sea (DoF, 2006). During the monsoon season, juvenile marine fish move to eat in the lower zone of estuaries, whereas Hilsa breed in the upper reaches of fresh waters. For fish measuring 35 to 50 cm in length, hilsa fecundity ranged from 1.5 to 2.0 million eggs. Different regions are seeing a decline in hilsa fertility. Hilsa productivity is naturally affected by this fall in fertility. The ratio of fully mature, gushing male and female Hilsa at the spawning grounds was 1:1.6 during the breeding season (Miah et al. 1999). At the spawning grounds, it was discovered that about 80% of the female fish were in an egg-realizing condition. A new moon with high river flow peaks during the spawning season in September and October, when major spawning occurs during the full moon (Miah, et al. 1997).

Comment [WU6]: Comparative research data can be displayed in the form of a table

Sex Ratio

M to F was a 1:2 sex ratio. This sex ratio varies every month, but males outnumber females. The results of Amin et al. (2005) are consistent with the dominance of females over males (males to females 1:5.09). Previous studies on the sex Hilsa populations have shown conflicting opinions (Quddus et al. 1984; Ahmed and Saha, 1996). An interesting metric that may be directly related to growth rate and natural and fishing mortalities is the monthly variation in the average GSI of female and male *T. ilisha* variations in the sex ratio corresponding to body length (Guoping et al. 2008). The sex ratio of *T. ilisha* in this study was M: F= 1:2. Although the sex ratio varied across the months, males still outnumbered females. The results of Amin et al. (2002) are consistent with the dominance of females over males (males to females 1:5.09). The fact that males and females frequently move in separate shoals may be the reason of these variances. The disparity in sex ratios has been attributed to a number of factors (Zhang et al. 2009). Shafi et al. (1978), Quddus et al. (1984), and Haldar and Amin have all undertaken studies on the sex ratio in *T.ilisha* (2005). These authors described how men or females predominated over particular months or seasons and demonstrated how the observed sex ratio differed significantly from the predicted ratio of 1:1. Baz and Grove (1995) noted that females predominated for nearly the entire year in Kuwaiti coastal waters of the Persian Gulf. 1:2.4 was the male to female ratio. The current sex ratio figures are generally in line with those from Kuwait. Males predominate in the smaller sizes and are absent in the bigger sizes, suggesting that this variation is most likely the result of a distinct rate of growth.

Comment [WU7]: Comparative research data can be displayed in the form of a table

Maturity

Hilsa males and females are able to reproduce at a size of 20.0 cm when they are one year old, when they attain sexual maturity (Blaber and Mazid 2001). Smaller hilsa are currently sexually mature. According to the GEF study (Haldar, 2004), mature male and female hilsa needed to be at least 18 and 101 g and 20 cm and 216 g in length and weight, respectively, to be obtained from commercial loan facilities. The hilsa population reaches sexual maturity at one year of age and is currently dominated by the one-year-old age group. Larger Hilsa groups are uncommon in the population. In the 1960s, a three-year-old size group made up the majority of the Hilsa population. A somewhat balanced population is being seen as a result of recent management initiatives. (Haldar, 2004).

Comment [WU8]: Comparative research data can be displayed in the form of a table

Ontogeny

The term "ontogeny" refers to the origin and growth of an organism, typically from the moment of egg fertilization to adulthood. Ontogeny, as opposed to phylogeny, which refers to the evolutionary history of a species, is the developmental history of an organism within its own lifetime (Smith, 1960; Gould, 1977).

Morphological Development of *T. ilisha*

Egg sac larvae (3.83 0.57 mm SL), pre flexion larvae (8.07 1.83 mm SL), flexion larvae (11.50 1.55 mm SL), post flexion larvae (14.72 1.70 mm SL), and juvenile (18.75 3.02 mm SL) are five separated groups of Hilsa based on their morphological characteristics. There were between 34 and 44 myomeres and 40 and 46 vertebrae, respectively. In the instance of the fin ray, the dorsal fin ray count ranged from 16 to 20; the anal fin ray count ranged from 18 to 22; the pectoral fin ray count ranged from 14 to 16; the pelvic fin ray count ranged from 7 to 9; and the caudal fin ray count ranged from 20 to 24. Between larval and juvenile stages, the relationship between the mean values of the body depth and standard length varied dramatically (Fig. 2) (Riar et al., 2020).

Comment [WU9]: It is better to add other references related to morphometrics

Ontogeny of the Mouth and Digestive Tract

Kulkarni (1950) first worked on artificial fertilization of *T. ilisha*. He described different stages of embryonic development (Fig. 3) and said that *T. ilisha* need 18-24 for hatching, depending on temperature. The larvae died after three days of hatching, which is why from his paper we found only descriptions of larval life (Fig.4). For a better understanding, he draws some picture of his research finding.

