Abstract

Quantitative measurements including the length-weight relationship, condition factor, growth rate, and gonadosomatic index are crucial in the study of fish biology (GSI). The following data was gathered to help guide this study's approach and ensure the validity of the fresh findings. All gobies are what biologists call "multiple-spawners," meaning they reproduce more than once in their short lifespan. It is *Pseudapocryptes elongatus*, a species with group-asynchronous ovary that spawns serially. This species of burrowing gobiid spawns in the wet season (June- July). South-east Bangladesh (especially the Cox's Bazar district) is teeming with this species. This study's goal was to learn more about Pseudapocryptes elongatus' reproductive traits in Bangladesh's southeast. From August 2021 through February 2022, 977 *Pseudapocryptes elongatus* were randomly taken from the Fishery ghat market in Chattogram Division. The samples used in this investigation were then collected, categorized, measured, and analyzed. According to the results, TL varied from 8.2 cm to 27.3 cm. The Gobi length frequency data ranges from 8.2 to 27.3cm in total length, and the population is regularly distributed. According to the estimated growth coefficient (b), *P. elongatus* exhibited negative allometric growth (b 3). 'Kn' the relative condition factor, averaged out to (1.019±0.093) for *P. elongatus*. The female reached sexual maturity at a size of 15 centimeters (Lm). While the reproductive biology of *P. elongatus* has been studied elsewhere, no such work has been done in Bangladesh. Knowing how *Pseudapocryptes elongatus* reproduces can help with conservation efforts, sustainable management practices, and adaptations to the local environment. The findings added to knowledge for fish population sustainability management and give important information on the reproductive biology.

Keywords: *Pseudapocryptes elongatus*, length-weight relationship; relative condition factor; Frequency distribution, length at first maturity, Gonadosomatic Index

CHAPTER-1

INTRODUCTION

Millions of people rely on fish for their food and jobs in Bangladesh, where it is the second most valued agricultural produce. It is Bangladesh's second-largest export sector. Fishing holds a unique position in the food web because it provides people with a high-quality source of animal protein and essential minerals. In 2016, marine capture accounted for 79.3 million of the world's 170.9 million tons of fish production. Millions of people around the world depend on fisheries and aquaculture for their livelihood, making these industries crucial economic drivers (FAO, 2018).

The fishing industry in Bangladesh can be split down into four distinct subsectors: maritime industrial fishing, artisanal fishing, mariculture (farm-based fishing), and inland catch and culture. The country's 4.34 million hectares of water resources—including small lakes, canals, small and huge rivers, and estuaries make it a leading producer of inland fisheries. An estimated 2.30 million hectares are used for artisanal and coastal fisheries along Bangladesh's 714 kilometers of Bay of Bengal coastline (Ghose, 2014). In addition, there is a vast marine fishery resource spread over an exclusive economic zone (EEZ) of 1, 66,000 square kilometers (DoF, 2018a). In terms of GDP and agricultural GDP, the fishing industry contributes 3.57 percent and 25.30 percent, respectively, while more than 11 percent of people rely on the sector for their living. In Bangladesh, fish accounts for around 60 percent of the country's daily animal protein consumption (DoF, 2018b). It is estimated that the average Bangladeshi consumes roughly 14 kilograms of fish per year, compared to the required minimum of 18 kilograms. A recent nationwide study conducted in rural Bangladesh found that the average daily intake of total protein was 48 grams, with 3 grams coming from fish. The rising number of people who need to eat has increased pressure on the world's scarce agricultural land and freshwater supplies. Bangladesh's population is growing at an alarming rate; hence the country's fish harvest will need to increase. It contends that a nation's health and economy would benefit greatly from more efficient and sustainable use of its aquatic resources. Despite the importance of fisheries resources to millions of people's livelihoods and to the nation's food and nutrition security, the industry faces a number of obstacles. These include climate change, inadequate fisheries infrastructure, resource mismanagement, water and environmental pollution, natural disasters like waterlogging and hurricanes, and a lack of knowledge among the farming population (Ghose, 2014).

One of the biggest fish families with over 2,000 species in more than 200 genera, the Gobiidae family of bony fish is commonly referred to as the "real gobies "(Patzner et al., 2011). The genus contains gobies that are commonly referred to as eel gobies and are members of the Gobiidae family, which references to their attenuated body form (Talwer and Jhingran, 1991). Estuaries, rivers, and shallow coastal waters are the habitats of this species (Allen, 1991). They often inhabit the bottom and are benthic. They are of tremendous relevance as prey species for fish that are commercially significant, such as cod, haddock, sea bass, and flatfish, even though they are rarely valuable as human food. Other gobiids, such the dartfish of the genus Ptereleotris, are interesting as aquarium fish (Agorreta et al., 2013; Agorreta and Rüber, 2012). Gobies are generally bottom-dwellers (Winterbottom, Richard; et al., 2011). In the Indo-pacific, coral reef gobies represent approximately 35% of the total fishes and about 25% of the fish diversity (Winterbottom et al., 2011). Amphibian euryhaline fish known as mudskippers (Gobiidae: Oxudercinae) are found across the Indo-Pacific area and have been shown to impede the growth of coastal intertidal mudflats (Murdy 1989; Clayton 1993). Members of the family Gobiidae (commonly known as mudskippers) including *Pseudapocryptes elongatus* (Fani et al., 2017). *Pseudapocryptes elongatus*, a species of fish that may be found from India to South East Asia, has only one confirmed record from Japan's Kyushu Islands. Indo-Pacific: from India to Tahiti and China to Bangladesh and Chilka Lake in Bangladesh and China in the Gulf of Thailand, and from India to Tahiti and China in the Indian Ocean. There is a common benthic freshwater edible fish known as *Pseudapocryptes elongates*, a fish that is mostly carnivorous and benthic. As other mudskipper species have shown, this species tends to migrate from interior canals to coastal/mangrove environments, potentially to build burrows and spawn (Macnae, 1968). All gobies are multiple-spawners, which mean they reproduce throughout the year, frequently during a wet period of the year. At least twice throughout its brief life span, the goby Aphia minuta spawns, making it one of the most prolific breeders in its genus (Caputo et al., 2003). Mudskippers are essential to subsistence fishing and provide a reliable source of income for those who rely on it (Mahadevan et al., 2019). Over the past decade, mudskippers have become more valued in countries like China, Vietnam, Thailand, and Japan as an integral aspect of aquaculture to support subsistence and commercial fisheries (Tran et al. 2019). Some of the best tasting mudskippers in Asia are the *Boleophthalmus* and *Pseudapocryptes* species (Mahadevan et al., 2017, 2019, 2020a, and b). Thus, mudskippers (*Boleophthalmus pectinirostris*) were successfully cultivated in China using monoculture and polyculture techniques, with yields ranging from 750 kg to 975 kg ha1 (Hong and Zhang, 2004). *Pseudapocryptes elongatus* has a high market value in Vietnam, ranging from 4-8 USD per kilogram, which promotes its widespread cultivation (Minh et al., 2010). The medicinal value of mudskippers is also widely acknowledged (Mazlan and Rohaya, 2008). In the Mekong Delta, it is cultivated in both semi-intensive and intensive systems. Seeds may only be attainable from the wild at this time due to the rapid expansion of aquaculture and the subsequent decline of fish stocks. West Bengal and the surrounding area is a commercially significant freshwater benthic fast-moving-mud-dueling fish species known as the *Pseudapocryptes elongatus* or gulee or Chemma fish. The *Pseudapocryptes elongatus* is a carnivorous fish that prefers freshwater environments, such as ponds, canals, marsh, jheel, rivers, and lagoons. Because of its widespread distribution and low danger, Pseudapocryptes elongatus is classified as Least Concern. *Pseudapocryptes elongatus* may be found all throughout the subcontinent, including Nepal, Bangladesh, Pakistan, and India and nearly everywhere throughout the drainage of the Ganges River. (Das et al., 2015)

Most of the species of gobiids of Bangladesh were found in marine and brackish waters environment. Among (three more species also recorded) 44 species of gobies from 29 genera reported in the country until now. Only seven species were found in brackish and freshwater in Bangladesh. This family's diversity in morphology, behavior, and habitat is impressive. However, because of their cryptic and covert nature, they are poorly understood, and a significant number of new species are described each year, making them the marine family with the highest number of newly described species (Ferahtia, 2021). In Bangladesh's freshwaters, gobiids have received less attention (Rahman, 2005). *Pseudapocryptes elongatus* (Cuvier, 1816) known as Chewa in Bangladesh (local name). The Bakkhali River estuary in Bangladesh's Cox's Bazar district is an important river estuary. The Bay of Bengal, it's interconnected (Indian Ocean). As a result of its marine environment, this estuary supports a wide range of commercially valuable fish species (Siddique et al., 2012). During the monsoon season, the Bakkhali River estuary is home to two species of *osmunda: O. rubicundus* and *P. elongatus.* This *(Pseudapocryptes elongatus)* species also found at Nijhum Island and estuaries areas of junction between Meghna River and Bay of Bangel, Hatiya (Latifa, et al., 2015). Because of their high market value in the Bakkhali River estuary, these Gobioid species is being heavily fished. As a result, their natural populations are rapidly dwindling (Siddique et al., 2015). People from all walks of life enjoy this fish because of its exquisite flavor in Bangladesh's south coast. However, the availability of this fish has declined recently as a result of environmental concerns.

