Chapter 1

Introduction

This chapter basically denominated about the background of the study, significance of the study, questions related with the study and finally objectives of the study.

1.1 Background of the Study:

The Hilsha (*Tenualosa ilisha*), as called Geographical Indication (GI) of Bangladesh. As a typical Hilsha Shad, body fusiform, deep and laterally compressed and a dark blotch found behind gill opening. The king of fish, Hilsha body color silvery with gold and purple. Due to its flavor, it is one of the most popular in the countries within the Bay of Bengal region. Hilsha is extremely rich in amino acids, minerals and lipids, especially essential and poly-unsaturated fatty acids (Alam et al., 2012).

Hilsha (Shad) is a diadromous fish in the South and South-East Asia especially in Bangladesh. The species had special keel bone which helped to swimming fast in marine water. Within a tropical range; 34°N - 5°N, 42°E - 97°E , the fish is marine, freshwater, and brackish. The marine distribution of the species forgather with the Indian monsoon region as Arabian Sea, with the Gulf and Red Sea, Bay of Bengal, South China Sea with Malay Archipelago. In general, this region is characterized by comparatively large continental shelf, monsoon, medium to high precipitation, surface temperature of 20°C-30°C, surface currents changing with the pattern of season, medium to low organic productivity, presence of sub- surface oxygen minimum layer and considerably low salinity of brakish waters (Pillay and Rosa, 1963).

Hilsha is considered as national fish in the country and contributes to the national economical sector. About 86% of the world's total Hilsha production comes from Bangladesh. Apart from Bangladesh, there are some other countries including India and Pakistan found Hilsha. More than 13% of the country's fish production comes from Hilsha. In 2019-20, Hilsha production was 5.33 lakh MT (DoF, 2020). Around 3.5 million people of the country are directly or indirectly involved in Hilsha fish industry. Multiplex measures are required to further enhance the protection, propagation and economic potential of Hilsha industry. In general, propulsion is a must and rivers must be sheltered from pollution.

The food and feeding habits of Hilsha have been drawing the inclination of fisheries researcher of the Asian countries for decades. Many researchers have conducted their studies on the food and feeding habits of Hilsha shad (*T. ilisha*) in different water bodies (Hasan et.al., 2016, Pillay and Rao, 1962; Halder, 1968; Ramakrishnaiah, 1972; De and Datta, 1990; De et al., 2013; Dutta et al., 2013; Rahman et al., 1992; and Jafri et al., 1999, and Narejo et al., 2005).

Notions of food and feeding habits of the species is still parochial to the scientific reports of De et al., 2013; Halder, 1968; Hora, 1938; Jafri et al., 1999;Nair, 1939; Pillay and Rao, 1962; Pillay, 1958; Rahman et al., 1992.Several findings on Hilsha only demonstrate about the status of food and feeding habits of Hilsha. However, detailed information on feeding or food and avoidance – in the context of Hilsha food and feeding biology is not yet available for the coastal area of Chattogram in Bangladesh waters. This study on Hilsha food and feeding biology offers essential information for effective management of the Hilsha fishery.

1.1 Significance of the study:

Knowledge on the diet of fish is important from the perspective of studies concerning food webs, trophodynamics, and resource partitioning. Food is an important factor in the biology of fishes to the extent of governing their growth, fecundity and migratory movements (Rao, 1964). Knowledge of food and feeding habits of various fish species is advantageous in their proper management and exploitation (Khan and Fatima, 1994). An understanding of the relationship between fishes and their food items, the monthly distribution of the food items helps to locate the potential feeding grounds which may in turn be helpful for exploitation of these resources. Stomach content analysis and features of the alimentary system provide information on food, feeding habits and feeding if any (Kuruppasamy and Menon, 2004). The stomach content analysis also helps to understand the tropic dynamic and the prey predator interaction in the ecosystem, which facilitate the ecosystem based fisheries management.

The present study was undertaken with a view to provide information on food items for Hilsha keeping in view for culturing those food items in mass scale for providing to the fish during culture in captivity.

1.2 Objectives of the study:

The Hilsha shad (*T. ilisha)*, which feeds on phytoplankton, zooplankton, ichthyoplankton, protozoa, small crustacean. The feeding habit may be differed by the season and age of the fish.

The aim of this study was to provide a quantitative and qualitative estimation of the food and feeding habits of Hilsha Shad.

Objectives:

- To determine how the food and feeding habit of Hilsha are influenced by the size of Hilsha;
- To know about the seasonal variation of food and feeding habit of Hilsha; and
- To observe the relationship between size group of Hilsha and index of stomach fullness

Chapter 2

Review of Literature

Scientific Classification of *Tenualosa ilisha*

Kingdom: Animalia

Phylum: Chordata

Class: Teleostei

Sub-class: Actinopterygii

Order: Clupeiformes

Family: Clupeideae

Genus: *Tenualosa*

Species: *Tenualosa ilisha*

Binomial name: *Tenualosa ilisha* (F. Hamilton, 1822)

Common name: Hilsha Shad

Local name: Ilish

Local status: Least concerned (Population decreasing)

Zone of Habitat: Pelagic- neritic

Food habit: Planktivorous

Feeding habit: Filter feeder

Distribution: Wide

Figure 1: Hilsha Shad (*T. ilisha*) (F. Hamilton, 1822)

2.1 Gut morphology of Hilsha:

The digestive system of Hilsha includes pharyngeal organ, buccopharynx and the gut. The morphology, histology of the alimentary tract include in gut contents of juvenile and adult Hilsha gained from the Ganga River near Allahabad, India (Swarup, 1959). According to him, the alimentary canal consists of buccal cavity, short pharynx, oesophagus, cardiac and pyloric stomach, duodenum, intestine and rectum. Hilsha has terminal mouth which is surrounded by thin upper and lower lips. The fish has four pairs of gill arches that support gill filaments and rakers on its outer and inner surface, respectively. The gill rakers are very fine and elongated, in the lower arm of the gill arches. In general, fishes with long, fine, closely set gill rakers are usually filter feeders (kapoor et al., 1975). The pharynx leads into short, moderately thick walled esophagus. The stomach is a V shaped muscular tube, which is parable into two parts, the anterior cardiac stomach and the posterior pyloric stomach. The pyloric, stomach and the anterior part of the intestine are covered with thick pyloric caeca (De and Datta, 1990).

