

## **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. Yolk sac larvae ( $3.83 \pm 0.57$  mm SL), pre flexion larvae ( $8.07 \pm 1.83$  mm SL), flexion larvae ( $11.50 \pm 1.55$  mm SL), post flexion larvae ( $14.72 \pm 1.70$  mm SL), and juvenile ( $18.75 \pm 3.02$  mm SL) were separated into five groups based on morphological characteristics. At the yolk sac stage, the mouth was closed, however at the pre-flexion stage, the larval mouth gape varied between  $177 \pm 25$  and  $367 \pm 47$   $\mu$ m. The ranges were  $241 \pm 31$  and  $497 \pm 59$   $\mu$ m, for the flexion stage,  $307 \pm 38$  and  $621 \pm 74$   $\mu$ m for the post-flexion stage, and  $393 \pm 61$  and  $788 \pm 119$   $\mu$ m for the early juvenile stage. Development of the digestive tract is complete at the juvenile stage of this species.

**Key Words: Habitat; Breeding biology; Ontogenic development; Digestive System; Morphological characteristics.**

## Introduction

The largest single fishery, the Hilsa shad, *Tenualosa ilisha* (Hamilton, 1823), 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 *T. ilisha* migrate from the ocean to freshwater riverine habitats to spawn. It is dispersed across 9390 km<sup>2</sup> of rivers, tributaries, and canals as well as the 118 813 km<sup>2</sup> 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 *T. ilisha* 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 *T. ilisha* is 0.25 million tons, valued at 1.3 billion USD (2.2 USD per kilogram). Additionally, it adds to the country's annual foreign exchange revenues of 5.5 to 11 million USD (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). *T. ilisha* fishing directly employs over 460,000 fishermen from 148 Upazilas, while the entire *T. ilisha* 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 *T. ilisha* 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 *T. ilisha* (Bhaumik, 2015)

### **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 hail fall 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, *T. ilisha* 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 *T. ilisha*'s migration range was in the Brahmaputra up to Tezpur.

### **Stock/Race of *T. ilisha***

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 *T. ilisha* stocks migrate. When it comes to their migratory patterns, some people believed that there are three different *T. ilisha* 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.

### **Migration and movement patterns**

The majority of freshwater-born *T. ilisha* 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).

### **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 previously 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.

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 *T. ilisha* 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 *T. ilisha* spawns (Hora, 1938, Malhotra et al. 1973, Chandra 1962). From May to July, Rao and Pathak (1972) observed the peak *T. ilisha* 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 *T. ilisha* breed in the upper reaches of fresh waters. For fish measuring 35 to 50 cm in length, *T. ilisha* fecundity ranged from 1.5 to 2.0 million eggs. Different regions are seeing a decline in *T. ilisha* fertility. *T. ilisha* productivity is naturally affected by this fall in fertility. The ratio of fully mature, gushing male and female *T. ilisha* 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).

## **Sex Ratio**

Male (M) to Female (F) were 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 *T. ilisha* 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.

## **Maturity**

*T. ilisha* 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 *T. ilisha* are

currently sexually mature. According to the GEF study (Haldar, 2004), mature male and female *T. ilisha* 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 *T. ilisha* population reaches sexual maturity at one year of age and is currently dominated by the one-year-old age group. Larger *T. ilisha* groups are uncommon in the population. In the 1960s, a three-year-old size group made up the majority of the *T. ilisha* population. A somewhat balanced population is being seen as a result of recent management initiatives. (Haldar, 2004).

### **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 *T. ilisha* 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). Yolk 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

$\pm 1.70$  mm SL), and juvenile ( $18.75 \pm 3.02$  mm SL) were separated into five groups based on morphological characteristics (Riar et al., 2020).

### **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  $177 \pm 25$  and  $367 \pm 47$   $\mu\text{m}$ . In the flexion stage, the range was  $241 \pm 31$  and  $497 \pm 59$   $\mu\text{m}$ , in post-flexion stage it ranged between  $307 \pm 38$  and  $621 \pm 74$   $\mu\text{m}$  and finally in early juvenile stage the range was  $393 \pm 61$  and  $788 \pm 119$   $\mu\text{m}$ .

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 Mahdiah (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 ( $R^2 = 0.97$ ) (Fig.6).

## **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 caught 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*.

