Chapter- 1

Introduction

1.1 Background

The fish's eggs and larvae, known as ichthyoplankton, when developing form part of the plankton assemblages. Larval abundance could be a good indicator of generational success. Data on where and when eggs and larvae are abundant can be used to identify the spawning grounds and spawning seasons of commercially significant fishes, as well as the closing seasons and closed areas (Fuiman and Werner, 2002). Larval phases are uncertain; however, it is assumed that marine fish larvae and juveniles migrate to coastal areas and estuaries to take advantage of food and protection from predators in order to maximize their chances of survival (Van der Veer et al., 2001). In order to access planktonic food resources, pelagic larvae must maintain their location on the surface of the water (Webb, 1999). Most marine fish species produce pelagic eggs and drift with the currents. The success of early life stages of marine fish depends on the ability of larvae to reach coastal nursery grounds that provide shelter and food availability for their growth and survival (Bailey et al., 2008).

Marine and coastal areas, including estuaries, are often referred as important fish larvae and juvenile nurseries (Amara, 2003; Baptista et al., 2019). Fish require coastal areas and estuaries for food, reproduction, development, and shelter, and they are important biological components in these ecosystems. (Rez-Guzaman and Huidobro, 2002). The size of marine larval fish ranges between 2.5 and 3.0 mm right after hatching to 10– 30 mm during transformation, which can take anywhere from a few days to several months. After hatching, the larvae float around in the water like plankton. Conducting larval fish study is the best way to provide information for fisheries resource management in these areas. Fish eggs and larvae have been crucial in the management of fisheries, and it is expected that they will continue to be imperative in the future enhancement and maintenance of fish populations. (Rutherford, 2002; Pattira et al., 2012).

The larval fish study is important for a variety of reasons. Identifying the number or biomass of populations that can be captured is one of the main objectives of ichthyoplankton field surveys (Heath, 1992). Data from larval surveys can be used to estimate recruitment. It is possible to learn about spawning seasons and places as well as the sustainability targets of important fish species by gaining knowledge about the diversity and distribution of fish larvae in that area. In addition, these surveys provide a low-cost, very effective means of checking up on marine fish populations and communities (Koslow and Wright, 2016).

In this present work, understanding the quantity and distribution of fish larvae in conjunction with climatic conditions could cover up a gap in the study of fish life cycle and be regarded as essential information for fisheries management. The larval stage is typically the most susceptible to ecological modifications; any alteration in the ecological factors will be detrimental to larval existence and may signify the possibility of future recruitment (Leis and Rennis, 1983). The main reason to investigate ichthyoplankton is that it is primarily responsible for the activities that shape the geographical distribution and recruitment efficiency of fish populations (Garstang, 1900).

The coastal region of Bangladesh uses traditional methods of fisheries management that are mostly focused on specific species management. Data gathered from fish eggs and larvae now clearly make a range of substantial contributions to fisheries science that are essential for proper fish population assessment and management (Fuiman and Werner, 2002). The Bay of Bengal's living and non-living resources can potentially help Bangladesh's economy if they are studied, explored, and managed. particularly in the context of current decisions by the International Tribunal for the Law of the Sea (ITLOS) on the maritime boundary between Bangladesh and Myanmar in 2012 and the UNCLOS Arbitral Tribunal on the maritime boundary between India and Bangladesh in 2014, which established Bangladesh's sovereign rights over more than 118,813 km2 of territorial waters and 200 NM of the Exclusive Economic Zone (EEZ), as well as all types of living and non-living resources under the continental shelf up to 354 nautical miles from the coast of Chittagong (MoFA, 2014).Ichthyoplankton studies in Shaplaphur could be used to establish production and management strategies by detecting seasonal and geographical differences in the abundance and composition of larvae across the regions. Fish eggs and larvae require complex taxonomic identification, which is a challenging task. Identifying fish in their juvenile and adult phases is more difficult. This is because of a variety of factors. Firstly, due to their small size, features that could be used to identify fish eggs and larvae can only be seen using a stereoscopic microscope. The key problem with fish larvae is that they go through constant and, in some cases, significant structural, morphometric, and pigmentary changes throughout their development. Furthermore, studying fish in their early stages is challenging since their size, shape, and behaviors change drastically not only between species but also during ontogeny within species (Moser, 1981). Advanced software that can handle large datasets and integrate all available data on the larval stages of different fish species, as well as ecological data like adult dispersion, reproductive season, etc., has been recommended as a solution to this issue (Froese and Papasissi, 1989).

The Shamlapur region is situated at Ukhiya in Cox’s Bazar district, the northern part of Teknaf. It is a maritime area that runs parallel to the coastline. Shamlapur is one of Bangladesh's important marine zones. The Rezukhal estuary, the Bakkhali river, and the Mahespara region all are notable areas near Shaplaphur. Many studies have been conducted in these areas to determine their importance in fisheries, but none have been carried out in Shaplaphur. As no research has been done in Shaplaphur, there are a variety of possibilities to explore this location. Some study has been done in areas besides Shaplaphur, such as the Naf Estuary, Bakkhali Estuary, Rezu Khal Estuary, and Moheshkhali Para, thus my research in Shaplaphur is unique and new. Despite the significance of young fish in the management of fisheries, limited research has been done. However, extensive scientific research is necessary to ensure the long-term viability of this fisheries resource. This study concentrated on the annual seasonal abundance of fish larvae in the Shamlapur region. It provides an estimate of the total number of families present in coastal areas throughout the year and categorizes them based on their spawning season and temporal assemblages.

1.2 Significance of the study

Several studies on the abundance and distribution of marine fishes, their life cycles, and spawning seasons were conducted in Cox's Bazar and the Bay of Bengal. Yet, no research on fish larval assemblages has been done in this region. Advancements in the identification of the fish larvae that live in Shamlapur will enable a more extensive assessment of the ichthyoplankton in terms of species diversity, geographic distribution, species combinations, and how fish larvae are influenced by climatic modifications, leading to an improved perception of the ecosystem. This study provides a comprehensive review of the abundance of larval groups present in the Shamlapur area on the Cox's Bazar coast. This research intends to gather additional scientific information for the sustainable management of Bangladesh's marine fisheries resources by identifying the spawning periods, spawning areas, and nursery grounds of various fishes in the specified area using the early stages of fish.

1.3 Objectives

- To identify larval fishes by their morphological characteristics in Shamlapur, Cox’s bazar.
- To identify the quantity and distribution of fish larvae, as well as their biodiversity indices.
- To analyse the assemblages of fish larvae from different seasons and to identify the key spawning season of particular fishes.

Chapter- 2

Review Literature

Ichthyoplankton refers to the earlier stages of life of marine fish that float with the currents and feature planktonic characteristics. The larvae of marine fish, or ichthyoplankton, are often pelagic, drifting in the sea and interacting with predators and zooplankton. The structure of the ichthyoplankton assemblage in the coastal areas and estuaries of Bangladesh has not been adequately investigated; while some fragmented studies on various biological elements of the coastal estuary system of Bangladesh have been conducted (Hossain et al., 2007), none of them looked at the structure of the larval assemblage. As a result, we only have a minimal understanding of the geographical and temporal variability of ichthyoplankton. Fishery biologists and administrators of fisheries can frequently learn a lot from studies on fish larvae. Even though fish larvae play a big part in fisheries management only a little research has been done on them, and none have been performed in the Shamlapur region. So, literature on ichthyoplankton of other water bodies has been reviewed.