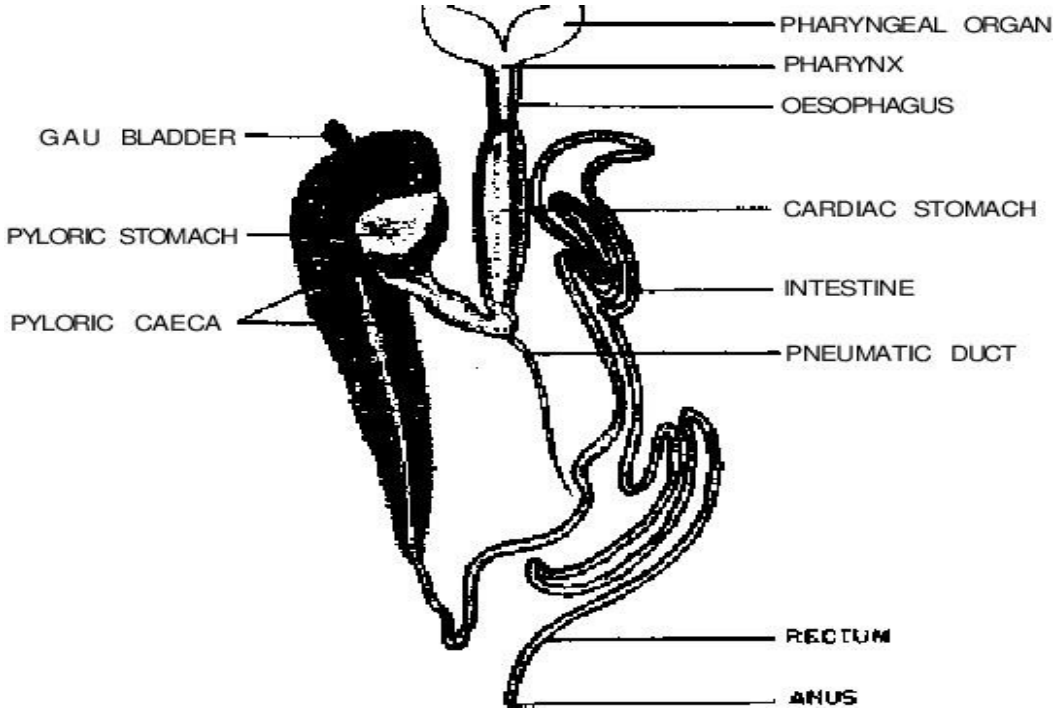

Figure 2: Gut morphology of Hilsha (D, D.K., 2009)

Morphology of digestive tract of Hilsha indicates presence of feeding adaptations. The absence of teeth in the mouth, presence of an efficient filtering mechanism in the form of fine, long gill rakers, the pharyngeal organ and the modification of stomach into gizzard, indicates filter feeding, in which feeding items are consumed by size and not by kind. The upturned mouth and taste papillae in the lips are characteristic features of its sight feeding habit (Jafri, 1988).

In adult Hilsha, the fully developed gill rakers with minute papillae form an efficient filtering mechanism for sieving minute food organisms, But less developed gill rakers except papillae in fish below 50mm can not have such efficient filtering capability (De and Datta, 1990). Short, narrow, cylindrical esophagus indicates its planktivorous habit. Carnivore and predatory fish possess longer and dilated esophagus (Mehrotra and Khanna, 1969). In Hilsha, without teeth and masticatory apparatus in the mouth and pharynx, respectively make up the presence of a highly developed gizzard stomach. Muscular gizzard like pyloric stomach can be used for crushing the food components and organic matter.

2.2 Feeding habit of Hilsha:

Knowledge of food and feeding habits of fish species is useful in their proper management and exploitation (Khan and Fatima, 1994). An understanding of the relationship between fishes and their favorite food items, the seasonal distribution of the food items are helped to detect the potential feeding grounds which may in turn be helpful for exploitation of these resources. Stomach content analysis and features of the alimentary system provide information on food, feeding habits and selective feeding if any (Kuruppasamy and Menon, 2004).

The anadromous migratory shad Hilsha, T. ilisha is plankton feeder fish. That's why, the food and feeding habit of Hilsha shows a great diversification. Early and post-larval stage, Hilsha are planktivore and mainly depend on crustaceans and algae, while the juveniles Hilsha prefer crustaceans besides consuming plant matter and insects (M. Rahman, 2020). Zooplankton is the main food of the juvenile Hilsha (M. Rahman, 2020). Copepods and Rotifers are performed as the chief food materials in that size range of Hilsha (M. Rahman, 2020). Phytoplankton specially algae and diatoms are called the chief food item constituting maximum of the total food materials in the adult mature Hilsha (M. Rahman, 2020).

Blue- green algae specially Spirogyra, Eudornia and Pediastrum are appointed in the pre- spawning periods (M. Rahman, 2020). Some particles are found in the stomachs of fishes but are not properly identified. They may be debris, plant parts or anything else (M. Rahman, 2020).