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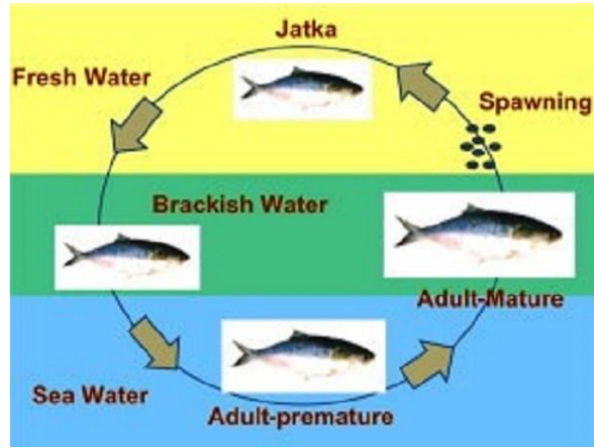
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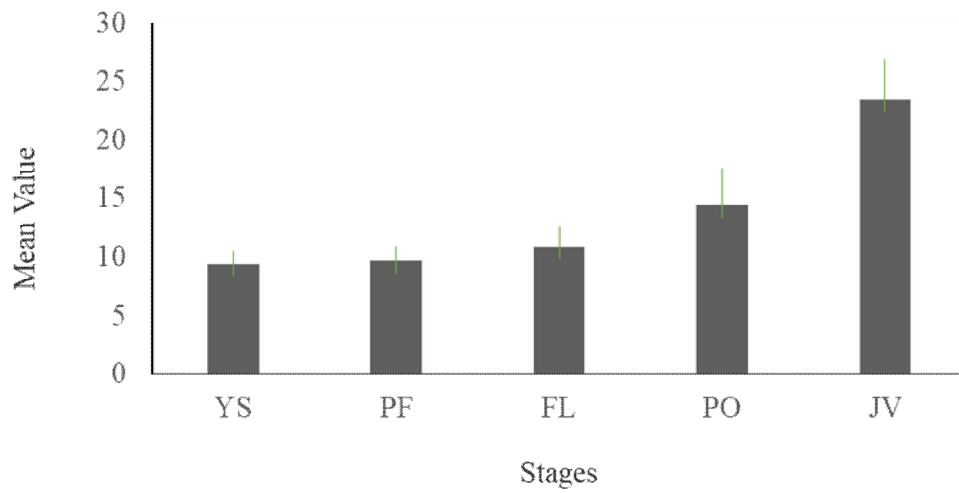
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**Table 1:** Development of Mouth opening for some fish species compare with *T. ilisha*

| <b>Fish species</b>      | <b>Day after hatching<br/>(DAH)</b> | <b>Reference</b>            |
|--------------------------|-------------------------------------|-----------------------------|
| <i>Tenualosa ilisha</i>  | 3                                   | Kulkarni., 1950             |
| <i>Clupea pallasii</i>   | 3                                   | Kawakami <i>et al.</i> 2011 |
| <i>Scomber japonicas</i> | 3                                   | Park <i>et al.</i> 2015     |
| <i>Sardinella dayi</i>   | 2                                   | Bensam, 1991                |
| <i>Rutilus frisii</i>    | 3                                   | Mahdieh, 2010               |