The length-weight relationship is essential to the study of fish physiology, ecology, the assessment of fishing practices, and the protection of fish populations. The health, growth, and ontogenetic changes of fish, as well as the dynamics of fish populations, are all important topics for fish conservationists around the world to understand (Simon et al., 2009). The length-to-weight relationship can also be used to estimate stock biomass from limited data and to translate length-to-weight equations used in stock assessment models. The condition factor was used to assess people's happiness in the study area (Ecoutin and Taskavak, 2007). Natural resources like fish populations are renewed via reproduction (Olusegun, 2011). An evaluation of gonads' growth cycle and histological investigation is essential to determining the precise spawning season and frequency throughout the breeding season (Conover, 1992). It is possible to distinguish the various phases of the ovary through histological testing, and it is also possible to establish when the ovum is ripe. An overview of the spawning season of the fishes may be gained from this data set. Prohibiting fishing during the spawning season is made possible by understanding the various phases of fish gonadal development. The gonado-somatic index (GSI) is also an important factor in determining the spawning phase since the gonad weight varies cyclically in proportion to the total body weight (Smith, 2008). Preparation for the breeding season is indicated by an increase in the GSI (the greater the number, the more likely it is that spawning will take place). Understanding target taxa's development and reproduction biology is a critical part of fisheries management (Teichert et al., 2014). Fishery management methods must be realistic and use correct assessments of biological aspects such as reproduction, growth, and population estimation in order to conserve this species. As a result, aquaculture relies heavily on the understanding of fish reproduction to supply the year-round need for marketable fish and fingerlings. Adult fish and other fish need to be protected from overfishing pressure by determining when the fish reproduce or breed. Reproductive cycles are intertwined with varied aquatic settings, making them a harmonic whole. Pseudapocryptes elongatus reproductive biology will be examined in this study in order to develop sustainable management techniques. Research into the reproductive biology of these fish, as well as variations in seasonal variation or patterns, will be useful for long-term management and usage, as well as for aquaculture development.

The objectives of the research are

- ✓ To determine the morphometric data for *Pseudapocryptes elongatus*, including the length-weight connection, condition factor, relative condition factor and gonado-somatic index (GSI); and
- ✓ To identify the breeding biology through studying the gonadal maturation cycle.

CHAPTER-2

REVIEW OF LITERATURE

Quantitative measurements including the length-weight relationship, condition factor, growth rate, and gonadosomatic index are crucial in the study of fish biology (GSI). Using length-weight relationships, it is possible to estimate weight from measurements taken during the yield evaluation. Conditions at different body lengths can provide insight into the fish's development and spawning stages, and a thorough assessment of the environment during different times of the year can reveal the breeding seasons. This section provides a summary of the literature on the length-weight connection, GSI, and cyclic variations in the gonadal development of the (*Pseudapocryptes elongatus*) species. To confirm the correctness of the new findings and to assist define the methods of this investigation, the following data was gathered.

2.1 The weight-to-length ratio

Two species of Gobioid fish, *Odontamblyopus rubicundus* (Hamilton, 1822) and *Pseudapocryptes elongatus,* were studied for their morphometric properties in the Bakkhali River estuary in Cox's Bazar, Bangladesh (Siddique et al., 2015) (Cuvier, 1816). A total of 308 fish samples were analyzed quantitatively (147 of O. rubicundus and 161 of *P. elongatus*). Comparing the two species, the average TL (SD) for O. rubicundus was 18.13 cm and for P. elongatus it was 16.82 cm. The maximum TL of O. rubicundus was 21.0 cm, while that of P. elongatus was just 19.7 cm. Allometric growth was calculated to be 2.734 for both *O. rubicundus* and *P. elongatus*, indicating hypoallometric or negative allometric growth ($b<3$). Total body length was used to determine 'Kn' values, which represent the relative state of an organism. The average relative condition factors ('Kn') for *O. rubicundus* and *P. elongatus* were 0.992992± 0.055 and 1.039992 ± 0.127, respectively.

When looking at the correlation between length and weight for the species *Glossogobius, giuris* (from Mithamoin haor in Kissorgonj, Bangladesh), the following equation was derived: Log W (Female) = 2.841 Log TL - 1.865 (r=0.963). 'Kn' = 1.009± 0.124 was the relative condition factor for female G. giuris (Hossain and Sultana, 2014).

From the beginning to the end of a mating cycle, female *G. giuris* fishes varied in size from 3.62± 0.20 to 21.49± 1.09 cm (Jabbar et al., 2019). The greatest sum of length was recorded in August at 21.49±1.09 cm, and the smallest sum of length was recorded in January at 3.62± 0.20 cm. During the month of August, the value was 113.17±11.58 g, while the lowest was recorded in January at 8.33±0.37 g.

According to Mahadevan et al. (2020b), researchers in the Indian Sundarbans employed the FAO-ICLARM Stock Assessment Tool to analyze length-frequency data from 945 individuals collected over a period of 15 months. A study of length-weight relationships found that *P. elongatus* populations grew at a negative allometric rate. *P. elongatus* were taken by fishermen and ranged in size and weight from 7.79 to 131.01 g and 9.0 to 23.5 cm. W = 0.0127 TL 2.927 (P <0.001; r2 = 0.988) was found to be the equation that best described the LWR and the 'K' value of the studied species was calculated to be more than one (1.002 ± 0.002), suggesting the species in the Indian Sundarbans are in good condition.

The length-weight relationship is useful for analyzing animal development and growth (LWR). The b values have been used to determine growth rates in fish species using length-weight correlations (Riedel et al., 2007). Alam et al. (2014) state that when b = 3, it denotes isometric growth, whereas when it is significantly different from 3, it denotes allometric growth. Fish are capable of isometric growth, negative allometric growth, and positive allometric growth. Isometric growth occurs when an organism maintains the same overall shape while expanding in size. When a fish's allometric growth is positive, it means it's getting bigger without getting any thinner, and when it's negative, it means it's getting bigger without getting any shallower (Lizama et al., 2002).

P. serperaster was studied in the Mekong Delta of Vietnam, and the length-weight relationship was determined to be LogW = 0.0057 + 2.874-LogTL, (n = 409), r 2=0.884, P0.05 for males, and LogW = 0.0057 + 2.921LogTL, (n = 600), r 2=0.854, P/0.05. In accordance with the regression slope values of LWRs, *P. serperaster* expanded isometrically (Dinh et al., 2016), with males having a W = 6.15*102SL2.160 and females having a W = 2.44*102SL2.542 (Bucholtz et al., 2009). The length exponents of males and female are significantly different (P<0.001): b = 2.160 and 2.542, respectively.

Pseudapocryptes elongatus were studied in 2015 by Siddique et al., along the south-east coast of Bangladesh (Bakkhali River estuary, Cox's Bazar) to determine their length-weight relationship, condition factor, and relative condition factor. The contemporary habitat, climate, and other components are vastly different from those of the past, making it crucial to check the fish data in order to evaluate the stock and adopt management techniques.

2.2. First sexually mature length (Lm):

A good indicator of the size of the monetizable stock would be the size at maturity. In fisheries, the size at first maturity (Lm50) is defined as the length at which half of the fish population reaches sexual maturity (Nandikeswari, 2016). Age at first sexual maturity was established during the spawning season. A fish was called juvenile if it was still in the first or second stage of development. Upon reaching stage three of maturity, they were deemed to have fully grown (Farmer et al., 2005). Fish population management and conservation relies heavily on information about fish length at maturity and spawning season since this information reveals when and at what length the fish should be safeguarded (Hunter et al., 1992).

Length at initial sexual maturity (Lm) for female *Pseudapocryptes elongatus* was reported to be 15.4 centimeters in previous studies conducted in various nations (Dinh et al., 2007b). 50% of *B. boddarti* adults were sexually mature at 11.52 cm (Wootton et al., 1990). Possible adaptability to the monsoonal climate is suggested by this fish's large size (11.52 cm at first sex maturity) and great fertility (9,800-33,800 eggs) (Quang et al., 2015). *Apocryptes bato* from the Payra River in southern Bangladesh reached sexual maturity at a length of 4.9 cm (Ahamed et al., 2018). Female *Periophthalmus barbarus* in Nigeria matured at an early age (10.2 cm) in length (Etim et al., 2002).

2.2 Reproductive biology and spawning season:

Knowledge of development and reproduction of target species is essential for effective fisheries management (Teichert et al., 2014). It is possible to estimate the spawning season in fish by using a correlation between GSI and the frequency distribution of gonadal maturity stages. Total length and body weight are just two of several biometric indicators that can be used to infer an organism's resource-acquisition strategies in the wild (TL and BW). GSI and CF all measure different aspects of health and wellness (K). Fat buildup, gonadal development, overall health, and the capacity for adaptation are additional indicators of physiology (Baldisserotto et al., 2019).

Pseudapocryptes elongatus gonad maturity was investigated in Kalilamong River, Indonesia, from July to September 2017 (Fani et al., 2017). The study found that female fish *P. elongatus* did not reach stage IV (Ripe) gonad development in July, and that male fish *P. elongatus* did not grow gonads, although they appeared to mature in September. The gonadosomatic index (GSI) is a percentage-based indicator of gonad development. Calculations using GSI demonstrate that *P. elongatus* caught between July and September do not have fully developed gonads, with males having a GSI of 0.65% and females having a GSI of 0.75%. P. elongatus fish in China had an average GSI value of 14.5%, whereas the same fish in Pakistan have an average GSI value of up to 4% in breeding-ready conditions, according to another study (Bucholtz et al., 2009).