2.2 Studies on feeding biology of Hilsha:

Food and feeding habits of Hilsha in its various stages of life cycle have been studied by many scientists time to time in different water bodies. The food and feeding habits of Hilsha differ with the time of the day, season, size of fish, ecological conditions and food substances present in the habitat (Hynes, 1950). Juveniles of Hilsha are plankton feeders; grazing on zooplankton at higher rate for five or six months in fresh water. They changed their food diet based on age and seasonal variability and slowly transform to phytoplankton feeding habit. Hilsha prefers to dwell in the brackish water region due to presence of sub surface oxygen, relatively low salinity, strong tidal flow, high turbidity, heavy siltation and rich growth of plankton (Pillay and Rosa, 1963). Chacko and Ganapati (1949) and Chacko and Krishnamurthy (1950) concluded that during maturation, Hilsa minimize their food intake and stop feeding during spawning migration. Halder (1968) found no evidence of mitigation or even any significant decrease in the food uptake during upstream spawning migration. In general, Hilsha is a plankton feeder and does not show any selectivity in feeding with its closely set sieve like gill rakers (Hora, 1938; Hora and Nair, 1940). Being a filter feeder, it takes food particles while swimming in the water. Hence, occurrence of different food material in the gut varies based on the season and location. Young Hilsha between 20 mm to 40 mm in length feed mostly on diatoms and sparingly on Copepods, Daphnia. According to Hora and Nair (1940), algae constituted the volume of food eaten during February to March, while diatom formed the main item during March to April. Major group of food items recorded from the gut of Hilsha include crustaceans (particularly Copepods), diatoms, green and blue algae, organic detritus, mud and sand particles (Hora, 1938; Hora and Nair 1940; Chacko and Ganapati, 1949; Pillay and Rao, 1963; Halder, 1968). Jones and Sujansinghani (1951) conjectured that the species does not indicate any selectivity in feeding as far as the different items of plankton are concerned. Stomach content analysis of fry, juvenile and adult Hilsha

revealed that copepods are the most important food item consumed by the fish of all sizes at all times of the year. They also mentioned that the fry and juvenile Hilsha mainly feed on copepods while the stomach content analysis of adult Hilsha showed considerable amount of organic matter along with the copepods. The mean percentage composition of food and feeding habit of adult and young Hilsha in the river and the structure of its digestive tract also recommend the planktivorous feeding habit of Palla (Jafri, 1987; Halder, 1968). In Godavari River, they found that organic debris, diatoms and crustaceans form the major constituents of food of both adults as well as young Hilsha (Pillay and Rao, 1963). Jones and Menon (1951) reported that the larval Hilsha diet mainly of Diatoms and Copepods. According to them, with further growth, the juvenile fish turn to feed on a variety of other planktonic organisms.

Rajyalakshmi (1973) revealed that mostly empty guts in the adults during monsoon in river Godavari, while juveniles appeared with fully fed guts, predominantly with Copepods and Rotifers. Das (1985) worked in Bangladesh and Pakistan, and expressed that T. ilisha is a planktivore, utilized both zooplankton and phytoplankton. On the other hand, Al-Nasiri and Mukhtar (1988) while working on *T. ilisha* from Ashar canal, Basrah, Iraq, concluded that the main food of this species is zooplankton (mainly Copepods, Cyclops) and phytoplankton such as Dinoflagelletes and Diatoms. The main food items were Cyclotella, Planktosphaeria, Oscillatoria and Cyclops. It was also found that the average volume of food in each stomach is more in small fishes than in larger ones.

Chapter 3

Materials and Methods

3.1 Study area:

The study was conducted from February, 2019 to January, 2020. Three sampling collection areas were chosen for Hilsha fish survey from the coastal area of Chattogram. Station 1 was Fishery Ghat of Chattogram, respectively, Station 2 was Faillatoli Bazar of Chattogram, respectively and Station 3 was Fish Landing Centre, Cox's Bazar (Figure 3). Fishery ghat, Chattogram is situated in between 22° 31' 92" N and 91° 83' 88" E. Chattogram fishery ghat, is one of the largest wholesale fish trading centers in the country where minimum hundreds of fishing boats and trawlers of various sizes berth by the Fishery ghat at late night. Fishermen with their catches from the Bay of Bengal as well as from different parts of the country are started to gather here in the early morning. After weeks in the sea, they unload their catches. Faillatoli bazar of Chattogram is located in between 22° 20' 39.8" N and 91° 46' 34.1" E. Faillatoli bazar is important for local community. Around 8 am, the wholesalers start to gather their fishes to sell in Faillatoli bazar. Cox's Bazar was selected as the study area as common marine fish landing stations were there. The location is in between 21° 34' 59" N and 92° 00' 60" E.

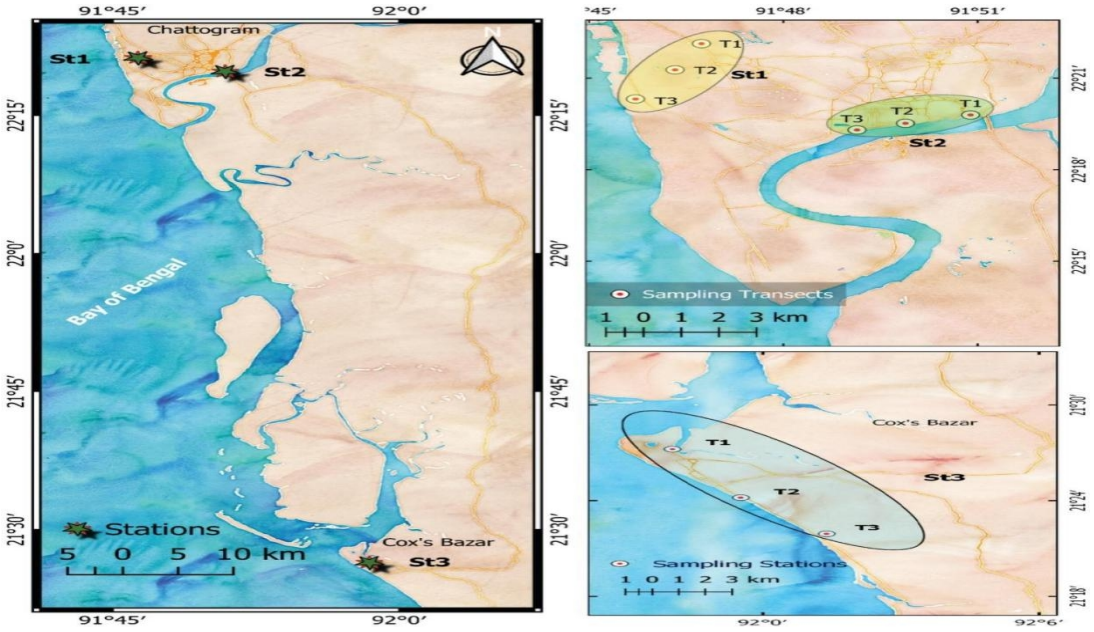

Figure 3: St1) Fishery ghat, Chattogram; St2) Faillatoli Bazar, Chattogram; St3) Fish Landing Centre, Cox's Bazar