However, due to the lack of improved technology, instruments and chemicals, his study could not clearly describe the embryonic and larval development of *T. ilisha*. Mouth morphology of larvae and early juvenile stages of *T. ilisha* was first reported by Riar *et al.* (2018) (Fig. 5) that the smallest mouth size was found at 45^0 while largest was found at 90^0. There are four larval stages (i) yolk-sack stage (ii) pre-flexion stage (iii) flexion stage and (iv) post-flexion. From his study he mouth was found to be closed at yolk sac stage. In the other hand at pre-flexion stage, the range of larval mouth gap between was 177 ± 25 and 367 ± 47 µm. In the flexion stage, the range was 241 ± 31 and 497 ± 59 µm, in post-flexion stage it ranged between 307 ± 38 and 621 ± 74 µm and finally in early juvenile stage the range was 393 ± 61 and 788 ± 119 µm.

Comment [WU10]: It is better to add other references

Just after hatching, no mouth opening occurred in fish larvae, and fish collected nutrients from the yolk sac. Different fish species need different times for mouth development (Table 1). After the mouth opened, the fish began exogenous feeding. The time for the first appearance of the oral cavity is given below:

The buccopharynx was constructed of a thin layer of stratified epithelium, which later developed test buds and mucous cells. The process begins with the opening of the mouth and concludes with the development of teeth and test buds. According to Mahdieh (2010), it takes

3-5 DAH in R. frisii, 3 DAH in S. japonicus, and 2-5 DAH in T. tambroides (Ramezani-Fard et al. 2011). According to Riar et al. (2019), the digestive tract was translucent and had a tube-like structure at the yolk sac stage. He claimed that the digestive tract's development was complete at the pre-flexion stage and that the gut loop was eventually discovered at the post-flexion stage. During larval development, the digestive system was equivalent to more than three-quarters of the standard length. The gut length and standard length were found to be strongly correlated (R2 = 0.97) (Fig.6).

length and standard length (R2 = 0.97).

Comment [WU11]: It is better to add other references

Conclusion

T. ilisha is the main catch in open water fisheries for Bangladesh, and many people depend on the *T. ilisha* fishery. However, due to the changes in their breeding behavior and migration pattern, many fishermen upstream lost their profession. The size and age of the catched fish decreased daily. On the other hand, a detailed understanding of the development of the mouth and digestive tract, particularly regarding ingestion, digestion and assimilation mechanisms, will contribute to the improvement of larval survival and growth in different management conditions through the development of feeding protocols that match the nutritional requirements and digestive ability of the larvae. In this context, a histological and histochemical description of the larval mouth and digestive system represents the first step towards the determination of the functional relationships between feeding and assimilation of *T. ilisha*.

Comment [WU12]: There needs to be a recommendation from the results of this study.. is it necessary to think about hatching this fish so that in the future it can be cultivated?,
or is there a need for conservation efforts including restrictions on fishing efforts and other measures to avoid excessive stock declines in nature?

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Comment [WU13]: not all references are in the contents of this article. Please complete and adjust

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Table 1: Development of Mouth opening for some fish species compare with *T. ilisha*

Fish species	Day after hatching (DAH)	Reference
Tenualosa ilisha	3	Kulkarni., 1950
Clupea pallasii	3	Kawakami *et al.* 2011
Scomber japonicas	3	Park *et al.* 2015
Sardinella dayi	2	Bensam, 1991
Rutilus frisii	3	Mahdieh, 2010

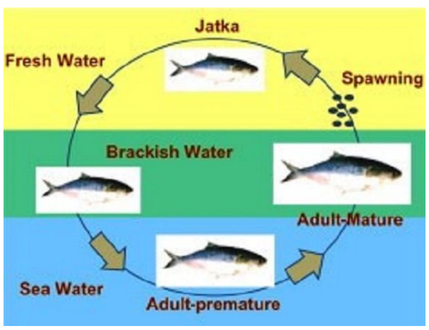

Figure 1: Movement and migration pattern of *T. ilisha* (Haldar, 2005).

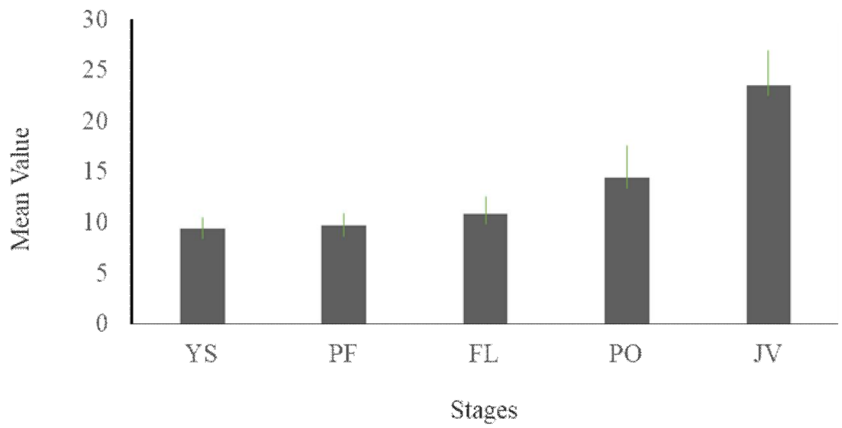

Figure 2: Body depth (BD) percentage with the standard length (SL) of *T. ilisha* larvae in different stages