According to Dinh et al., the months of July and October are *P.elongatus* most productive reproductive months (Dinh et al., 2007a). At first maturity, males and females measured 15.4 and 16.3 centimeters in Lm, respectively. It was shown that the GSI of both male and female fish increased on a monthly basis from May to December. July saw the highest average GSI for female, followed by a dip in August and September and then a rebound in October. Then it dropped again in November and December before leveling off in April. But the highest GSI values were recorded in November and July. It was also found in February that the goby's ovaries were developing (Stage II), maturing (Stage III), and becoming fully mature (Stage IV) in the months leading up to June, when they would take over reproduction. There were no females with ovaries in the stages of running (Stage V) or spent (Stage VI).

According to, the highest GSI values for female were reported between July and October, while the highest GSI values for male were reported between July and November (Dinh et al., 2007a). Findings suggested a possible breeding season of June through November, with two spawning peaks in July and October.

Mudskipper population biology was studied in ‘Bac’ Lieu Province, in the Lower Mekong Delta of Vietnam (Bucholtz et al., 2009). There were no mature males or females among the mudskippers sampled from estuary canals in 2004 in dry season. Some scientists assume that *P. elongatus* will head to the ocean to breed once the rainy season begins. No ovaries were found in ‘Bac’ Lieu mudskippers. For female generally, the mean GSI was low, increasing by only 0.2% over the course of the sample period.

A total of 110 male and 77 female Glossogobius giuris were gathered for study in the Kissorgonj region of Bangladesh between January and December of 2013. Two peaks in the fish spawning cycle occurred over the course of many months. Peaks in the gonadosomatic index in March, June, and October each represent a different time of year (Hossain, 2014).

Between January and December, male and female *G. giuris* GSI values ranged from 0.216± 0.11 to 9.62 ± 2.21. Females' GSI values peaked at their highest in March (5.265), June (7.774), August (7.558), and October (9.62) during their two peak spawning months. Therefore, the fish kept laying eggs for a long time, which is in line with observations showing a protracted breeding season from August to January, with the peak in September (Rao and Rao, 2007). It was also stated that this species is abundant and breeds year-round (with a supposed peak in August) (Islam, 2004). April's highest GSI readings were also reported to have been seen in captive circumstances (Islam and Mollah, 2013).

The peak spawning season for *Boleophthalmus boddarti* in Vietnam occurred during the months of August and October over the period of March 2013 to February 2014 (Quang et al., 2015). Ovary development accelerated from stages I and II to stage V in just four months (July to October). The data shows that by the end of September, the majority of women in ovarian maturity stage V had been identified. Ovaries that had formed prematurely were found between April and December, while stage I ovaries were found at all times during the experiment. Wet season ovaries were more fully mature and fertile than those during the middle of the rainy season (August to October). This behavior is typical of certain fish in the Mekong Delta, such as *Pseudapocryptes elongatus,* and suggests that *B. boddarti* is also a multi-spawner that produces offspring throughout a three-month period (August–October) during wetter years (Tran, 2008).

It has not been clearly established in Bangladesh how *Pseudapocryptes elongatus* (Chiring) reproduces. Work established on other types of gobies (mudskipper) such as *Glossogobius giuris, (*Hossain, 2014; Jabbar et al., 2019) and other Eco-biological, morphological and induced breeding analysis or observation took place (Islam, 2004; Islam and Mollah, 2013). It is necessary to have knowledge of the biological aspects of mudskipper (*Pseudapocryptes elongatus*) reproduction in order to use commercially important and sustainable resources in the future. The long-term management and usage of the mudskipper study along the south-east coast of Bangladesh will benefit from research on the reproductive biology of these fish as well as fluctuations in seasonal variation or pattern.

CHAPTER-3

MATERIALS AND METHODS

There are several methods and resources employed to accomplish the study's goals, and this chapter discusses them. Any study would be incomplete without an understanding of the research's methodology. This investigation was conducted in accordance with a methodical, scientific approach. *P.elongatus* gonadal maturation cycle sought to be elucidated in this work. Data was collected to aid in the analysis of the findings in a laboratory setting. The following approaches were used to study the reproductive cycle of *P.elongatus*.

3.1 Site of sampling and collecting of samples

Chattogram New Fishery Ghat, patharghata was sampled monthly from August, 2021 to February, 2022. Plate 1 shows the sampling site of this study. After being collected, each month's batch of *P.elongatus* samples (150 totals) were promptly frozen in an ice box at a ratio of 1:2 samples to ice. Data was collected to aid in the analysis of the findings in a laboratory setting. The following approaches were used to study the reproductive cycle of *P.elongatus.*

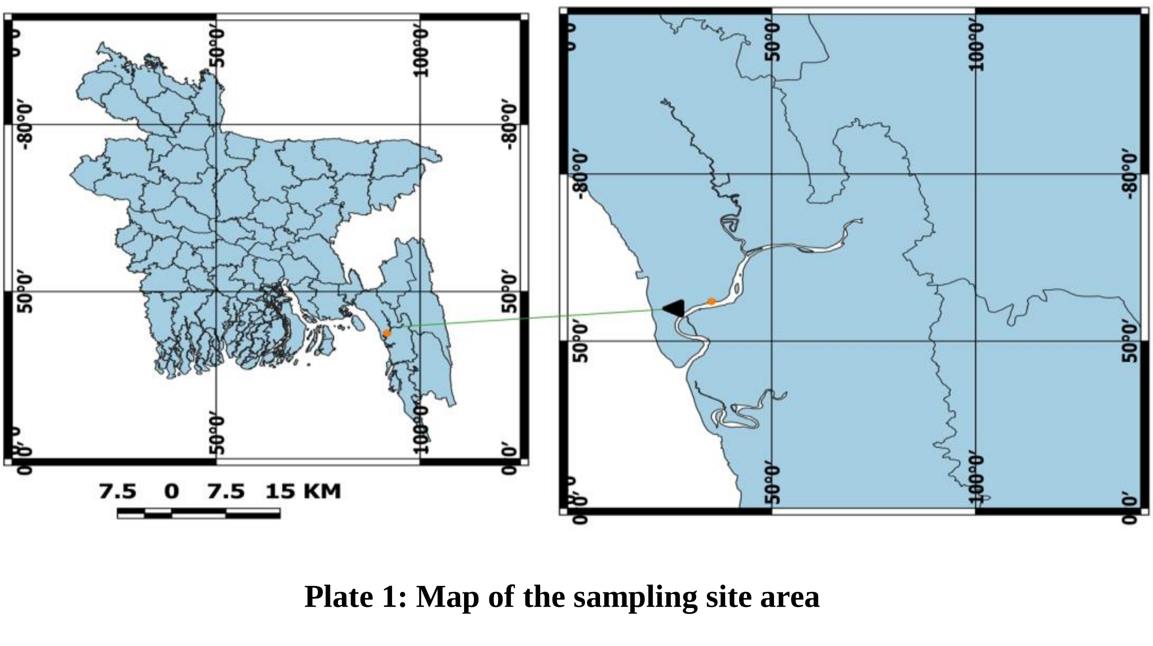

Plate 1: Map of the sampling site area

3.2 Recording of length-weight data and determination of the length-weight Relationship

To the nearest 0.01 centimeter (cm), we measured the total length (TL) and standard length (SL) of each fish using a measuring scale that shows in plate 2, and we used an electrical balance (REDWAG, WRT12F1/NV) to determine the weight of each fish in grams (g).

Plate 2: Recording of length-weight data of *P.elongatus*

TW = qSLb is a typical representation of the relationship between fish length (TL) and weight (W) based on the exponential equation, here ‘q’ is a coefficient related to body form (Le Cren, 1951).

There is an exponent "b" that indicates isometric development when it equals "3," which is an exponent connected to body shape, where TW is the total weight (expressed in "g"), and the standard length (expressed in "cm").

The rate at which a creature's mass increases as a function of its length is described by the product of these two numbers, called the allometry co-efficient (b). Using natural logarithms, this power curve equation was transformed into a linear form (Le Cren, 1951):

Log TW = Log a - b Log TL,

The regression equation is the same as this equation: There are two ways to express the formula, one of which is as follows:

Log TW, where a represents the slope of the regression line, b the intercept, and X the corresponding log TL value.

In Excel, we made a scatter diagram by plotting the length along the X axis and the weight along the Y axis. Once the length-weight data had been transformed to natural logarithms, it was time to plot it (cm) where,

Y-axis = Log weight (g)

X-axis = Log Total length (cm)

A scatter diagram might be constructed by re-applying the length-weight data that has previously been translated. The values of q and b were derived from the diagram depicted in this article.

3.3 Determination of condition factor

When it comes to body composition, one of the most essential components is known as the condition factor (K). This fish health indicator measures the weight-to-length ratio of the fish's body. To gauge the impact of environmental conditions, it is also commonly used. Calculations based on the following formulas were used to estimate Fulton's condition factor the following formula is used to calculate it (Fulton, 1904).

$$K = W*100/L^3$$

Where,

W = Weight of fish in gram (g)

L = Length of fish in centimeter (cm)

3.4 Relative condition factor determination

Fishery biological studies need information on seasonal changes in the state of a fish in respect to both its internal and external surroundings. The health of a fish can fluctuate greatly according to a variety of factors, including physiological, environmental, nutritional, and biological cycles. In order to better comprehend the fish's dietary and biological cycles, researchers have discovered the relative condition factor (Kn). Individual fish or groups of fish that deviate from their predicted weight for length due to fatness, general health, or gonad development are signs of condition (Le Cren, 1951). It was determined using the following formula to get "Kn" (Le- Cren's, 1951).