2.1 Coastal areas as nursing ground

Coastal areas are made up of nutrient-rich surroundings that hold a variety of food chains and serve as a garden center, feeding, breeding, and nursing grounds for diverse fish and invertebrates. The Bay of Bengal, a semi-enclosed tropical basin, defines Bangladesh's marine area. Like other tropical areas, Bangladesh's coastal and marine waters are home to a wide variety of aquatic life. About 17.84 percent of Bangladesh's total (3.06 million tons) fish production comes from its coastal and marine fisheries. In 2010–2011, the nation produced 0.55 million tons, an increase of 5.5% each year. Hilsa is the leading species, producing 339845 tons in 2010-11 (Alam et al., 2013). Due to the abundance of nutrients and high levels of productivity in these ecosystems, many species spend the majority of their life cycles here. In or near productive coastal bays and estuaries, several marine fish, including invasive species, spawn (Chute and Turner, 2001). Coastal habitats and estuaries are commonly referred to as marine fish larval and juvenile habitats (Amara, 2003; Baptista et al., 2019). Fish larvae and juveniles normally spend little time in estuaries and coastal environments and are euryhaline, denoting that they are in the center of an inshore and offshore migration (Yanez-Arancibia et al., 1980; Beckley, 1985). Depending on the species' spawning seasons as well as environmental changes, these assemblages change across space - time (Garcia et al., 2003). It is assumed that sea fish larvae and juveniles migrate to coastal areas to reap the benefits of the plentiful food and shelter from predation in order to optimize survivability because these early stages are quite fragile (Frank and Legget, 1983; Van der Veer et al., 2001).

2.2 Fish larvae and its importance

The management of fisheries has benefited greatly from the use of fish eggs and larvae, and it is anticipated that they will continue to play a vital role in enhancing and conserving fish supplies in the long term. Researchers determine where key fish species spawn and what their environmental requirements by using information on the distribution and richness of fish eggs and larvae. Furthermore, it is essential to know ichthyoplankton because, as a part of the oceanic food web, it can act as a connecting link between tiny planktonic and larger nektonic species (Raymond, 1983). Finally, the survival of fish larvae may have a direct impact on the number of adult fish stocks in the future. Fish stocks undergo considerable inter - annual variations in biomass because the majority of activities governing recruiting intensity and geographic distribution of fish populations occur during the planktonic phase of fishes. Additionally, they are used to assess the spawning population, spawning regions, spawning times, and nursery areas of the commercial fishes. Over the last 40 years, research on fish early life has grown at an incredible rate (Rutherford, 2002; Pattira et al., 2012). However, ichthyoplankton research can give a depth of knowledge on the ecosystems and structure of fish populations at economical rates in a quite concise way than data drawn from juvenile or adult populations. Because of this, one capture of plankton hauls could give details on the majority of pelagic and demersal fish species that spawn in a certain area, while adult samples would demand large vessels and a variety of research equipment and procedures.

2.3 Larval family

Tzeng et al. (1997) conducted an experiment in Yenliao Bay, Northeastern Taiwan. Pomacentridae were the most common family in this survey, accounting for 23% of all captures, followed by Apogonidae 15%, Ambassis sp. 9%, Auxis sp. 9%, Gobiidae 6%, Carangidae 6%, Myctophidae 4%, Tripterygiidae 3%, Engraulis sp. 3%, and japonicus 2%.

Lirdwitayaprasit et al. (2008) ran an experiment in the Bay of Bengal (BOB) by dividing the study region into three sections: northern, western and eastern. In this large-scale study of three different regions of the Bay of Bengal, much more information was found regarding fish larvae. Fish larvae have been recorded in 52 different families in total. Twelve families of fish larvae, including Photichthyidae, Myctophidae, Bregmacerotidae, Carangidae, Labridae, Callionymidae, Gobiidae, Sphyraenidae, Gempylidae, Scombridae, Bothidae, and Cynoglossidae, were discovered in all three locations.

El-Regal et al. (2014) performed research on the Egyptian Red Sea coast, finding that the Mullidae and Clupeidae larval families dominated, representing 43.2 % and 20.2 % of all larvae collected. Gerreidae larvae were abundant, with a percentage of 11.4%. Tripterygiidae and Phosichthyidae were common with a percentage of 8.2% and 5.4% respectively. Trichodontidae and Scombridae were represented by one larva. Mullidae, Clupeidae, Gerreidae, Tripterygiidae, Phosichthyidae, Blenniidae, Gobiidae, Serranidae, Gobiesocidae, and Labridae formed 82.3% of all larvae. Larvae of commercial species formed 69% of all larvae sampled, larvae from 21 species accounting for 40% of all species.

Clupeidae was the most common family in a study at the Pandas River estuary in Peninsular Malaysia by Arshad et al. (2012), contributing to 41.07 % of all families. Next on the list were the Blenniidae 24.45%, Teraponidae 8.80%, Gobiidae 5.40%, Sillaginidae 3.22%, Nemipteridae 1.72%, and Mullidae 1.28%.

Many studies have found that the Gobiidae family is highly dispersed in coastal regions, regardless of climate or other parameters such as seagrass diversity, temperature, or biological factors (Blaber et al., 1997; Kwak and David, 2003). The high prevalence of the

Gobiidae family can be linked to clumps of extremely varied recruitment in schooling species, which apparently originated from aggregative settling (Anand and Pillai, 2005).

There have been 102 fish larval families identified in the northwest Indian Ocean by Nellen (1973). He found 58 shelf fish larval families and 44 oceanic deep benthic fish larval families.

2.4 Abundance and distribution

In forecasting future fish populations, it is necessary to know the species composition and abundance of fish larvae and juveniles. Since larval dispersion is strongly influenced by currents, the flow patterns near spawning grounds determine whether larvae are dispersed or retained (Bakun, 2006). Larval abundance could be a good indicator of generational success. Data on where and when eggs and larvae are abundant can be used to estimate the spawning grounds and spawning seasons of commercially significant fishes as well as the closure seasons and closed areas (Smith & Richardson, 1977; Fuiman and Werner, 2002).

Tzeng et al. (1997) carried out an experiment on fish larvae in Yenliao Bay, Northeastern Taiwan. The overall number of larval fishes collected was 9969, covering 138 different species and 80 different families. Pomacentridae, Apogonidae, and Tripterygiidae were prevailing and much more abundant at the stony areas, whereas Gobiidae appeared prominent at the estuarine locations. The bay is a notable nursery area for sardine and anchovy larvae and juveniles, which are main targeted species in coastal larval fishing. The bay's fish ecosystem consists of coral reef and coastal pelagic species that support diverse coastal fisheries. Fish larvae and juveniles from Yenliao Bay was significantly correlated with environmental factors.

Arshad et al. (2012) yielded total 2687 larvae during the 12-month of study period from the estuary of Pendas River, Malaysia with an average prevalence of 28.29 larvae every 100m3.The larval fish composition of Peninsular Malaysia consisted of 19 families, with 17 found in the middle estuary, 16 in the lower estuary, and 14 found in the upper estuary. The cumulative number of fish families and densities in the estuary notably declined from the lower estuary to the higher estuary, according to the distribution pattern of overall fish larvae. This shows that the fish larvae in the estuary migrated from the sea.

In a survey of fish larvae in the Gulf of California, Aceves-Medina et al. (2003) discovered 283 taxa, including 173 species and 53 families. The Gulf is home to some of the most extensive and unique ichthyofaunas in the eastern Pacific. That favors the designation of the region as a different zoogeographic zone from the Panamic zone, where it is typically included because of the huge number of tropical species present there (Walker, 1960). A more detailed analysis of the ichthyoplankton's species diversity, geographic distribution, species abundances, and how fish larvae are influenced by changing environments has been made possible by advancements in the identification of fish larvae in the Gulf. This has enhanced our understanding of the ecosystem.

In a study by Hedberg et al. (2019) in coastal East Africa, 2279 fish larvae were obtained throughout nine areas, and 1834 individuals from 51 families were identified, leaving 445 individuals unidentified. The analysis shows fish larvae dispersion patterns and diversity in tropical ecosystems, as well as significant changes in fish larvae abundance between habitat and sites.

Brogan (1994) did research on near reef larval fishes to define the families that use the area during all phases of development, analyze reef fish distributions for indications of larval survival, and relate reef fish larval distributions to egg type. More than 93 percent of the larvae collected near reef habitats belonged to 16 families and at least 11 families appeared to utilize near reef habitats throughout development.

El-Regal (2013) identified 2453 larvae from 93 different reef fish taxa. A total of 31 species, representing 33% of the species under research, were considered to be commercially significant. The Red Sea reef fish breeding seasons are discussed in detail in this article, and this information can be utilized to manage their fisheries.

A study from the Bay of Bengal got a total of 14,584 specimens of fish larvae from 52 different families. Of those, 24 had substantial economic importance (Lirdwitayaprasit et al., 2008).