3.2 Sample Collection:

In one year investigation, Hilsha samples were collected from the three stations. Fishes were randomly selected covering available sizes in the station throughout the study period for feeding biology study. Samples were preserved in ice in a insulated box and brought to laboratory. Each month 10 individuals of Hilsha fishes were collected and selected for gut content analysis.

3.3 Processing of sample:

In the laboratory, samples were identified and their total length were measured to the nearest cm using a ruler. The weight was taken using electrical balance.

Figure 4: Morphometric data collection

3.4 Stomach content analysis:

The fish was dissected and stomach was separated out from the fish by using surgical scissor. Diet content was removed by using surgical scalpel and was preserved in 10% buffered formalin in a petri dish instantly to cease digestion of the food materials in the gut. Each stomach contents were analyzed separately. No fish with empty stomach noticed during the study. Then, the entire gut content was diluted carefully with 50 ml water. The volume of each food item or the total food of each fish was examined.

Figure 5: Stomach content collection

3.5 Observation of diluted gut content under microscope:

Stomach content was expressed as g. The gut content was well mixed with 50 ml water and 1 ml sub- sample was taken into Sedgewich Rafter counting cell for qualitative and quantitative analysis (APHA, 1992). Ten fields out of 1000 fields of the counting cell were chosen randomly and total number of plankton found in the 10 fields were counted. The diluted gut content was observed under microscope (Optica B-190TB digital LCD microscope) with 10x magnification.

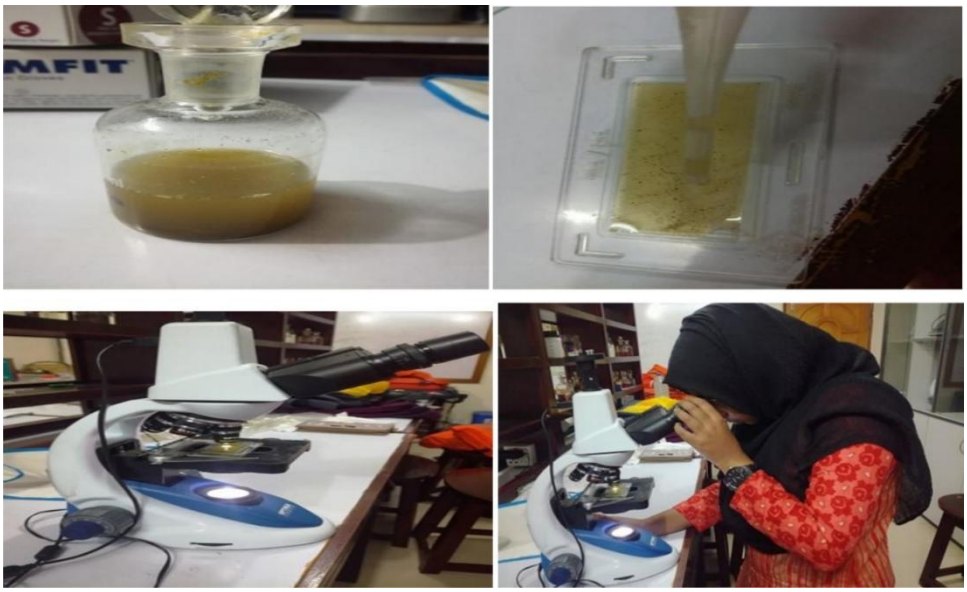

Figure 6: Observation of diluted gut content under microscope

3.6 Analysis of water sample and plankton number of gut content:

The cell was filled and covered with cover slip so as to eliminate air bubbles and left to stand for 15 minutes to allow the plankton to settle.

The Plankton in 10 randomly selected cells were identified up to genus level and counted under a binocular microscope with imaging facilities.

Plankton Abundance was calculated by using this formula:

$N=(P\times C\times 100/L)$

Where,

N= Number of plankton cells (Counted by using Sedgewick-Rafter cell)

P= the number of plankton counted in 10 fields

C= the volume of final concentrate of the sample (millilitre)

L= the volume (L) of the sample

3.7 Determination of Food and Feeding of Hilsha:

There were various methods used for the determination of food items taken by Hilsha, these were-

a) Numerical method;
b) Frequency of occurrence method;
c) Points method; and
d) Index of stomach fullness method;

a) Numerical (Number) method:

The method is used to expressed to which number of each food items in gut as the percentage of the total number of food items found in the guts (Hynes, 1950; Windell and Bowen, 1978; Hyslop, 1980; Dewan et al., 1991; Coastal et al., 1992).

Percentage by number,

$\% Oi = Ni / Nt \times 100$

Where,

% Oi is the percentage of food item i

Ni is the number of particular food item i

Nt is the total number of food item

b) Frequency of occurrence method:

This number was taken expressed as a percentage of all stomachs or all those containing food (Hyslop, 1980).

c) Point's (Volumetric) method:

Point's method is a contrast to the eye estimation method. Instead of direct estimation of the volume by sight as in the former method, each food content in the stomach is added in a certain number of points based on its volume. While adding of points both the length of the fish and the fullness of the stomach were taken into account by researchers.