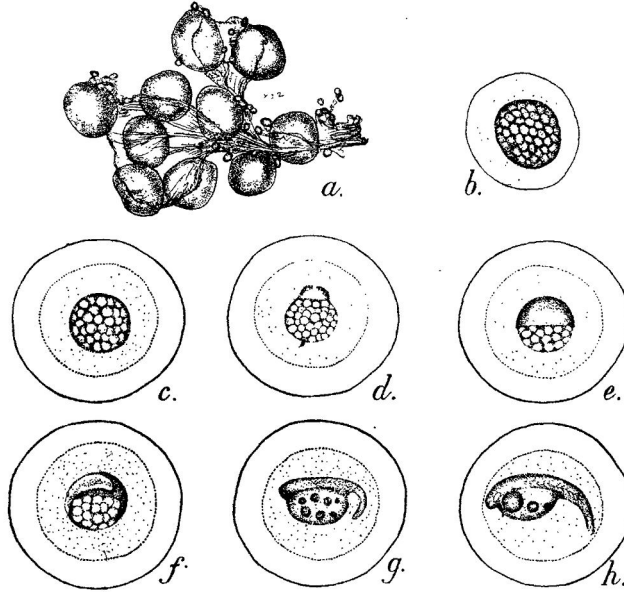


**Figure 1:** Movement and migration pattern of *T. ilisha* (Haldar, 2005).

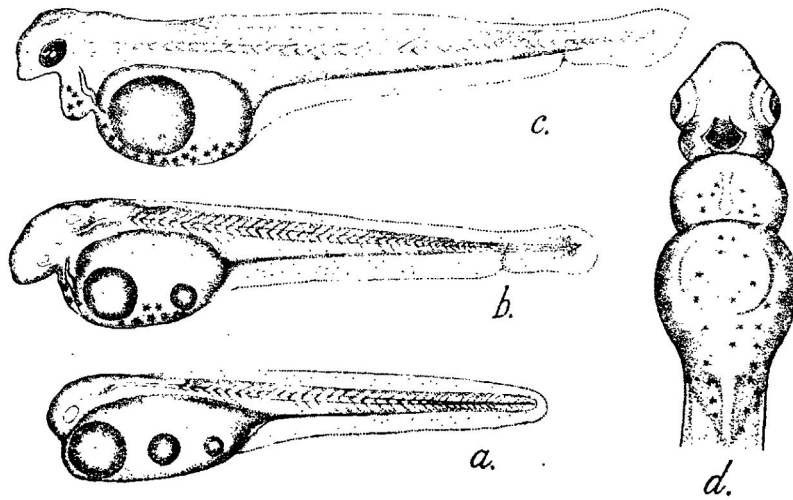


**Figure 2:** Body depth (BD) percentage with the standard length (SL) of *T. ilisha* larvae in different stages

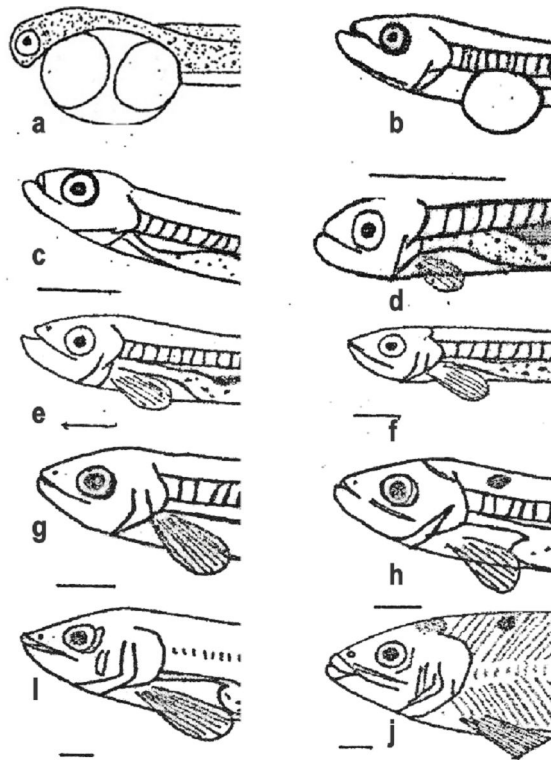
\*Yolk sac (YS), pre-flexion (PF), flexion (FL), post- flexion (PO) and juvenile (JV). All stages expressed by mean value  $\pm$  sd



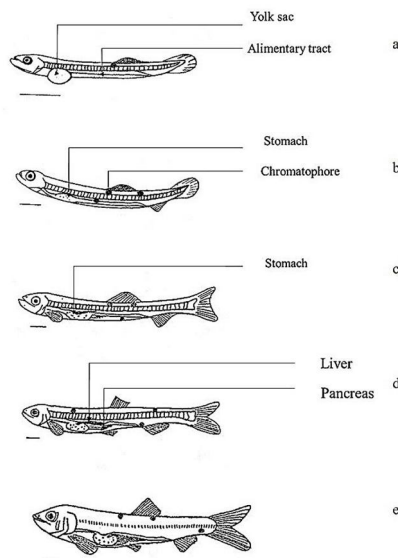
**Figure 3:** Embryonic development of *T. ilisha*. a. A piece of fully developed ovary, b. Egg before fertilization, c. Just after fertilization, d. 30 min. after fertilization, e. Four hours after fertilization, f. 8 hr after fertilization, g. 12 hr after fertilization, h. 17 hr after fertilization.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