Along the Egyptian Red Sea coast, El-Regal et al. (2014) documented 1336 fish larvae from 57 different fish taxa. The open water regions produced the most larvae (517), whereas the seagrass areas produced the fewest (129 larvae).

In 25 South African estuaries, Strydom (2015) researched patterns in larval fish diversity, frequency, and dispersion and reported a total of 89 species, including 29 larvae families.

2.5 Spawning season

In a descriptive study at Yenliao Bay, Tzeng et al. (1997) depicted that, fish eggs were abundant from February-June, with a large temporal change in abundance. Fish larvae in Yenliao Bay have a community structure that includes typical rocky environment fish, seaside pelagic fish, and estuarine fish. Fish larval abundance peaked in May and then began to decline. The majority of larval species spawn in the early spring.

Research on the Egyptian Red Sea coast by El-Regal et al. (2014) confirmed that fish larvae were prevalent in late spring and summer (May-July), with the highest value in May (350 individuals/1000 m^3), followed by June (305 larvae/1000 m^3) and July (170/1000 m^3), whereas the lowest abundance was recorded in September.

A study on several Red Sea fishes were studied by El-Regal (2013). From May to August, the majority of commercial Red Sea species spawn. The commercial fish species accounted for 44% of the 13 summer spawners. Winter and spring each supplied six and five species, accounting for 19% and 16% of commercial species, respectively. Clupeidae and Engraulidae are two species that have been shown to spawn at different times of the year and with no clear pattern.

The most common family found in research at the Pandas River estuary in Peninsular Malaysia was clupeid larvae, which had the maximum numbers in February–March, which coincided with Peninsular Malaysia's northeast monsoon season. During the monsoon season (February–March), the clupeid number increased, indicating seasonal spawning. Teraponidae, the second most common family, was found throughout the year, with a peak in February, indicating the family's reproductive season. These larvae were considerably more common in other months as well.

Lirdwitayaprasit et al. (2008) revealed that during the post-summer monsoon, fish larvae diversity was found to be at its highest throughout different regions of the Bay of Bengal (BOB).

Azhagar et al. (2009) found that larvae belonging to the Teraponidae family were the most abundant (26.09 %) during the post-monsoon season in the Bay of Bengal in India's South East coast, while Tetrodentridae were the least abundant (1.30 %). However, in the summer, Clupeidae was the most abundant family (17.22 %), whereas Teraponidae was the least common. During the pre-monsoon season, Leiognathidae was the most common family (25.58 per cent), while Latidae was the least frequent. The Pomadasydae family was the most abundant during the monsoon season (35.26 %), while the Carangidae family was the least abundant.

Chapter- 3

Materials and Methods

3.1 Study area

The study was carried out in the Shamlapur region (N 21°04'18.0", E 92°08'05.7") with monthly sampling from March, 2020 to February, 2021. It was situated in the northern portion of Teknaf, in the Cox's Bazar district. The study area was chosen because of its ecological significance to coastal fisheries. The coordinates were taken using a GPS meter, and the map was created using the software QGIS (version 3.4.5) (Figure-1).

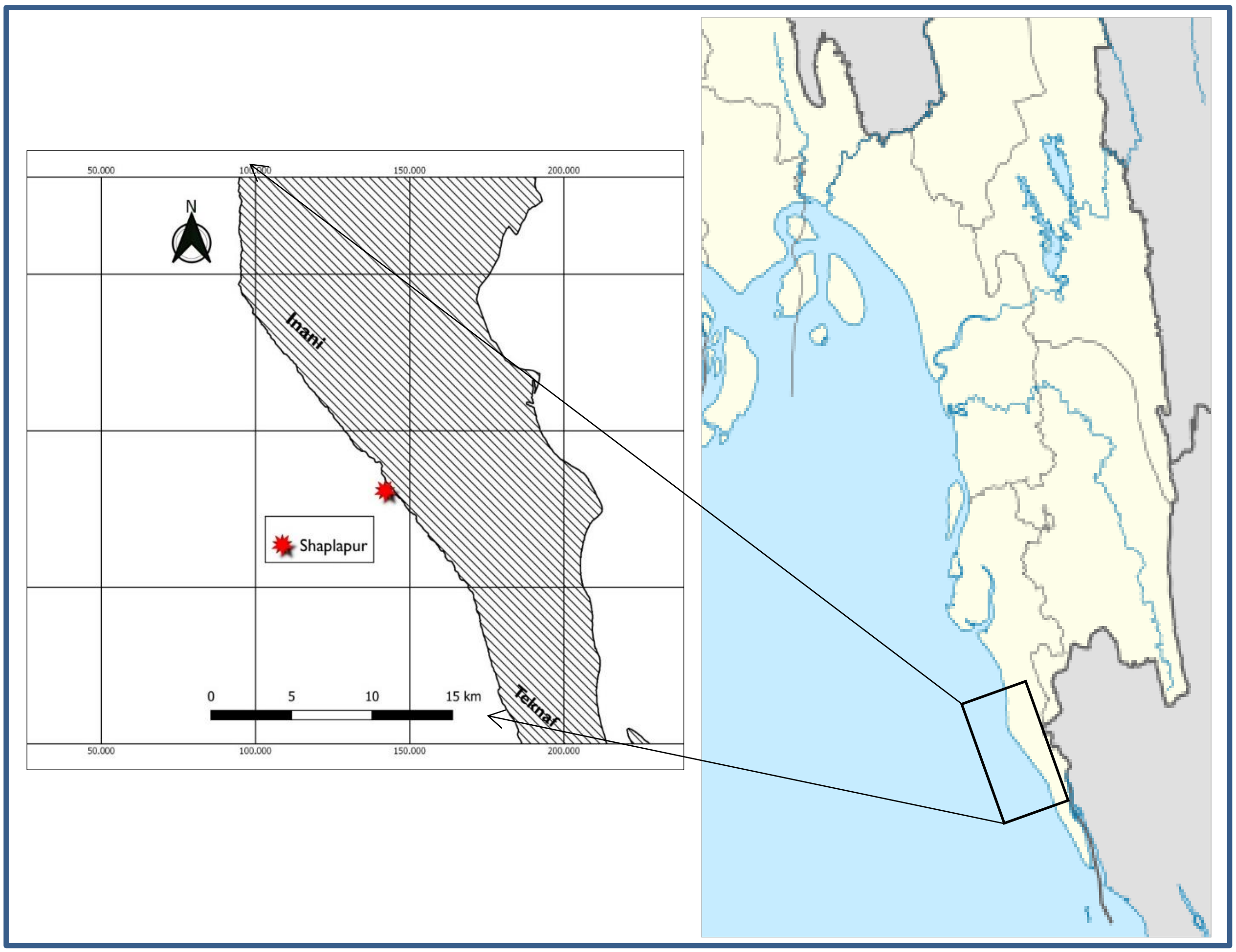

Figure. (1) Map of Cox's Bazar region and study site

3.2 Sampling procedure

Fish larvae were collected from the selected location by using a Bongo Net (0.50 m mouth diameter, 1.3m length, and 500µm mesh at the body). A flow meter (Model: KC Denmark A/S 23.090-23.091) was fixed to the entrance of the net to measure the amount of seawater filtered during each tow. The sampling period was about 10 minute's surface tow. The collected specimen was preserved in 90% ethanol and transported to the aquatic ecology laboratory of CVASU for sorting out based on morphology and other attributes and freshly preserved in 90% ethanol.

3.3 Fish larvae preparation

Larvae were separated from the entire sample for taxonomic identification. The first step of larvae preparation was to discard ethanol from the sample. To do this, samples were sieved through meshes of 0.1 mm and thoroughly washed with distilled water so that sand particles, plastics, leaves, and other unwanted matters could easily be removed. Washed larvae were again placed into a jar with fresh ethanol and each sample was placed in a petri dish one by one to be analyzed under a stereo microscope (OPTIKA Microscope ITALY C-B3) at low magnification (10x) and several pictures were taken. Each picture was given a specific code so that it can be easily found later.