Percentage volumes within each sub-sample were calculated as:

$$\alpha = \frac{\text{Number of points allocated to component } \alpha}{\text{Total points allocated to sub sample}} \times 100$$

Where, α is the percentage volume of the prey component α

The points were allotted to each of the stomach according to the number of plankton in the following way-

Table 1: Points allotted in each gut according to number of plankton:

Plankton number of each gut	Points allotted
00001+ - 10000	1
10000+ - 20000	2
20000+ - 30000	3
30000+ - 40000	4
40000+ - 50000	5
50000+ - 60000	6
60000+ - 70000	7
70000+ - 80000	8
80000+ - 90000	9
90000+ - 100000 and plus	10

Points were allotted in each gut in the above and then averages were taken. Point's method is more convenient for analyzing herbivores fish diet, where measuring volumes of microscopic organisms such as diatoms and filamentous algae are complex.

d) Index of stomach fullness (ISF):

Index of fullness determines the ratio of food weight to body weight. This index is extensively effective and it could be applied to the food in the stomach, or to that in the whole digestive tract (The ratio of volume can also be used) .

Index of Stomach Fullness, (ISF) = Wg / Wf X 1000

Where:

Wg is the weight of the stomach contents (g)

Wf is fish body weight

The visual estimation of the degree of fullness of the stomach was made in accordance with the vastly used classification established by Ball (1961). The points added to each stomach in order to the degree of fullness were in the following ways:

Table 2: Index of the stomach of fullness:

Degree of fullness	Criteria	Points
Empty	Stomach collapsed	0
1/4 full	One fourth of the stomach volume occupied by food	1
1/2 full	Stomach containing food, generally along most of the length, but the inner surface is longitudinally pleated and well feels thick and hard	2
3/4 full	Stomach nearly filled with food but some region of the wall feels thick and hard	3
Full	Stomach full of food, entire wall feels soft and thin	4
Distended	Stomach over packed with food. Wall cannot be pinched with forceps and is thin	5

An index of fullness of the stomach was determined neutrally of size of stomach of the fish. The points was determined size groups which gave a stomach fullness index of fish by general.

3.8 Statistical analysis:

To examine the total number of food item found in the gut content of Hilsha, the monthly value of plankton was computed in Microsoft Office Excel 2010 and then analyzed by IBM SPSS Statistics 25, Correlation and regression were performed and finally displayed with graphically and in tabular form.

Chapter 4
Results

There were three aspect of feeding biology: general investigation of diets, seasonal variation in feeding diets and relationship between fish size and feeding diets. The result of gut content of *T. ilisha* was analyzed for above three aspects. Four method; numerical method, frequency of occurrence method, index of fullness method and point's method were based for the examination of gut contents of *T. ilisha.*

4.1 Plankton compositions in the gut analysis:

In total, 58 genera of phytoplankton are identified in the analysis of Hilsha gut, including Bacillariophyceae (26 genera), Chlorophyceae (15 genera), Cyanophyceae (5 genera), Dinophyceae (8 genera), Pyrrophyceae (4 genera) and 13 genera of zooplankton are identified in the analysis of Hilsha gut, Copepoda (4 genera), Cladocera (4 genera), Rotifera (5 genera) (Table 3). One year study revealed that Hilsha was more dependent on Phytoplankton (93%) than Zooplankton (7%).

Table 3: Groups of plankton found in Hilsha gut:

Plankton Group		**Genus**
Phytoplankton	1. Bacillariophyceae	*Asterionella, Bacillaria, Biddulphia, Chaectoceros, Cocconeis, Coscinodiscus, Cyclotella, Diatoma, Fragillaria, Gyrosigma, Leptocylindicus, Licomphora, Melosira, Navicula, Nitzschia, Odontella, Plagioselmis, Polykrokos, Pleorosigma, Pseudo-nitzschia, Rhizosolenia, Synedra, Triceratium, Thallasionema, Thallasiosira, Thallassiothrix*

	2. Chlorophyceae	*Ankistrodesmus, Actinastrum, Chlorella, Closterium, Microspora, Oocystis, Oscillatoria, Pleurococcus, Palmella, Pediastrum, Scendesmus, Tetraedron, Ulotrix, Volvox, Zygnema*
	3. Cyanophyceae	*Anabaena, Aphanizomenon, Chroococcus, Microcystis, Trichodesmium*
	4. Dinophyceae	*Amphidinium, Alexandrium, Ceratium, Dinophysis, Gyrodinium, Gonyaulux, Gymnodinium, Protopderinium*
	5. Pyrrophyceae	*Bacteriastrum, Botrydium, Prorocentrum, Pyrocystis*
Zooplankton	1. Copepoda	*Copepods, Cyclops, Diaptomus, Nauplius*
	2. Cladocera	*Daphnia,, Bosmina, Moina, Sida*
	3. Rotifera	*Asplanchna, Brachionus, Hexarthra, Keratilla, Filina*

4.2 Percentage of different groups of plankton:

Their feeding habit mainly depended on Bacillariophyceae and Chlorophyceae. Beceause, Bacillariophyceae (57%) is the most frequent one among the various groups of phytoplankton, followed by Chlorophyceae (29%), Dinophyceae (4%), Cyanophyceae (2%), Pyrrophyceae (2%) and with a small quantity of zooplankton groups, where Copepoda (2%), Cladocera (1%), and Rotifera (4%) (Figure 7) were

found in the gut contents of Hilsha. In the groups of Bacillariophyceae, *Coscinodiscus spp* appeared with the most dominant one, followed by *Pseudo-Nitzschia, Nitzschia, Thallasionema, Cyclotella, Diatoma, Pleorosigma, Navicula, Biddulphia.*