In other words, 'Kn' = W / ^w

Where, W = Actual weight of fish in gram (g)

^w = Expected weight [w = (Log W* = log a + b log L)]

Where, W* = Average of W

The monthly samples were used to construct the condition factor and relative condition factor, which were utilized to detect seasonal fluctuations in fish condition.

3.5 First Sexual Maturity Size (Lm)

Size at first maturity is defined as the length by which half of the fish population has reached sexual maturity (Lm). Length (Lm) was estimated using a variety of methods, including those based on the gonado-somatic index (GSI), the modified GSI, the Dobriyal index (DI), and other indices (Khatun et al., 2019).

The GSI, MGSI, and DI which were calculated by (Nikolsky, 1963) as

GSI (%) = (GW/BW) × 100;

MGSI (%) = (GW/BW-GW) × 100; and

DI = (GW) ^1/3 (Dobriyal et al., 1999)

Where, BW= body weight, GW= gonad weight

3.6 Gonadosomatic Index (GSI):

Upon obtaining the fish's measurements in terms of length and mass, the fish will be dissected so that the gonad can be removed. To get to the gonad, the gross stuff like filth, digestive organs, and the intestines had to be removed with forceps. The GSI excels at determining when spawning seasons are based on the ratio of gonad weight to total body weight. The gonadosomatic index (GSI) is an important metric for determining spawning phase since it compares gonad weight to total body weight (Vladykov, 1956).

GSI (%) = Weight of gonad (g)/ Total body weight of fish (g) x 100

Plate 3: Gonad dissection of *P.elongatus*

3.7 Histological process

Several steps of the histology procedure are described below that showed in plate 4.

3.7.1 Fixation

At first the samples were preserved in a vial with Bouin's fixatives for maximum 24 hours for fixation that shows in plate 4. Then the samples are washed with tap water to drain out the fixative 2-3 hours before dehydration.

3.7.2 Dehydration

After washing, the gonads were removed, cut into tiny (1 cm) pieces, and placed singly into pre-labeled cassettes. The tissue blocks were then subjected to a series of rising alcohol concentrations to induce dehydration (Table-1). The appropriate tissue consistency for sectioning into thin slices requires dehydration.

Table 1: Dehydration schedule

Solution	Time
I. ethanol 50%	2-3
II. Ethanol 70% 2-3	2-3
III. Ethanol 80%	2-3
IV. Ethanol 90%	2-3
V. Ethanol 95%	2-3
VI. Ethanol 100%	2-3
VII. Ethanol 100%	2-3

3.7.3 Cleaning

After dehydration the blocks were passed through successive changes of xylene until the alcohol from the tissue is replaced by xylene (Table-2).

Table 2: The cleaning schedule

Solution	Time
1. Alcohol (50%) + Xylene (50%)	2hours or overnight
2. Xylene	2 hours
3.Xylene	2 hours or overnight

3.7.4 Infiltration

After clearing, the tissue blocks were placed in melted paraffin in the oven usually at 60°C. Heat causes evaporation of xylene and the space in the tissue become infiltrated with paraffin (Table- 3).

Table 3: The infiltration schedule

Solution	Time
Paraffin + xylene (50%+50%)	2 hours
Paraffin	2 hours
Paraffin	2 hours
Paraffin	2 hours

3.7.5 Embedding

A paraffin block was then made of the gonadal tissue. Paraffin blocks were cut after embedding the tissues to permit precise sectioning.

3.7.6 Trimming

It is necessary to cut away the unwanted wax layers from the embedded blocks before they can be used to create new, better-looking blocks. It makes sectioning easier. Trimming was done to remove extra wax layers after correct embedding.

3.7.7 Sectioning

The microtome was used to slice the blocks into sections of 5 to 7 micrometers thick. Before drying overnight in an incubator, the sections were mounted on slides. Sections were dewaxed by soaking them in xylene, alcohol, and water baths before staining.

3.7.8 Floating of section in water bath

A water bath of 42℃ was used to keep the ribbon-like portions of paraffin at a temperature lower than the melting point.

3.7.9 Staining and mounting

Harris Traditional staining methods included the use of Hematoxylin and eosin (Bancroft and Stevens, 1996). After the appropriate levels of staining were attained, with the aid of D. P. X. mounting material, the slides were securely attached. Plate 2 shows the staining procedure.

Table 4: The staining schedule

SL No.	Solutions	Time	Process
1	Xylene	10 minutes	Clearing
2	Xylene	10 minutes	
3	Xylene	10 minutes	
4	100% alcohol	5 minutes	Rehydration
5	100% alcohol	5 minutes	
6	90% alcohol	3 minutes	
7	80% alcohol	3 minutes	
8	70% alcohol	3 minutes	
9	50% ethyl alcohol	2 minutes	Staining
10	Distilled water	15 dips	
11	Hematoxylin	3 minutes	
12	Wash in tap water	15 minutes	
13	50% ethyl alcohol	10-15 dips	
14	95% ethyl alcohol	30 seconds	
15	Eosin Y	1 minute	
16	95% ethyl alcohol	2 minutes	Dehydration
17	100% ethyl alcohol	1 minute	
18	100% ethyl alcohol	3 minutes	
19	100% ethyl alcohol	1 minute	
20	Xylene	20 minutes	Clearing
21	Xylene	20 minutes	
22	Drying at room temperature	Overnight	Drying

3.7.10 Microscopic observation:

The mounted slides were examined using a microscope (Optika; B-190 Series, Italy), coupled with a computer and a digital camera. Using this method, many different high-magnification photographs were taken.

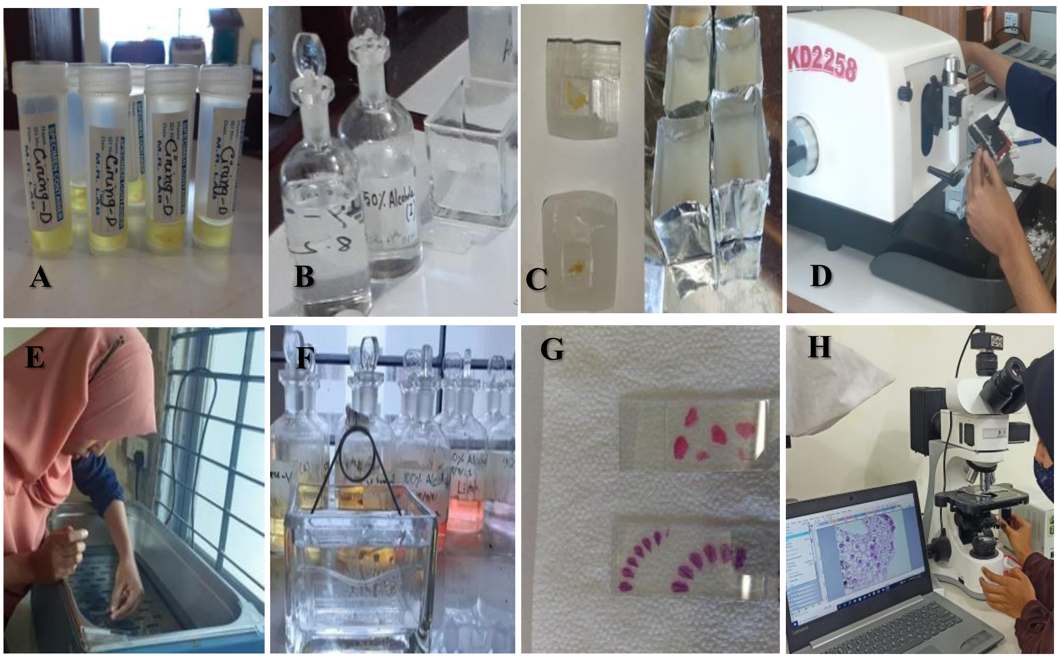

Plate 4: Histological stages: A.F fixation, B. Dehydration, Embedding, Trimming, D. Sectioning, E. Floating of section in water bath, F. Staining, G. mounting, H. Microscopic observation

3.8 Statistical analysis of data

Microsoft Excel was used to accomplish all statistical analysis and data recording. To explain the data, we utilized the mean and standard deviation (S. D.).

CHAPTER-4

RESULT

The findings of an inquiry are presented in the results section in a systematic, logical, brief, and concise way. The length-weight relationship, condition index, GSI, and the histological changes in the gonads of *P. elongatus* throughout the year are all covered in detail in this section of the existing research endeavor.

4.1 Length-weight Relationship

During this study period 977 sample collected from the waters off the coast of southeast Chattogram to see the correlation between total length and weight off the fish. Females have a different linear and logarithmic equation: W = 0.17327* TL 2.4179 (R 2 = 0.83) and log W = -1.7529 +2.4179logTL (Figure-1). In females, a negative allometric growth tendency is seen when the overall length-weight relationship (b <3) is less than 3. Simple linear regression were used to identify the morphometric relationships and represented in figure 1. The "b" values obtained from the regression analysis were evaluated whether it is significantly different to 3.0.

The 'b' value indicates an allometric growth (<3, negative) pattern of *P. elongatus.* The coefficient of determination (R^2 = 0.8284) revealed that 82.84% of the variation in body weight was due to variation in total length in the sample collected over the period from August 2021 to February 2022.