3.4 Morphological identification of fish larvae

Fish larvae were identified under the stereo microscope up to family level using the descriptions of related taxa given in Leis and Rennis (1983), Leis and Carson-Edwart (2000) and Rodriguez (2017). The body structure, coloring pattern, and meristic and morphometric traits are the most significant characteristics to identify larval fish. The different measurements of a larva are known as its morphometric features. These measurements include total length (TL), standard length (SL), preanus length, head length, or the distance between the tip of the snout and the border of the cleithrum, and the maximum dimension of the eye (Figure.2). Considering larval growth is allometric, the development phase of the larvae must be taken into consideration while measuring the various body areas for identification purposes.

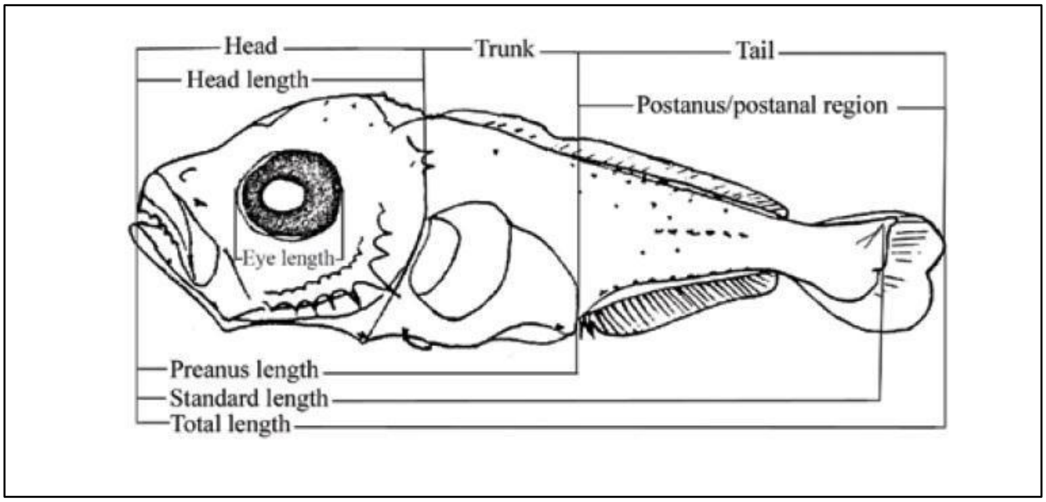

Figure. (2) Morphometric characteristics of a fish larvae

Meristic features are countable, serially-appearing structures, such as the number of miomeres, vertebrae, or fin rays. They are limited by the fact that some of them, like fin rays, only fully develop in older larvae, which are rare in plankton samples. Others, such as miomeres or vertebrae, are difficult to see even with staining procedures or other techniques such as X-rays (Pothoff, 1984). Fish larvae have a wide range of pigmentary cells, often known as chromatophores. Melanophores are pigments that are either black or brown in color; those with yellow pigments are called xanthophores and erythrophores are red pigments (Russell, 1976). However, only black pigmented cells or melanophores remain in ethanol–preserved specimens. As a result, while identifying larvae, only the latter are usually taken into account. Melanophores are pigments that are present throughout the body and define a species-specific pattern of pigmentation (Rodriguez et al., 2017). Unidentified larvae samples were categorized as "unidentified" due to the samples were too small to identify.

3.5 Determination of larvae, diversity indices and constancy of occurrence

Number of fish larvae according to specific family were counted through naked eye. This number is simplified into per $1000m^3$ for further analysis. Temporal variation of fish larvae was determined by number of larvae along with diversity indices. Diversity of the larval fish assemblage was measured by the Shannon-Wiener index (Shannon, 1949) and equitability or evenness was expressed by Pielou's evenness index (Pielou, 1966). Family richness was calculated following Margalef (1958). At its most basic level, diversity refers to the number of different species that exist. In this study, Shannon index was used to analyses family richness and evenness to calculate biodiversity.

3.5.1 Number of larvae individual per 1000 m^3

Bongo net diameter, d = 0.50m

So, net radius, r = 0.25m

Net opening area= πr^2

$= 3.1416 \times 0.25^2$

$= 0.19635 \times 2$; as each net has two openings

$= 0.3927$

- Volume of water passed in each sampling =

Indicated number of revolutions× Pitch of the impeller (0.3) ×Net opening area (m^2) ×1000

- Number of larvae per $1000m^3$ = (Number of larvae in sample×1000) ÷Volume of water passed

3.5.2 Measurement of diversity

The type of diversity used here is E- diversity which is the diversity of species within a community or habitat. The diversity index was calculated by using the Shannon – Wiener diversity index (1949).

- Diversity index, $H = -\sum Pi \ In \ Pi$

where Pi = S / N

S = number of individuals of one species

N = total number of all individuals in the sample

In = logarithm to base e

The higher the value of H, the higher the diversity of species in a particular community. The lower the value of H, the lower the diversity. A value of $H = 0$ indicates a community that only has one species.

3.5.3 Measurement of species richness

Margalef's index was used as a simple measure of species richness (Margalef, 1958).

- Margalef's index = (S – 1) / In N

Here, S = total number of species

N = total number of individuals in the sample

3.5.4 Measurement of evenness

For calculating the evenness of species, the Pielou's Evenness Index (e) was used (Pielou, 1966).

- e = H / In S

Here, H = Shannon – Wiener diversity index

S = total number of species in the sample

3.5.5 Determination of the constancy of occurrence

The constancy of occurrence was determined based on the ecological index by Schifino et al. (2004), and the following formula was used for the calculation;

- Formula: C = P/Q x100

Where, C = Constancy of occurrence of the family (%),

P = number of samples where the family occurred

Q = total number of samples. The identified families were further divided into three categories based on the value of constancy of occurrence, which was; (1) constants (when $C>50\%$), (2) accessories (when $25\%\leq C\leq 50\%$), and (3) accidental (when $C<25\%$).

3.6 Determination of the spawning season

The spawning season was determined by considering the month before the month in which larvae began to be found in the selected station. Based on the monthly larval abundance, the spawning season of the identified families was categorized as the summer, winter and rainy monsoon. The winter season continues from November to February, while the summer season lasts from March to June. Monsoon months cover July, August, September and October.

3.7 Statistical analysis

All the data were entered into MS excel (Microsoft office excel-2007, USA). Data management and data analysis done by SPSS (Version- 25.0). SPSS Statistics is a software package used for logical batched and non-batched statistical analysis.

Chapter- 4

Results

4.1 Fish larval composition and abundance

A total of 827 larvae were collected from the study area, with a mean abundance of 68.92 per 1000m^3.The larval fish assemblage included 08 families and unidentified samples were tagged as "Unidentified" (Table-1). The families are- Clupeidae, Ambassidae, Engraulidae, Carangidae, Blenniidae, Mugilidae, Labridae and Gerreidae. Among them, Clupeidae was the most abundant family, which contributes about 69.65% followed by Engraulidae (20.19%), Ambassidae (5.44%), Mugilidae (2.54%), Blenniidae (1.09%) and others (1.09%) (Fig.4). Three dominant larval families are Clupeidae, Engraulidae and Ambassidae, which used Shamlapur region as their nursing ground.