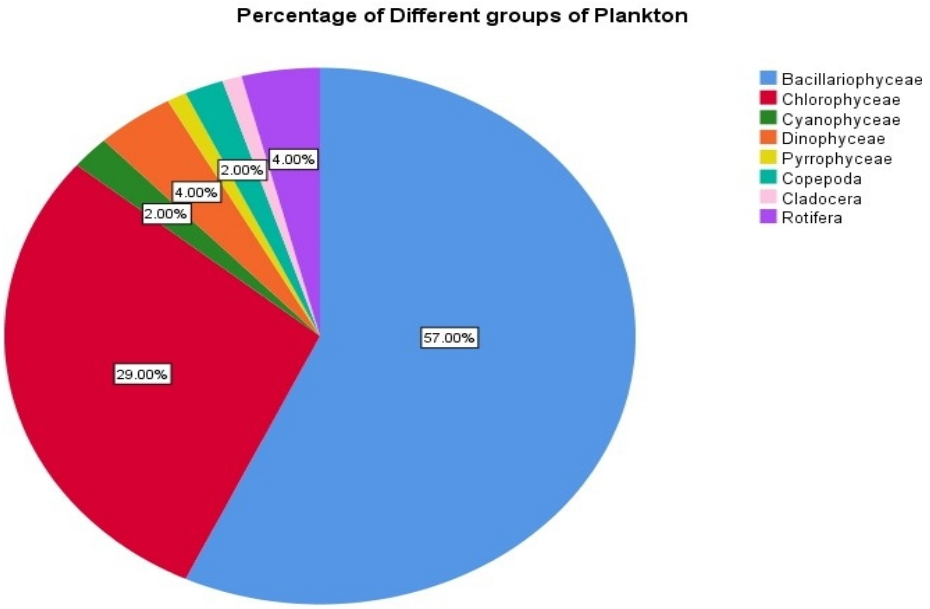

Figure 7: Percentage of different groups of plankton

4.3 Food categories based on frequency of occurrence method:

4.3.1 Phytoplankton:

a) Bacillariophyceae:

On the basis of percentage of occurences it was found that, *Coscinodiscus, Cyclotella, Nitzschia, Pleurosigma, Pseudo-nitzschia, Thallasionema* were the most dominant genus. The standard deviation higher in all the genera of Bacillariophyceae group except in *Coscinodiscus* of the method.

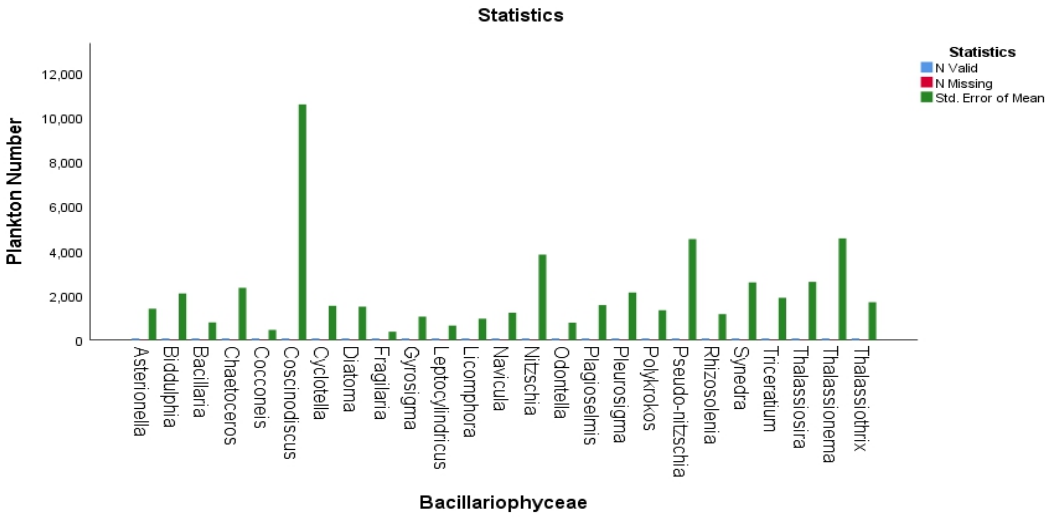

Figure 8: Abundance of Bacillariophyceae according to frequency of occurrence method in the gut of Hilsha collected from the Chattogram coastal area of Bangladesh

b) Chlorophyceae:

According to frequency occurence, Chlorophyceae was the second dominant class. In Chlorophyceae, Chlorella, Microspora, Oscillotaria, Ulothrix, Zygonema, Closterium were the most dominant genus.

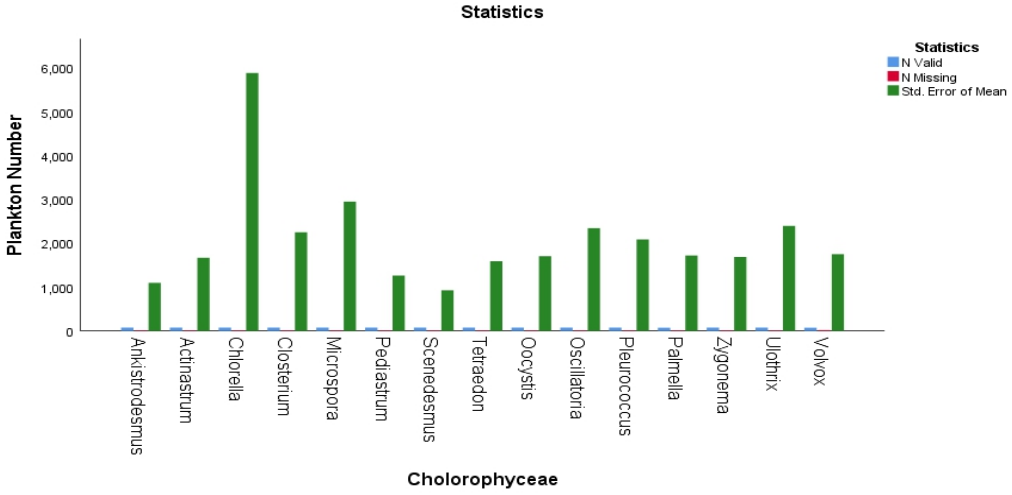

Figure 10: Abundance of Chlorophyceae according to frequency of occurrence method in the gut of Hilsha collected from the Chattogram coastal area of Bangladesh

c) Cyanophyceae:

According to Plankton frequency occurence method, Anabaena, Chrooccus, Trichodesmium were the highest plankton of genus in Cyanophycea.