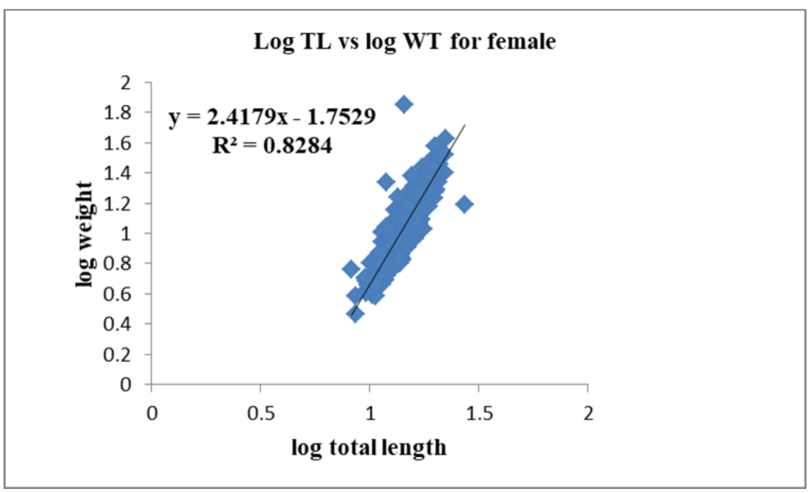

Figure 1: Logarithmic relationship between the total length and weight of female *P.elongatus.*

4.2 Condition factor and relative condition

Both the condition factor (K) and the relative condition factor ('Kn') were used once a month to assess the fishes' overall well-being. The condition factor (K) and relative condition factor ('Kn') are used to determine how much a fish's length and weight deviate from the ideal.

The monthly K value varied between 0.37- 0.43 and the ‘Kn’ value varied between 0.97- 1.13. Data are presented as mean ± standard deviations for each month over the period from August 2021 to February 2022. Both ‘Kn’ and K had their highs and lows in January (1.13± 0.18 and 0.97 ±0.11 respectively) and January (0.4 ±0.07 and (.37± 0.075 respectively) and August (.37 ±0.075). In this study, the average value of the relative condition factor (‘Kn’) for *P. elongatus* was (1.019 ±0.093) which indicates the fish was in good condition during the sampling and the value is showed in figure 2 and 3.

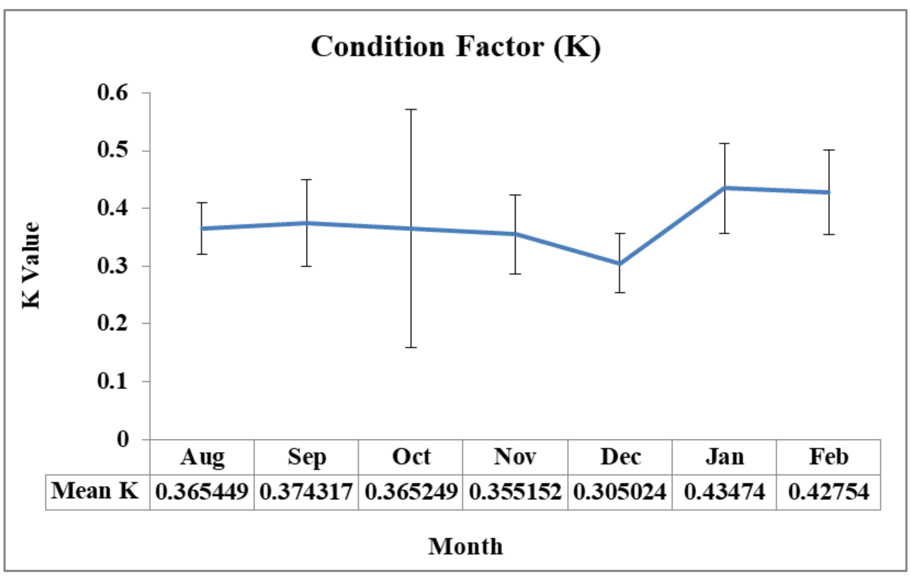

Figure 2: Condition factor based on female data of *P. elongatus* during this study.

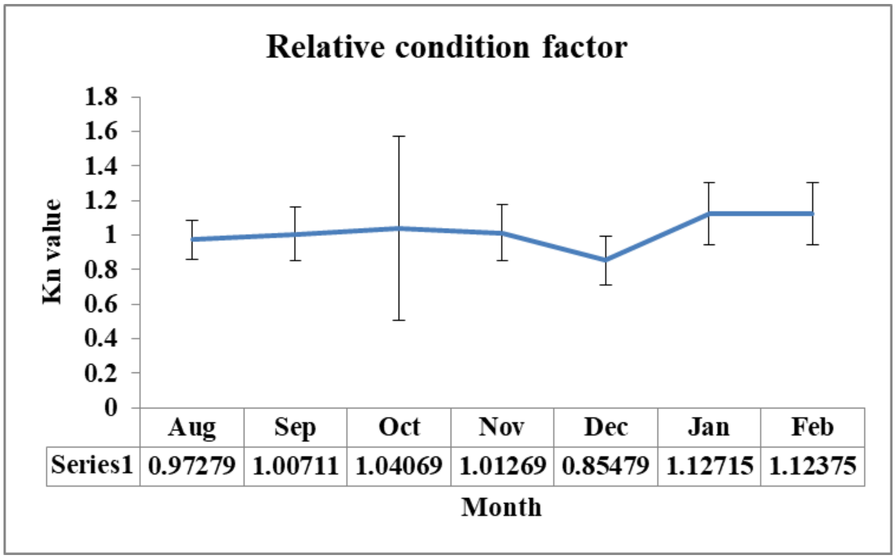

Figure 3: Relative condition factor based on female data of *P. elongatus* during this study.

4.3 Frequency distribution

A frequency distribution uses a set of class intervals to depict the range of values in a data set. The ranges of each class are determined by the minimum and highest values in the dataset. These class intervals also have a maximum and minimum value. There were a total of 977 females identified in the sample of (*P. elongatus*) elongated mudskipper where the total length ranged 8.2–27.3cm and the peak at the 14 –16 cm size class. The population is normally distributed. Female *P. elongatus* length-frequency distribution over sampling interval is depicted in Figure 4.

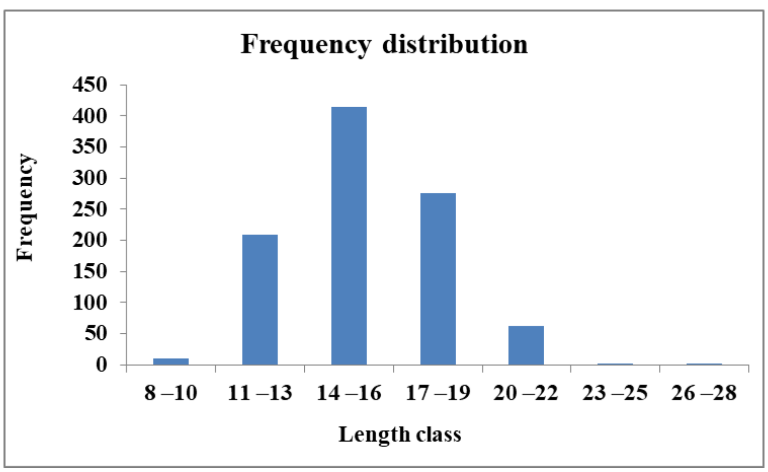

Figure 4: Distribution of female *Pseudapocryptes elongatus* length throughout the whole sampling period

4.4 Size at first sexual maturity (Lm)

The period of sexual maturity and the amount of body mass matter greatly to growth, maximum size, and lifespan.

Four distinct models were used in the current investigation to assess the Lm of female p. elongatus. The first one is using the relationship between TL vs. GSI, TL vs. MGSI, and TL vs. DI as a functional maturity as reported by several authors (Hossain et al., 2017). Our findings demonstrate that the Lm of female *p. elongatus* was 15 cm TL in the southeast coast of Chattogram. As can be seen in the graph, GSI, MGSI, and DI are all related to *P. elongatus's* TL (Figures 5, 6 and 7). Females with a TL of less than 15 cm saw a significant drop in both GSI and MGSI (<0.080). Even though both were the same length, the DI value for (<0.20) female GSI, MGSI (>0.080), and DI all increased dramatically at 15 cm in TL. Female *P. elongatus* Size at first sexual maturity (Lm) over sampling interval is depicted in Figure 4, 5, 6.