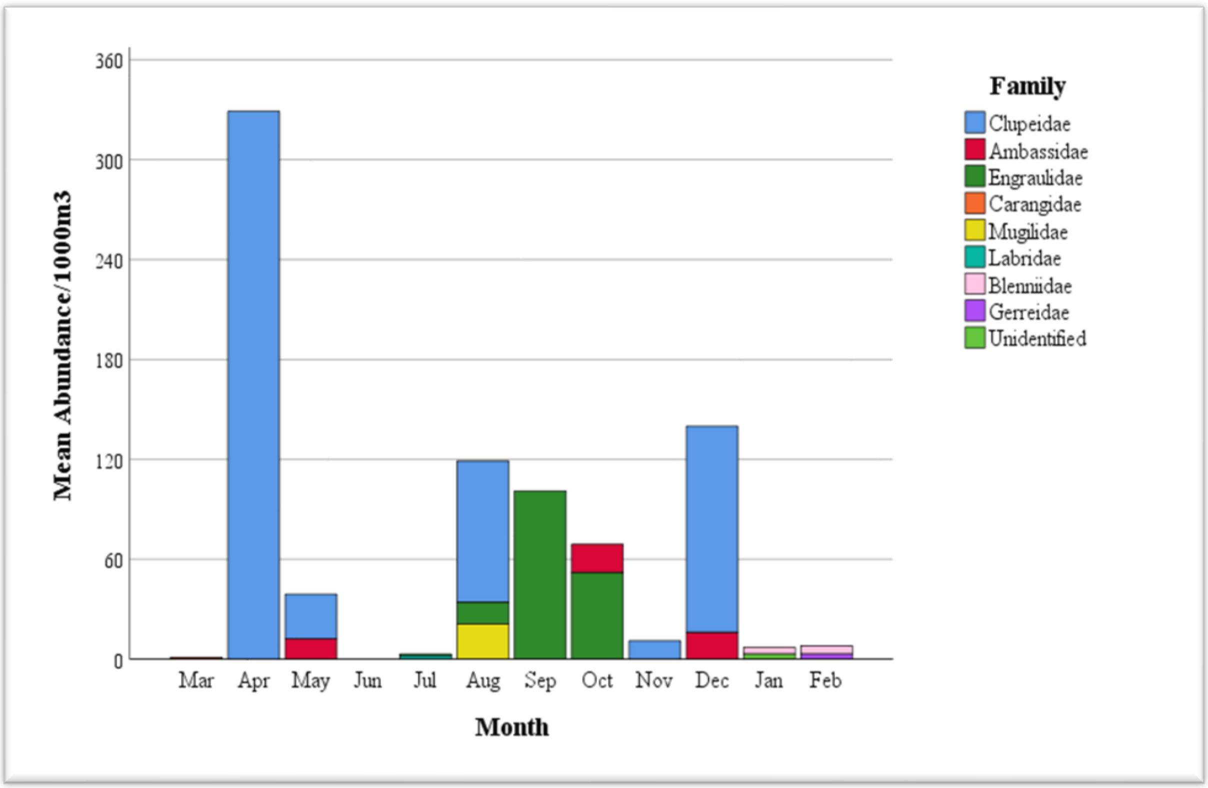

Figure. (3) Temporal variation of abundance of larval family

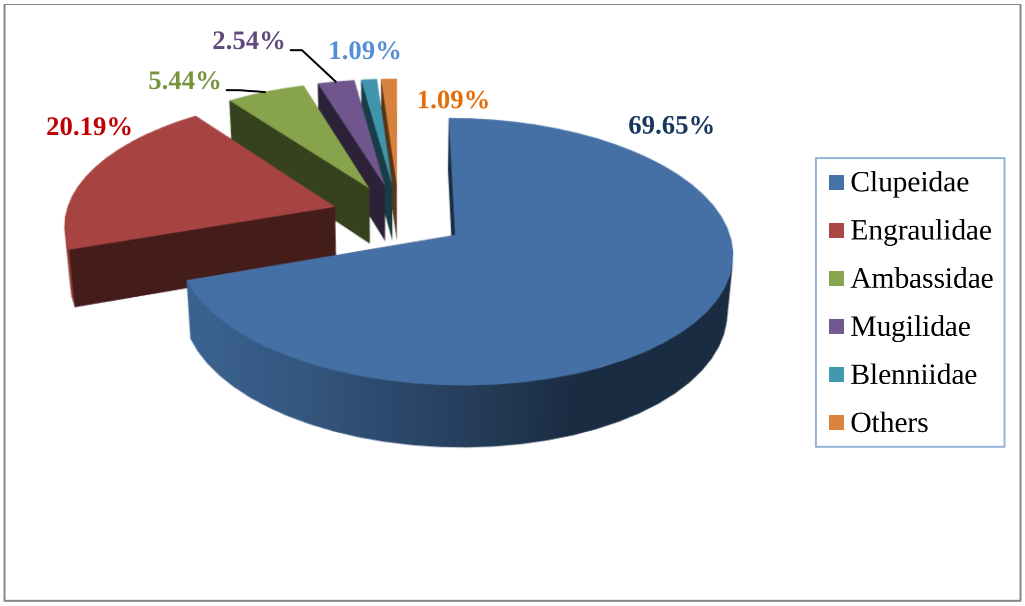

Figure. (4) Percentage of the families

Table. (1) Total number of fish larvae/1000 m^3 and constancy of occurrence

Family	Total number of larvae (larvae/ 1000m3)	Mean number of larvae	SD	Standard error	Percentage of total catch	Rank	Frequency of Occurrence	Classification according to Constance of occurrence		
								1	2	3
Clupeidae	576	48.00	97.26	28.08	69.65	1	41.67		*	
Engraulidae	167	13.92	31.26	9.02	20.19	2	33.33		*	
Ambassidae	45	3.75	6.88	1.99	5.44	3	25.00		*	
Mugilidae	21	1.75	6.06	1.75	2.54	4	16.67			*
Blenniidae	9	0.75	1.76	0.51	1.09	5	16.67			*
Gerreidae	3	0.25	0.87	0.25	0.36	6	8.33			*
Labridae	2	0.17	0.58	0.17	0.24	7	8.33			*
Carangidae	1	0.08	0.29	0.08	0.12	8	8.33			*
Unidentified	3	0.25	0.87	0.25						
* (1) constants; (2) accessories; (3) accidental										

4.2 Constance of occurrence

The percentage of constant: accessory: accidental families was 00:37:63 based on the constancy of occurrence among the 8 families (Table. 1). This region had no constant family. According to this data, only 37.5% of families use the Shamlapur area as a nursing ground on a seasonal basis. Ambassidae, Clupeidae, and Engraulidae are regarded as accessory families. The majority of the families (62.5%) were assumed to have been founded accidentally due to their scarcity in this region.

4.3 Top three abundant families

4.3.1 Clupeidae

Clupeidae were the most abundant larvae and contributed more than half of the total abundance (69.65%) of the Shamlapur region. This family was found in five months of a year- April, May, August, November and December (Figure. 8). The mean density of this family was 48±97.26 and the highest abundance was 329 individuals/1000m^3 in April. Several commercially important species under the Clupeidae family are found in Cox's Bazar and Teknaf coasts, such as *Tenualosa ilisha, T. toil, Hilsha kelee, Escualosa thoracata*.

4.3.2 Engraulidae

Engraulidae family was the second abundant family, which contributed 20.19% of the total abundance. This family was found in four consecutive months- from July to October. The highest number was 101 individuals/1000m^3, which was found in September and mean density of the larvae was 13.92±31.26. Species that are common under this family in this region are, *Stolephorus indicus, S. waitei* and *Coilia ramcarati*.

4.3.3 Ambassidae

Ambassidae family comprised 5.44% of the total abundance. This family was found in three months of the sampling year- May, October and December. The mean density of the larvae was 3.75±6.88 and the highest abundance was observed in October of 17 individuals/1000m^3. Species that is common under this family in this region is *Ambassis dussumieri.*

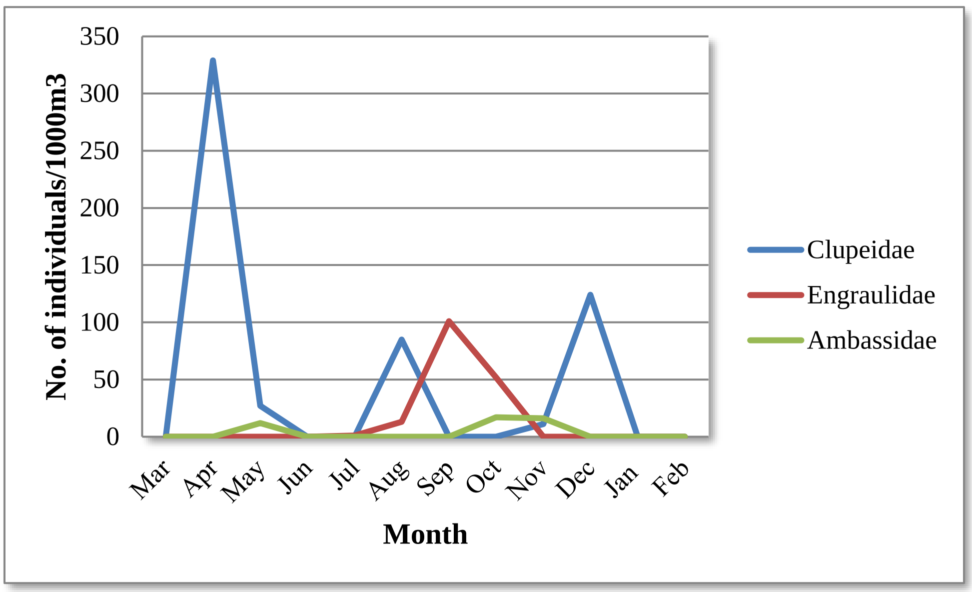

Figure. (5) Temporal abundance of top three families

4.4 Temporal density and diversity indices

The highest density of larvae (329 individuals/1000m^3) was observed in the month of April, while in June no fish larvae were found (Figure.5). However, in August, the highest number of families (03) was observed (Figure.3). Diversity indices showed significant variation within months. The highest Shannon-Wiener index was found in August (0.788) (Figure.6). Margalef's family richness reached its maximum value in July (0.910) (Figure.7). The maximum value of Pieulo's evenness was 0.918, which was observed in January (Figure. 8).