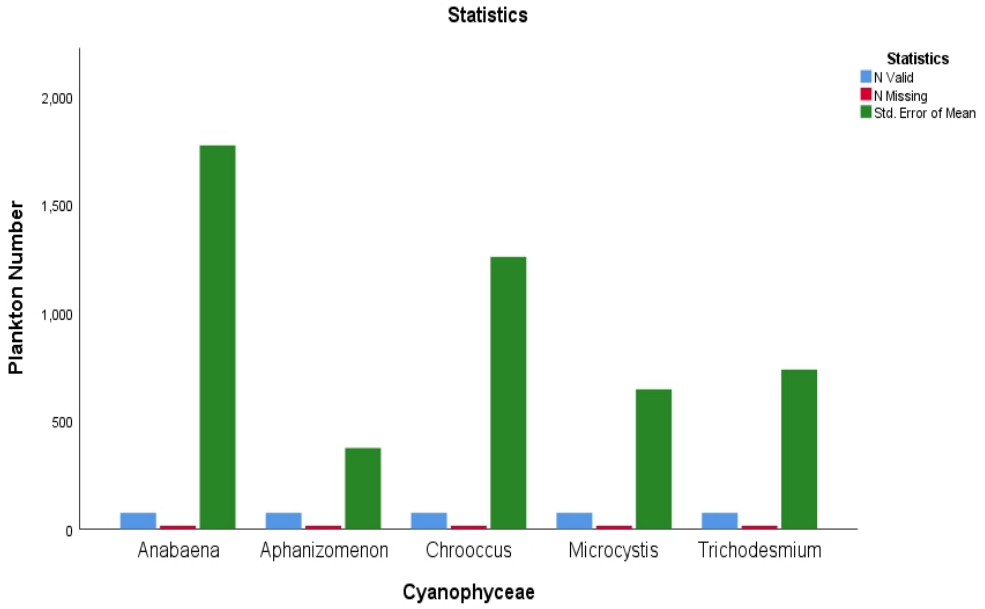

Figure 11: Abundance of Cyanophyceae according to frequency of occurrence method in the gut of Hilsha collected from the Chattogram coastal area of Bangladesh

d) Dinophyceae:

According to frequency method, Dinophyceae was the important for Hilsha feeding diet. Alexandrium, Amphidinium, Ceratium, Gonyaulax, protopteridinium were the highest amount of genus in Dinophyceae.

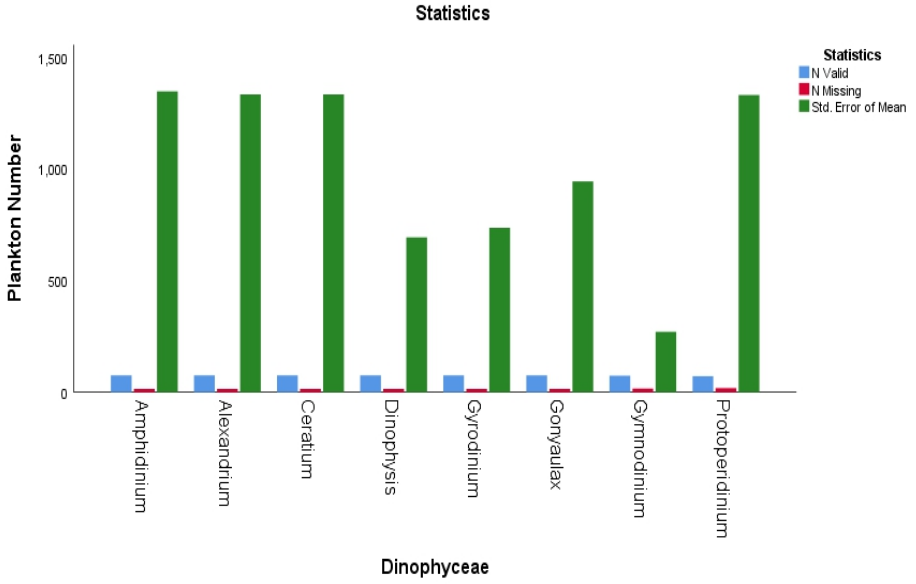

Figure 12: Abundance of Dinophyceae according to frequency of occurrence method in the gut of Hilsha collected from the Chattogram coastal area of Bangladesh

e) Pyrrophyceae:

In Pyrrophyceae, Bacteriostrum and Pyrocystis which were dominated genus.

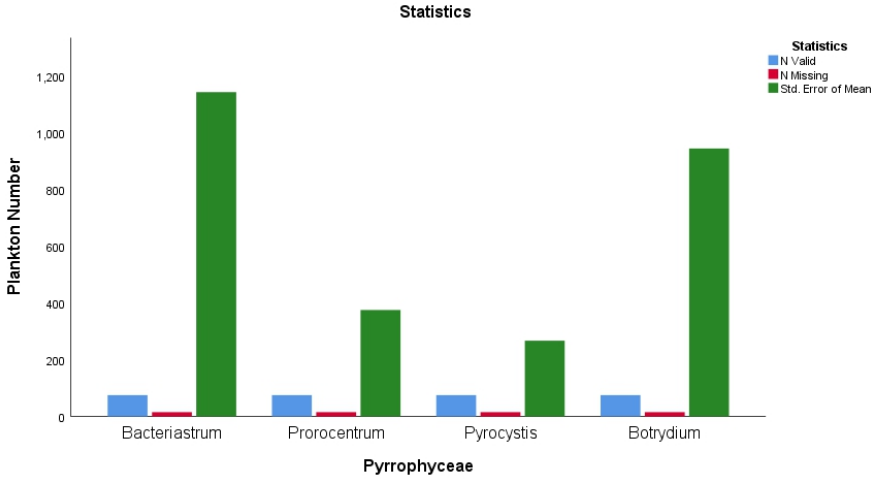

Figure 13: Abundance of Pyrrophyceae according to frequency of occurrence method in the gut of Hilsha collected from the Chattogram coastal area of Bangladesh

4.4.2 Zooplankton

a. Copepoda:

4 genera were found in Copepoda group. Copepods and Cyclopes were the most dominant genera in Copepoda.