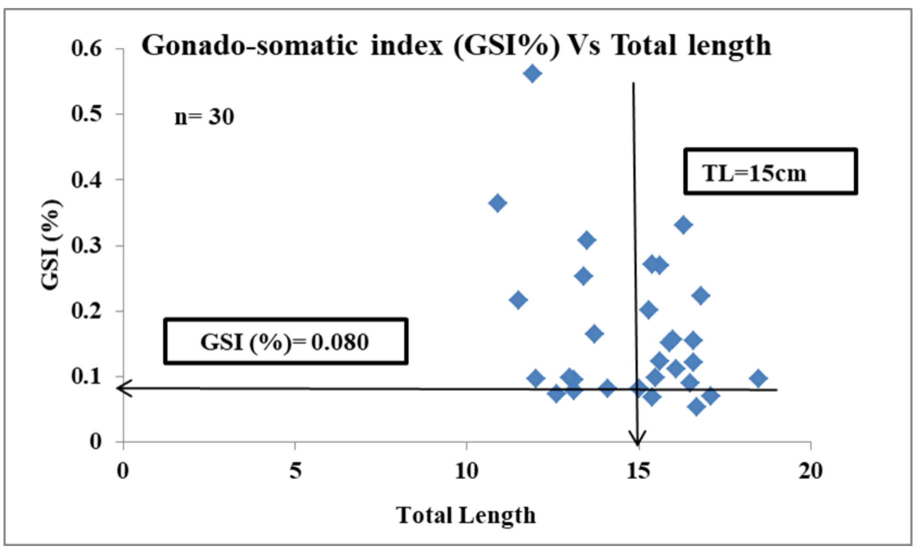

Figure 5: Relationship between gonado-somatic indexes (GSI %) with a total length of female *P. elongatus*

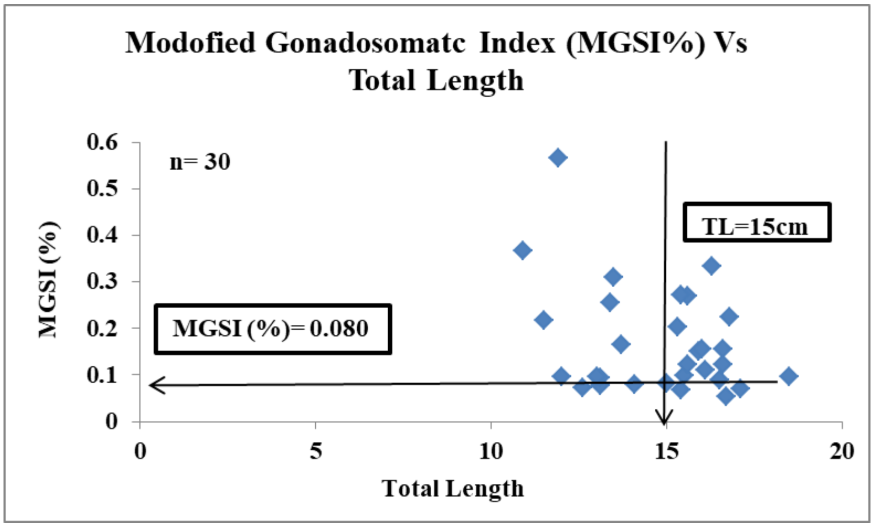

Figure 6: Relationship between modified gonado-somatic indexes (MGSI %) with a total length of female *P. elongatus*.

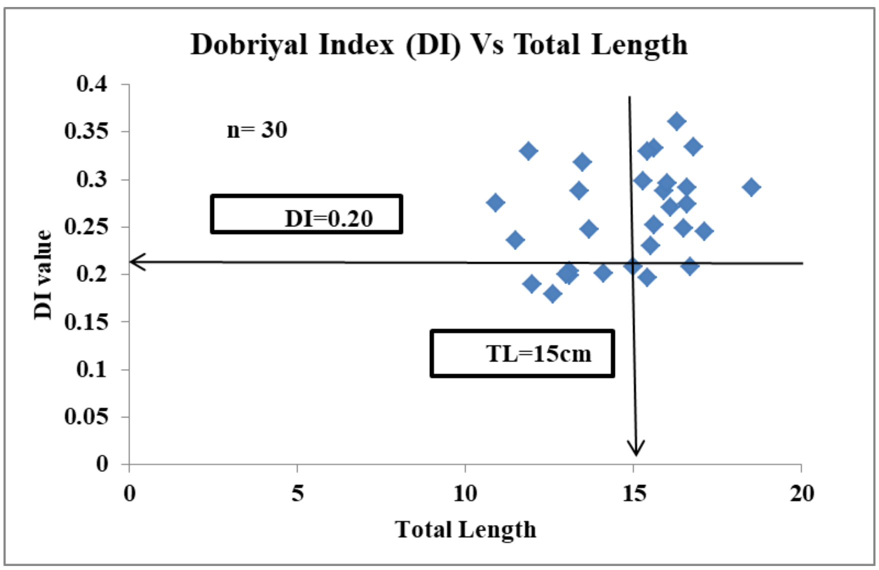

Figure 7: Relationship between Dobriyal indexes (DI) with a total length of female *P. elongatus*

4.5 Gonado-somatic index (GSI)

This study solely included female participants when calculating GSI monthly. The female gonadal-somatic index (GSI) was highest in January (0.325952±0.059009), then again in February (0.319501± 0.03682), and the lowest GSI was recorded in September (0.104±0.04054). On the other hand, August (0.179), October (0.235), November (0.158), December (0.1824) GSI value are more or less similar (0.179138±0.115902), (0.234708±0.047185), (0.157985±0.055956**),** **(**0.182365± 0.042565).Female *P. elongatus* had an average GSI of 0.179 in August, which declined significantly in September, climbed somewhat in October, dropped again in November and December, and peaked in January and February. Data are presented as mean ± standard deviations for each month over the period from August 2021 to February 2022 that showed in figure 8.

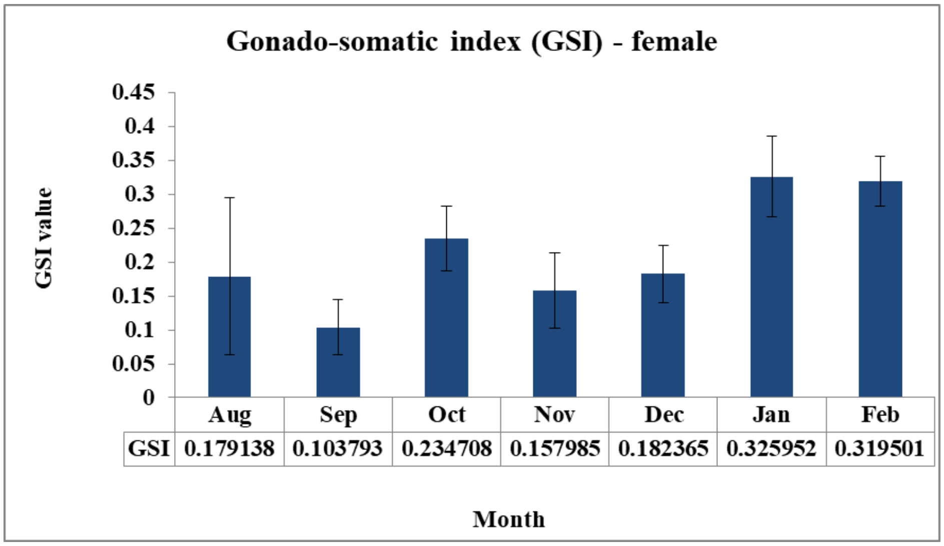

Figure 8: Monthly variations of gonado-somatic index (GSI) in female (n=30) *P. elongatus*.

4.6 Gonadal stage composition

Ovary development from stage I to stages IV and VI was observed for seven months (August 2021–February 2022) and month-wise changes in gonad stage composition of female *P. elongatus* showed in figure 9. However, stage V (spawning) was not found. The majority of immature ovaries (70%) are diagnosed in August (stage I). Ovarian maturation stage II was start to be appeared from the month of October and remain observed every month of the research, and the highest proportion recorded in October (54.55%).

Ripening stage (Stage III) ovaries appeared in November and the highest percentage were found in December (70%). Primary oocytes (PO) and oogonia (O) were present in all ovarian developmental stages having reached maturity in February.

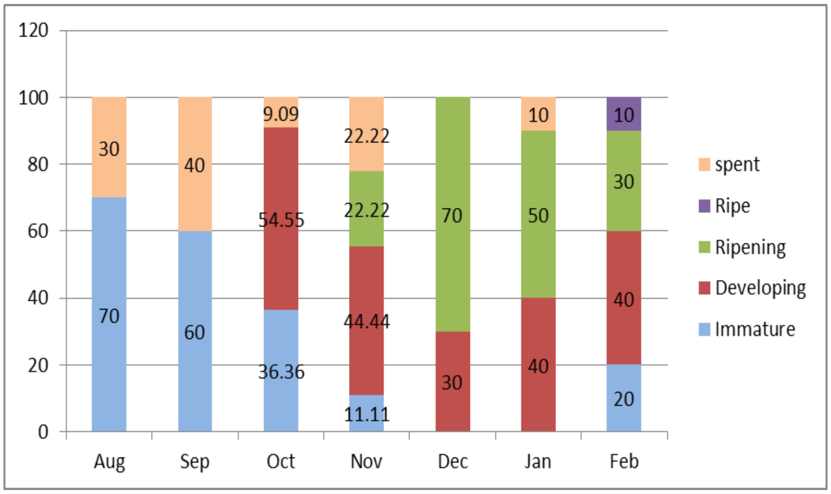

Figure 9: Month-wise changes in Gonad stage composition of female *P. elongatus*

4.7 Gonadal maturation stages in female

4.7.1. Immature stage

The ovary in its first stage is elongated but immature, consisting primarily of connective tissue. The primary oocyte, oogonia, chromatin nuclear, and germ cells, Perinuclear oocytes, are some of the primary oocytes that are present at this stage (PO). This stage observes in the month of August that showed in the plate 5.

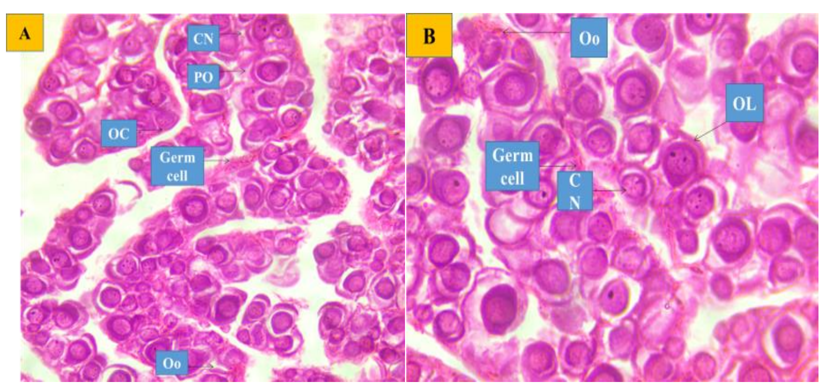

Plate 5: Ovarian cross- sections *P. elongatus* (A, B) represent the immature stages. Ovarian sections show germ cells (GC), Oogonia (O), Chromatin nuclear (CN), Primary oocyte (PO).