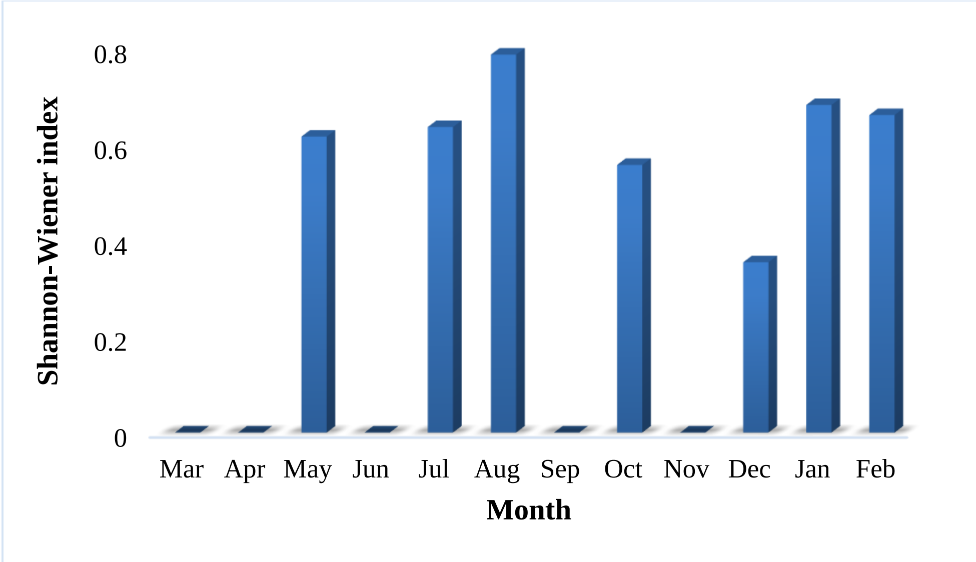

Figure. (6) Shannon-Wiener index of diversity of each month

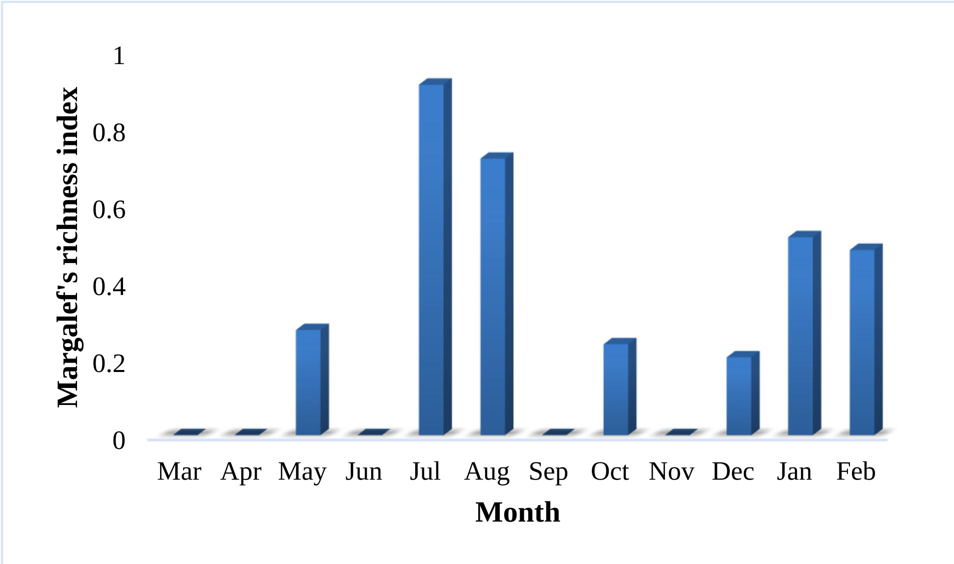

Figure. (7) Richness index of family of each month

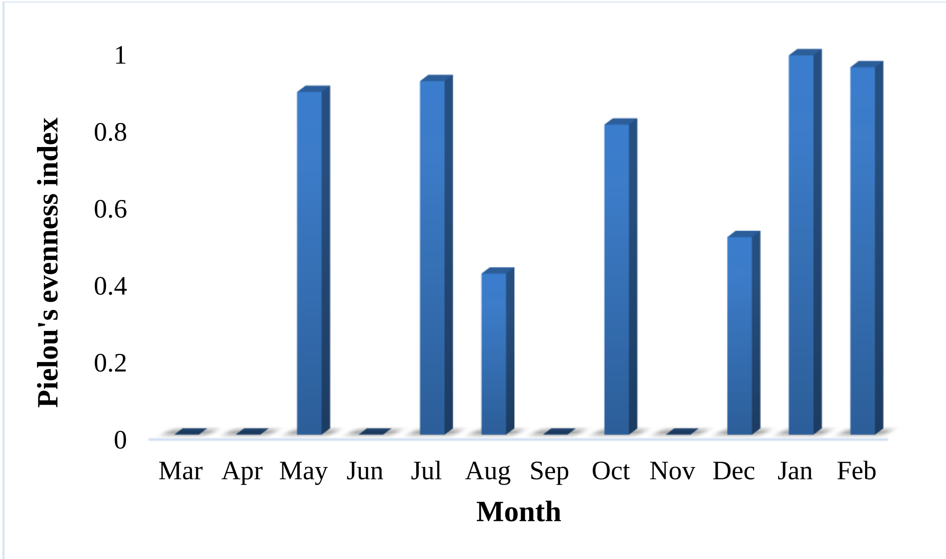

Figure. (8) Pieulo’s evenness index of each month

4.5 Spawning season

Larvae of 08 fish families were collected and their time of occurrence was used as indication of their spawning season. The spawning seasons of the families were classified as Summer, Winter and Monsoon. Most of the families spawn in the cooler months of the year (November to February) based on the availability of their larvae (Figure.9). Among the families, Clupeidae and Ambassidae were confirmed as spawner of summer, monsoon and winter, as their larvae were found in seven months of the year (Table.1). Engraulidae family was recorded to spawn in late summer, early and mid-monsoon. Mugilidae was documented to reproduce in early monsoon, Blenniidae reproduce in mid-winter. Gerreidae, Labridae and Carangidae were confirmed as mid-winter, late summer and late winter spawners (Table. 2).