***Yolk sac (YS), pre-flexion (PF), flexion (FL), post- flexion (PO) and juvenile (JV). All stages expressed by mean value ± sd

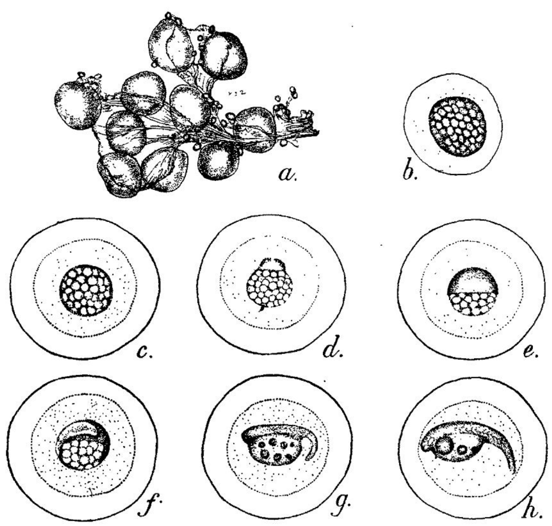

Figure 3: Embryonic development of *T. ilisha*. a. A piece of fully developed ovary, b. Egg before fertilization, c. Just after fertilization, d. 30 min. after fertilization, e. Four hours after fertilization, f. 8 hr after fertilization, g. 12 hr after fertilization, h. 17 hr after fertilization. (Kulkarni, 1950)

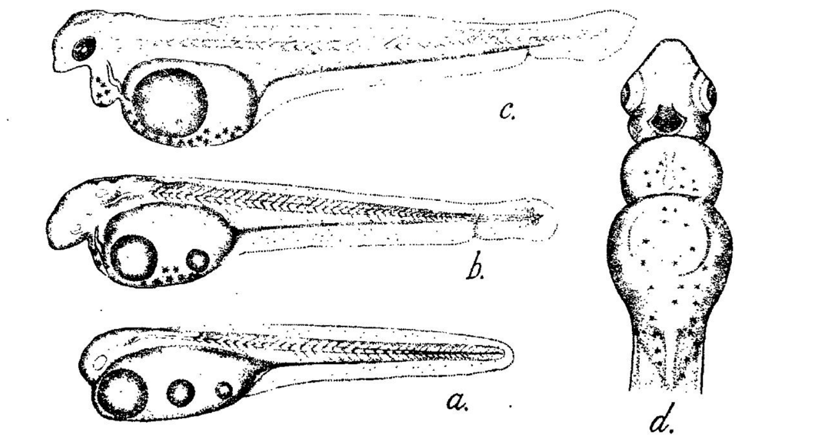

Figure 4: Larval development of *T. ilisha*. a. hatchling 1DAH, b. 2 DAH, c. 3 DAH, d. Ventral view of the larvae. (Kulkarni, 1950).

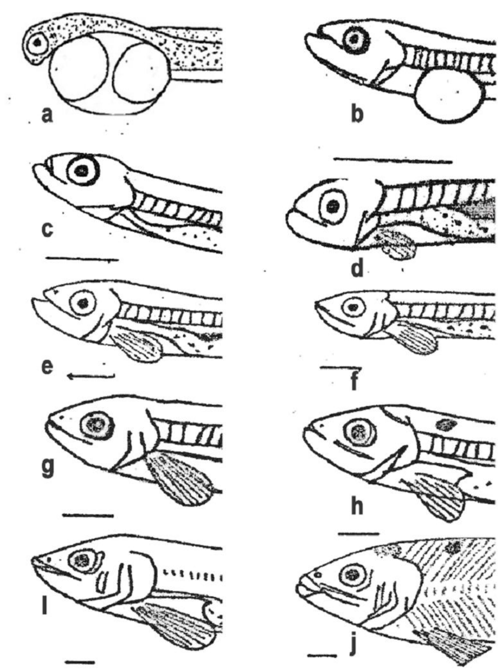

Figure 5. Mouth morphological development of *T. ilisha* larvae and juvenile. Yolk sac stage (a,b), pre-flexion stage (c,d), flexion stage (e,f), post- flexion stage (g,h) and juvenile stage (i,j). Bar = 1mm (Riar *et al.* 2018).

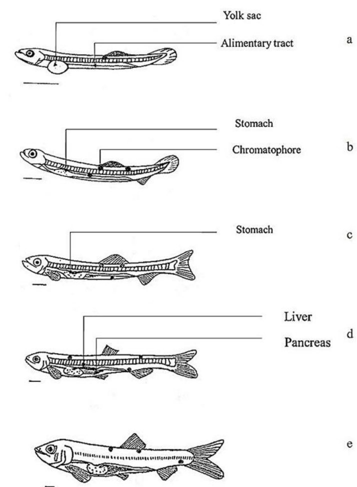

Figure 6: Development of the digestive tract with growth of *T. ilisha* larvae. Yolk sac stage (a), pre-flexion stage (b), flexion stage (c), post-flexion stage (d) and juvenile (e) (bar = 1mm) (Riar *et al.* 2019)