4.7.2. Developing stage

The ovaries of females at this (**stage II)** point in their reproductive process are more yellow and are covered in visible blood vessels. The ovary is made up of a variety of different cells, including Germ cell, Oogonia and primary oocyte and Primary vitellogenic oocytes. This stage observes in the month of October that showed in the plate 6.

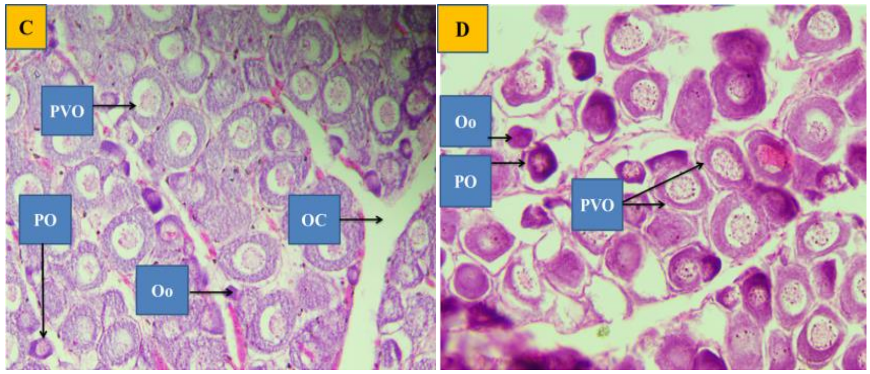

Plate 6: Ovarian cross- sections *P. elongatus* (C, D) represent the Developing stages. Ovarian sections show germ cells (GC), Oogonia (O), Chromatin nuclear (CN), Primary oocyte (PO), and Primary vitellogenic oocytes.

4.7.3. Ripening stages

Ovaries in stage **III** are larger than those in stage II, have grown transparent and detached from the ovary, displaying a translucent, orange egg. More yolk present than usual in the ovary (e. g., Secondary vitellogenic oocyte). There were a number of Oogonia (Oo), primary oocytes (PO), and the vast majority of secondary vitellogenic oocytes discovered in the ovaries (SVO). This stage observes in the month of November that showed in the plate 7.

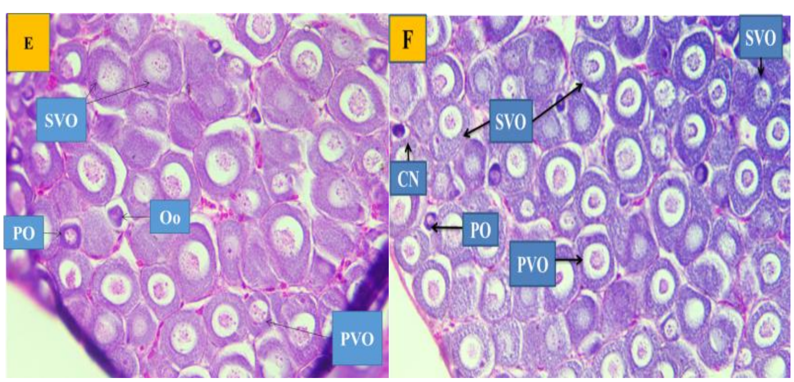

Plate 7: Ovarian cross- sections *P. elongatus* (E, F) represent the ripening stages. Ovarian sections show germ cells (GC), Oogonia (O), Chromatin nuclear (CN), Primary oocyte (PO), Primary vitellogenic oocytes and secondary vitellogenic oocytes.

4.7.4 Ripe stage

When a female reaches follicular maturation stage **IV,** her ovaries produce little white eggs with visible blood veins that can be pushed out with a slight abdominal squeeze. Primary vitellogenic oocytes (PVOs), secondary vitellogenic oocytes (SVs), and SVs made up the bulk of the ovarian sections (SVO). This stage observes in the month of February that showed in the plate 8.

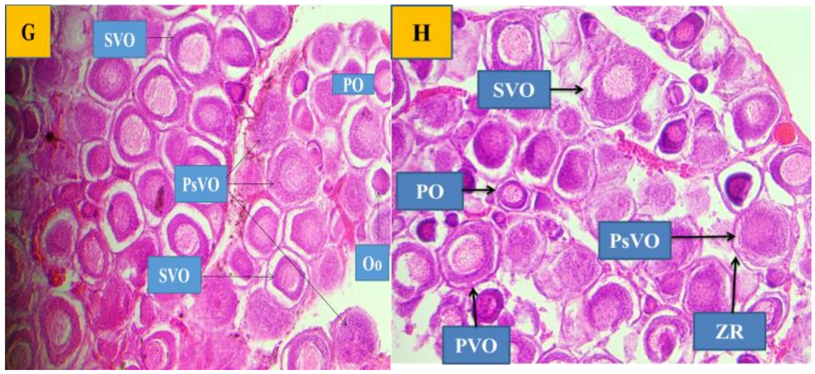

Plate 8: Ovarian cross- sections *P. elongatus* (G, H,) represent the ripe stages. Ovarian sections show germ cells (GC), Oogonia (O), Chromatin nuclear (CN), Primary oocyte (PO), secondary vitellogenic oocytes and post vitellogenic oocytes.

4.7.5. Spawning stage

No rip runners or spawning (V) ovaries were found over the course of this investigation.

4.7.6. Spent stage

The ovary dramatically decreases in size at stage VI, when the eggs are discharged. Ovaries were depicted as a reddish bag with a hollow inside. We also saw immature eggs and ova that had been denatured.

A partially spent ovary has oocytes in the Oogonia and perinucleolar stages, while a fully spent ovary contains a large number of degenerating post-ovulatory follicles, atretic oocytes, and a reserve supply of oocytes in these stages. This stage observes in the month of August and septembar that showed in the plate 9.

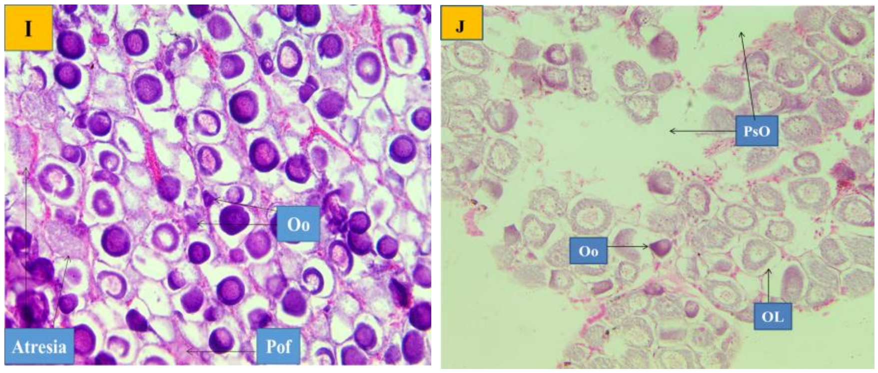

Plate 9: Ovarian cross- sections *P. elongatus* (I, J,) represent the spent stages. Ovarian sections show post-ovulatory follicles at different stages of degeneration, atretic oocytes and a reserve stock of oogonia and perinucleolar stage

CHAPTER-5

DISCUSSION

The studies conducted on elongated mudskipper, *Pseudapocryptes elongatus* include several aspects, such as Nutritional assessment from Diamond Harbor, West Bengal, India (Mahadevan et al., 2019), growth, condition, mortality, and exploitation status in the Indian Sundarbans (Mahadevan et al., 2020), population biology in Vietnam (Minh et al., 2010) and length-weight relationship in Bangladesh (Siddique et al., 2015). There were a lot of work has been done in our neighboring countries like India, Vietnam, Myanmar, Indonesia. The reproductive aspects of *P. elongatus* on the southeast coast of Bangladesh have not been recorded before, and FishBase has no records of it either. Past experience from different regions of the world was taken into consideration for the breeding biology studies of the species. The purpose of this study was to describe *P. elongatus's* breeding biology. This study shows that *P.elongatus* in the southeastern coast of Bangladesh varies in terms of condition factor, growth pattern, length-weight relationship, and reproductive biology. The descriptions and interpretations of research work's findings, explanations of the results and their related issues make up this chapter.

5.1 Length-weight relationship

Measurements of length were taken during the yield evaluation that can be utilized in conjunction with known length-weight relationships to estimate total product weight (Pauly, 1993). Fish can develop in one of three different growth patterns such as: isometric, negative allometric and positive allometric (Nehemia et al., 2012). There is no noticeable alteration to the overall body shape as the organism grows, which is known as isometric growth. On the other hand, allometric growth can be negative, which means the fish gets thinner as it gets bigger, or positive, which means it gets thicker and deeper as it gets longer (Riedel et al., 2007).