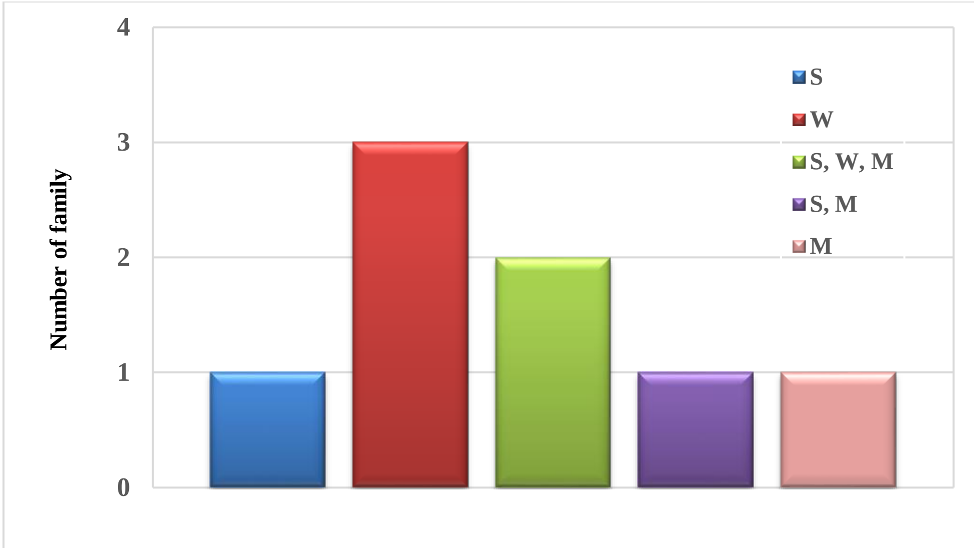

Figure. (9) Number of families in different spawning season (S=Summer, W=Winter, M= Monsoon)

Table 2. Spawning season of identified fish larvae with their frequency of occurrence and spawning month

Family	**Larvae occurrence**	**Spawning month**	**Spawning season**
Clupeidae	Apr, May, Aug, Nov, Dec	Mar, Apr, Jul, Oct, Nov	Early summer, Mid-summer, Early monsoon, Late monsoon, Early winter
Engraulidae	Jul, Aug, Sep, Oct	Jun, Jul, Aug, Sep	Late summer, Early monsoon, Mid monsoon
Ambassidae	May, Oct, Dec	Apr, Sep, Nov	Mid-summer, Mid monsoon, Early winter
Mugilidae	Aug	Jul	Early monsoon
Blenniidae	Jan, Feb	Dec, Jan	Mid-winter
Gerreidae	Feb	Jan	Mid-winter
Labridae	Jul	Jun	Late summer
Carangidae	Mar	Feb	Late winter

Chapter- 5

Discussion

5.1 Fish larval composition and abundance

Most fish larvae are often overlooked as they're so small, and they have been categorized as a substantial category of zooplankton. Ichthyoplankton, on the other hand, are important in order to understand how climate change is affecting fisheries, the environment, and their life cycles. In addition to managing fisheries resources effectively, it is required to assess ichthyoplankton because they are a major component of the marine food chain and a significant source of food. According to the present study, 827 different fish larvae specimens were discovered in the study areas. They belonged to 8 families. These were Clupeidae, Ambassidae, Engraulidae, Carangidae, Blenniidae, Mugilidae, Labridae and Gerreidae. Clupeidae was the most prevalent family among them, followed by Engraulidae and Ambassidae. Most of the families spawn in the cooler months of the year (November to February) based on the availability of their larvae. This appears to have less diversity than the previous work in the various parts of the Bay of Bengal and Indian Ocean.

Brogan (1994) reported that more than 93 percent of the larvae collected near reef habitats belonged to 16 families, and at least 11 families appeared to use near reef environments throughout their development in a study near reefs in the Gulf of California. In the southeast Indian Ocean, Youngs et al. (1986) identified 103 larvae fish families, whereas Lirdwitayaprasit et al. (2008) discovered 52 families in the Bay of Bengal and recognized Photichthyidae, Myctophidae, Bregmacerotidae, Gonostomatidae, Callionymidae, and Carangidae as abundant families in the Bay of Bengal. El-Regal et al. (2014) conducted research on the Egyptian Red Sea coast and found 1336 fish larvae representing 57 different fish taxa across all environments. On the west coast of Thailand, Janekarn (1988) found 62 families of fish larvae. Nellen (1973) found 102 larval families in the Indian Ocean's north-eastern region, including the Arabian Sea, Red Sea, and the Persian Gulf. Chamchang (2006) discovered 62 fish larvae families in the Andaman Sea along Thailand's and Myanmar's coastlines. Beckley (2019) discovered 92 neritic and 21 mesopelagic teleost groups in the tropical eastern Indian Ocean. In the Indian Ocean, Rathnasuriya et al. (2021) used morphological and genetic methods to identify 80 species belonging to 69 larval families. Lower larval diversity could be associated with low productivity along the Cox's Bazar-Teknaf coasts, as nutrients carried by rivers are assumed to be lost in deeper seas due to the narrow shelf (Qasim, 1977). In the Bakkhali river estuary, Rashed-Un-Nabi et al. (2011) found 49 fish and shrimp species using char jal. On the other hand, Hossain et al. (2007) reported gathering 161 species from the Naf River estuary, which is about 50 kilometers south of the current research site, using various types of nets. The rubber dam has produced a controlled environment in the Bakkhali estuary, reducing the number of species, which is the cause of this variation. The dam's changes in water characteristics may have a significant impact on the river's species population. (McAllister et al., 2001). Another research conducted by Tzeng et al. (1997) at Yenliao Bay's estuary stations confirmed Pomacentridae, Apogonidae, and Tripterygiidae as dominant families at the rocky stations, with Gobiidae being abundant. Chesalina et al. (2013) identified the four most common families: Sparidae, Scombridae, Clupeidae, and Nemipteridae. Arshad et al. (2012) studied Clupeidae as the most abundant followed by Blenniidae, Teraponidae, Gobiidae, Sillaginidae, Nemipteridae, and Mullidae in Pendas River estuary, Peninsular Malaysia.

5.2 Constance of occurrence

The percentages of constant: accessory: accidental families were 00:37:63 based on the consistency of occurrence among the 8 families. There was no constant family in this region. According to this data, just 37.5% of families use the Shamlapur region as a nursing ground periodically throughout the year. Ambassidae, Clupeidae, and Engraulidae are regarded as accessory families. Most of the families were thought to be accidental (62.5%) because they were not commonly seen in this region.

5.3 Temporal density and diversity indices

The abundance of fish larvae was greatest in April, during the mid-summer. The majority of the fish families, though, were discovered in August. The highest Shannon-Wiener index was found in August (0.788), which is the monsoon season (H). The greater the value of H, the greater the diversity of families in a given sample. The lower the value of H, the less diverse the population. On the other hand, Richness was the highest in July & Evenness was the highest in January. Margalef's richness index reached its peak in July (0.910). The highest value for Pieulo's evenness was 0.918 (January), and the second highest value was 0.845. (February). Pielou's evenness is an indicator that shows both diversity and species richness. While family richness refers to the number of different family present in a particular region, evenness refers to the number of individuals of each family present. Pielou's evenness has a predicted number ranging from 0 (no evenness) to 1 (complete evenness). Pielou's evenness is connected to the Shannon-Wiener index since it is determined by dividing the Shannon-Wiener index by the total number of families. In this study, the evenness index is zero (0) for June, September and December, indicating that there is no evenness.

The obtained Shannon-Wiener index in this study matched with Arshad et al. (2012) that indicated significant variation within monsoon and intermonsoon season at Pendas River estuary. However, family richness peaked in March-May at this estuary.

This study also shared similarities with Brinda et al. (2010), where Margalef's richness ranged from 0.71 (May) to 0.91. (March). The evenness index for Pielou's ranged from 0.71 in May to 0.93 (April). The study was carried out at three different locations in the Vellar Estuary, which is located on India's Southeast coast.

5.4 Spawning season

Fish spawning season is the reason of the existence of fish larvae. Fish usually go through a planktonic phase that lasts a few weeks to a few months (Victor, 1986; Brothers et al., 1983). Studying spatial and temporal variability, as well as the availability of fish larvae in connection to environmental conditions, can provide information about the adaptation and impact of spawning behaviors on the annual strength of all physical and biological processes (Somarkis et al., 2002). Clupeidae and Ambassidae were proven to be prolonged spawners in this study as their larvae were recorded in all three seasons: summer, rainy monsoon, and winter. Spawning of the Engraulidae family has been observed in late summer, early and mid-monsoons. While Blenniidae are known to reproduce in the middle of winter, Mugilidae are known to do it in the early monsoon. Gerreidae, Labridae, and Carangidae were identified as midwinter, late summer, and late winter spawners, respectively. El-Regal (2013) reported that Clupeidae and Engraulidae tended to reproduce at irregular intervals throughout the year with no apparent pattern.