The present study found that the *P.elongatus* grew more elongated (allometric) rather than isometrically (the slope b value was less than 3.0, at b=2.4179). In *P. elongatus* from the Bakkhali River estuary in Cox's Bazar, Bangladesh, Siddique et al. (2015) reported results that were almost identical in that the estimated growth coefficient (b) was 2.660, indicating the allometric growth pattern (Siddique et al., 2015).Moreover, Bucholtz et al. (2009) also reported negative allometric growth in female fish of *P. elongatus* where the 'b' value was 2.542 which are almost similar with the current study. In another study Khaironizam and Rashid (2002) reported much higher b values than the present study from the coastal areas of Selangor, Malaysia (b = 2.810). From the above study it can be concluded that *P. elongatus* has an allometric connection in which the fish becomes proportionally lighter as it lengthens. The number of specimens examined, the environment in which they were found, seasonal changes, the health of the specimens, and the examiners' data collection techniques are just a few of the variables that may have an impact on the observed length ranges of the specimens tested (Wooten, 1998). Other variables include sexes (Joadder, 2009), food supply and habitat (Olim and Borges, 2006), growth stage, size range, gonad maturity, stomach content, health status, and preservation techniques (Tesch, 1971).

5.2 Condition factor and relative condition factor

The condition factor is a metric used in the field of fisheries science to evaluate the overall health, fatness, and fitness of fish (Ighwela et al., 2011). According to Abobi and Ekau (2013), condition factor characterizes the health of fish by reflecting via changes, some information on the animal's physiology; better health is inferred from a higher condition factor value.

In this study, the mean values of the relative condition factor (Kn) for *P. elongatus* was 1.019 ±0.093 and the monthly mean K values were ranged from 0.37- 0.43 that was highest in January and lowest in September whereas Kn value was highest in January and lowest in August. According to Siddique et al., (2015) the mean Kn was 0.97±0.276 for *P. elongatus* which was lower than the present study and condition factor was from 0.60 to 1.37 which is higher than our finding range reported from the Bakkhali River Estuary. In a previous study, Mahadevan et al., (2020a) observed higher condition factor (K) in May and September month and lower in October month that was contradictory to ours current result. Fluctuations in the condition factor of fishes may depend upon on region or geographical distribution, feeding rhythm, physiological state of fish because of the presence of various physic-chemical factors of environment, sex, maturity, developmental changes, gear selectivity, season and even time of day which can justify the differences observed herein (Le Cren, 1951).

5.3 Length frequency Distribution

In this present study, total length of *Pseudapocryptes elongatus* ranged from 8.2 to 27.3cm and the peak at the 14 –16 cm size class where the population is normally distributed. In a previous study, Mahadevan et al. (2020) reported two dominant length class of *Pseudapocryptes elongatus* one is 15–16cm (n = 140) and other one is 14–15 cm (n = 124) during the harvest (Mahadevan et al., 2020) which is coincides with the present findings. Male length frequencies exhibited a normal distribution, peaking at the 13.0–13.9 cm size class, whereas female length frequencies varied from 9.7 to 17.8 cm (Bucholtz et al., 2009).

5.4 Size at sexual maturity

Initial sexual maturity size was determined by the point at when the large increase in GSI began. Size and age at sexual maturity are strongly linked to growth, maximal size, and longevity. Understanding and managing an ecosystem is facilitated by tracking the development of individual species. As female's TL increased to 15 centimeters, the GSI and MGSI both remained low at 0.080, while the DI spiked at about the same time. Female *Pseudapocryptes elongatus* along the southeast coast of Bangladesh had an Lm of 15 centimeters. According to previous research done by Dinh et al. (2007a) reported Lm value of 15.4 cm in *Pseudapocryptes elongatus* from the Mekong Delta's coastal mud flat which is almost similar with the present study. In several earlier studies, other species of mudskippers have also been measured and characterized in terms of their length at first maturity which is 15.8 cm in burrow dwelling goby (*Parapocryptes serperaster*) (Dinh et al., 2016), 27.4 mm in crystal goby (*Crystallogobius linearis*) (Caputo et al., 2003) and 16.59 cm in red goby (*Trypauchen vagina)* (Dinh et al., 2018).

5.5 Gonadal histology and spawning periodicity

The majority of immature ovaries (stage I) in the current investigation were identified in August. Ovarian maturation stage II was starting to be appeared from the month of October and remain observed every month of the research, and the highest proportion recorded in October. Ripening stage (Stage III) ovaries appeared in November and the highest percentage was found in December. Primary oocytes (PO) and oogonia (O) were present in all ovarian developmental stages having reached maturity in February. Stage V (spawning) was not found in the present study. In a previous study Dinh *et al.*, (2007a) reported that, goby's ovaries were seen to be developing (Stage II) in February, maturing (Stage III), mature (Stage IV), and becoming dominant (Stage VI) in April, May, and June, respectively. However, no females with running (Stage V) or spent (Stage VI) ovaries were discovered. Breeding season of *Pseudapocryptes elongatus* was occurred in two spawning peak in July and October, breeding season of the goby occurred from June to November, nearly during the rainy season (April-November) (Dinh *et al.*, 2007a). In another study, breeding season of *Pseudapocryptes elongatus* was extended during the rainy season, with the spawning peaks in July and October (Dinh et al., 2007b). The findings of the present study indicated that *Pseudapocryptes elongatus* was in resting phase from August to September and gradually increase yolk stage oocyte in number up to February month where a very low amount of ripe eggs were observed and it would be took March, April and May month to produce large quantity of ripe eggs and spawning will occur during the beginning of the rainy season which is from June to July as Dinh *et al.* (2007a) reported almost similar gonadal development stage. Moreover ripe and spent stages of goby *Trypauchen vagina* gonads occurred in the wet season from June to August (Dinh, 2018) and from this current study we found highest spent ovary in august septembar which is almost similar to Dinh (2018) findings.

In this sampling duration gonadal-somatic index (GSI) was highest in January and February, and lowest GSI in September and August, climbed in October, dropped again in November and December, and peaked in January and February. This study was similar with the findings of Dinh et al. (2007a) who found a highest average GSI value in July; where it dropped in August-September, increased again in October, then dropped again in November-December and remained low until April. According to the findings of present study and findings of Dinh et al. (2007a), it can be concluded that, the fish would be spawn just before the month of August as we recorded lowest GSI and maximum spent ovary in August and September as well as.

CHAPTER-6

CONCLUSION

Realistic fisheries management techniques and precise estimations of biological parameters, including as reproduction, growth, and population estimation, must be employed to protect this species. Fisheries management greatly relies on the information of different stages of reproductive development of any fish population because reproductive traits of any particular species determine its intrinsic capacity and sustainability of exploitation. Moreover the development of artificial breeding techniques for any species is a crucial reason to understand breeding biology. Aquaculture and fisheries that are productive and sustainable create livelihoods, safeguard the environment and natural resources, improve food security, and increase revenue. A sustainable approach to fisheries and aquaculture will help to protect natural resources and ensure that fish stocks are available for future generations. *P. elongatus* is fast growing species and reached sexual maturity 15 cm in total length so this could be targeted for aquaculture, similar to the other countries. Knowing the size at maturity could allow fisherman and local authorities to set the appropriate size limit for fish catches and the fishing period in the dry season or late wet season to avoid catching a spawning fish population. The present study has been carried out with an aim to describe the life history characteristics of the *P. elongatus* in the south east coast of Bangladesh. The current data on this species can be used as the foundation for additional research on the breeding and culture of this mudskipper in the direction of sustainable management.

CHAPTER-7

RECOMMENDATIONS AND FUTURE PERSPECTIVES

The aim of this study was to describe the spawning season and life history characteristics of the *P.elongatus* in the southeastern coast of Chittagong. Also, this study will be helpful for the establishment of artificial breeding. Although a qualitative approach was followed to explore the objective of the research, there are some limitations of the study which can be minimized by following the recommendations.

- ✓ One year sampling need to be done to determine the breeding season.
- ✓ Nutritional profile of the *P.elongatus* should be done as there is a relation between gonad maturation and nutrient content of the fish body
- ✓ Different sample collection site should be followed to identify the differences of spawning season based on the geographical location.
- ✓ Samples should be collected from authentic sources because authentic samples lead to a concrete result.
- ✓ Fresh and properly preserved samples give better histological diagram. So, samples should be collected directly from the fisherman immediately after catch.

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Appendix 1: Month wise gonado-somatic index (GSI) of *P. elongatus*

Month	GSI (Mean ± S.D.)
August, 2021	0.179± 0.116
September, 2021	0.104± 0.041
October, 2021	0.235±0.048
November, 2021	0.157±0.056
December, 2021	0.182±0.043
January, 2022	0.326± 0.059
February, 2022	0.319±0.036
Average	0.215± 0.027

Appendix 2: Month wise condition factor and relative condition factor data of *P. elongatus*

Month	Mean K ±S.D.	Mean Kn± S.D.
August, 2021	0.365±0.044	0.973±0.109
September, 2021	0.374±0.074	1.007±0.155
October, 2021	0.365±0.206	1.041±0.534
November, 2021	0.355±0.068	1.013±0.162
December, 2021	0.305±0.051	0.855±0.142
January, 2022	0.434±0.078	1.127±0.179
February, 2022	0.428±0.073	1.124±0.182
Average	0.375±0.054	1.019±0.093

Brief Biography

Asma Kulsum completed B.Sc. in Fisheries (Hon’s) from the Faculty of Fisheries of Chattogram Veterinary and Animal Sciences University (CVASU), Chattogram, Bangladesh with CGPA 3.66 out of 4.00. She has passionate in research of fisheries and his research interests are on histology, identification of fish breeding season, development of breeding techniques etc. Now, she is a candidate of Masters of Science in Department of Marine Bioresources Science, Faculty of Fisheries, Chattogram Veterinary and Animal Sciences University (CVASU).