Chapter- 6

Conclusion

This study was aimed at assessing the spatio-temporal distribution of fish larvae at Shamlapur by identifying larval fish in the area, as well as to obtain more scientific data for the ecological sustainability of Bangladesh's marine fisheries resources by developing a larval fish ecological model for conservation and long-term viability. Ichthyplankton research is crucial because their survival has a direct impact on the amount and distribution of adult fish. Furthermore, Identification of marine fish larvae is crucial in deciding and evaluating spawning seasons and the marine fish stock-recruitment process. The goal of this study was to identify commercially important marine fish larvae and their spawning seasons along the Shamlapur region. The research findings will aid in decision-making about marine fisheries management in the Shamlapur area.

Chapter- 7

Recommendation and Future Perspective

According to this research work, the following recommendations maybe done:

- Fisheries management decisions in the Shamlapur region should be done by sound scientific data. Where this information is insufficient, precautionary measures should be developed and then improved through intensive research.
- Physical, chemical and biological characteristics of Shamlapur region should be monitored.
- Further research work should be conducted to determine different aspects of fisheries with a view to improving the productivity of Shamlapur region.
- The importance of this region should be made aware to people.
- The dumping of oil and garbage by water vehicles and surrounded people should be monitored.

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Appendix-1

Operation of fish larvae sampling in the Shamlapur region, Cox's Bazar

Month	Flowmeter reading	Interval between flowmeter reading	Volume of water passed(m3)
Mar, 20	R1(67899-69380) R2(71995-73410) R3(69387-71992)	1481 1415 2605	174 167 307
April, 20	R1(08234-10907) R2(10920-13876) R3(13888-16387)	2673 2956 2499	315 348 294
May, 20	R1 (36588-39712) R2 (39713-41611) R3 (41612-43574)	3124 1898 1962	368 224 231
June, 20	R1 (65285-67159) R2 (67159-69059) R3 (69059-71201)	1874 1900 2142	221 224 252
July, 20	R1 (65285-67159) R2 (67159-69059) R3 (69059-71201)	1874 1900 2142	221 224 252
August, 20	R1 (21401-24506) R2 (24507-27061) R3 (27065-29192)	3105 2554 2127	366 301 251
September, 20	R1 (45174-47213) R2 (47213-49461) R3 (49461-52138)	2039 2248 2677	240 265 315
October, 20	R1 (84657-87857) R2 (87857-90643) R3 (90643-93810)	3200 2786 3167	377 328 373
November, 20	R1 (23346-25430) R2 (25432-27001) R3 (27001-29637)	2084 1569 2636	246 185 311
December, 20	R1 (13009-14986) R2 (14986-16368) R3 (16368-19031)	1977 1382 2663	233 163 314
January, 21	R1(61757- 64146) R2 (64147- 66449) R3 (81151- 83739)	2426 1559 2588	286 184 305
February, 21	R1(03657-05978) R2(05980-07970) R3(07971- 09919)	2321 1990 1948	273 234 229

Appendix-2

Monthly abundance of fish larvae and biodiversity index:

Month	Family	Number of individuals (per 1000m3)	Shannon-Wiener index	Margalef's richness index	Pielou's evenness index
March, 20	Carangidae	1	0	0	0
April, 20	Clupeidae	329	0	0	0
May, 20	Clupeidae Ambassidae	27 12	0.255 0.363	 0.273	0.367 0.523
June, 20	0	0	0	0	0
July, 20	Engraulidae Labridae	1 2	0.366 0.270	 0.910	0.528 0.390
August, 20	Engraulidae Clupeidae Mugilidae	13 85 21	0.242 0.240 0.306	 0.418	0.220 0.219 0.279
September, 20	Engraulidae	101	0	0	0
October,20	Engraulidae Ambassidae	52 17	0.213 0.345	 0.236	0.308 0.498
November,20	Clupeidae	11	0	0	0
December,20	Clupeidae Ambassidae	124 16	0.107 0.248	0.202	0.155 0.358
January, 21	Blennidae Unidentified	4 3	0.683	0.514	0.985
February, 21	Blennidae Gerreidae	5 3	0.662	0.481	0.954

Appendix-3

Temporal variation of biodiversity index at Shamlapur region:

Month	Shannon-Wiener index	Margalef's richness index	Pielou's evenness index
March, 20	0	0	0
April, 20	0	0	0
May, 20	0.617	0.273	0.89
June, 20	0	0	0
July, 20	0.637	0.91	0.918
August, 20	0.788	0.718	0.418
September, 20	0	0	0
October, 20	0.558	0.236	0.805
November, 20	0	0	0
December, 20	0.355	0.202	0.513
January, 21	0.683	0.514	0.985
February, 21	0.662	0.481	0.954

PHOTO GALLERY

Plate-1: Sample collection

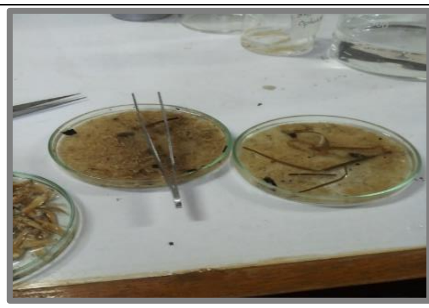

Plate-2: Fish larvae sorting from sample

Plate-3: Larvae labeling and storage

Plate-4: Larvae identification

Plate 5: Clupeidae larvae

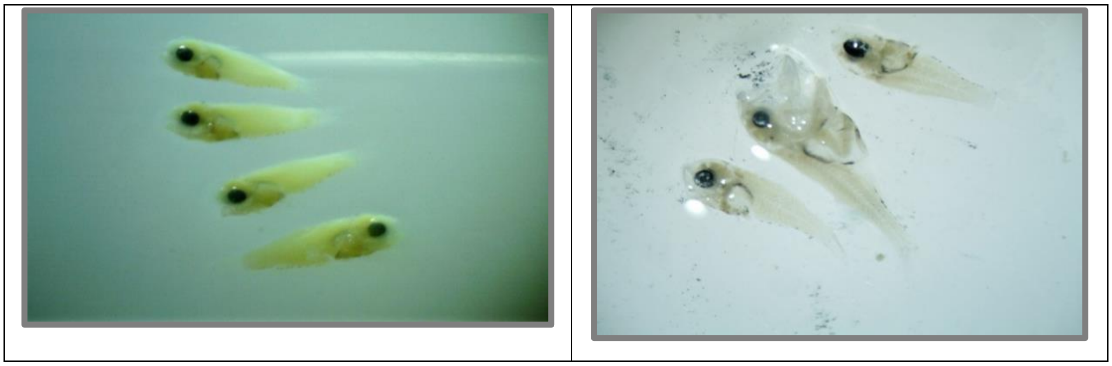

Plate 6: Ambassidae larvae

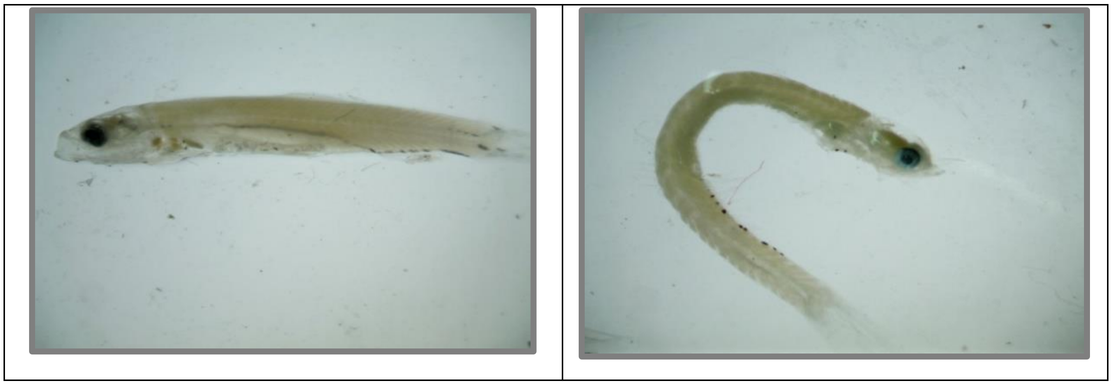

Plate 7: Engraulidae larvae

Plate 8: Carangidae larvae

Plate 9: Blenniidae larvae

Plate 10: Mugilidae larvae

Plate 11: Gerreidae larvae

Plate 12: Labridae larvae

Brief biography of the author

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