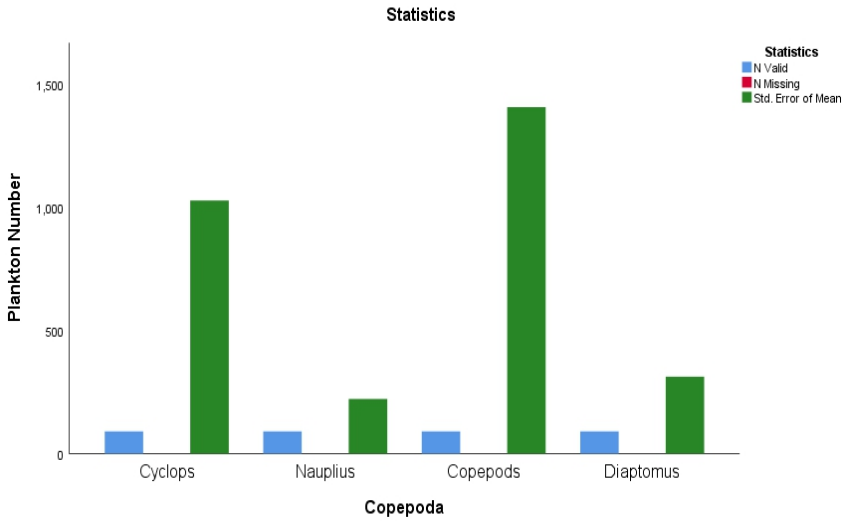

Figure 14: Abundance of Copepoda according to frequency of occurrence method in the gut of Hilsha collected from the Chattogram coastal area of Bangladesh

b. Cladocera :

4 genera were identified in Cladocera group. *Sida, Bosmina* and *Daphnia* were the most dominated in Cladocera.

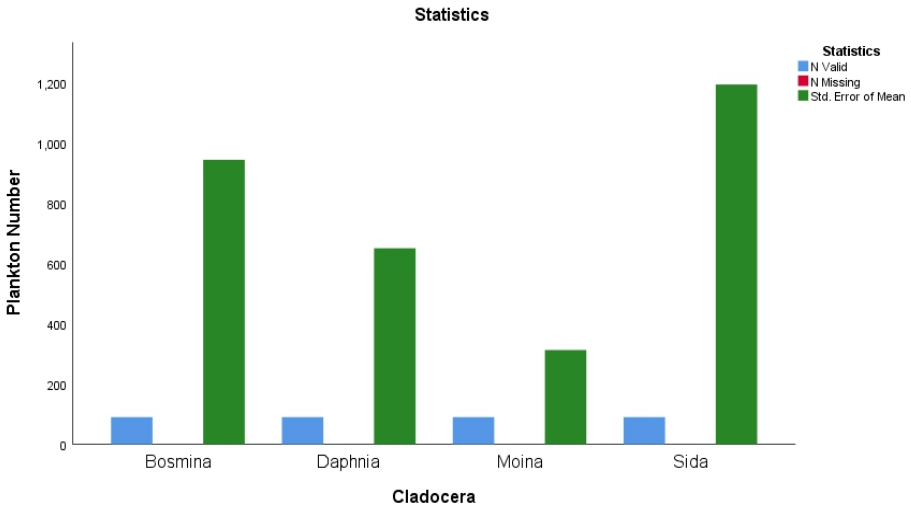

Figure 15: Abundance of Cladocera according to frequency of occurrence method in the gut of Hilsha collected from the Chattogram coastal area of Bangladesh

c. Rotifera :

4 genera were observed in Rotifera group. *Asplancha, Hexarthra* were the most dominated in Rotifera.

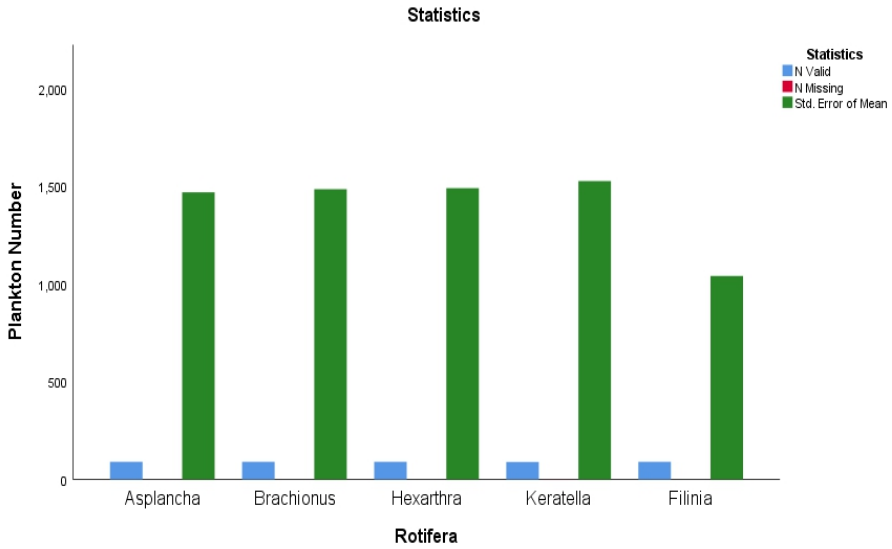

Figure 16: Abundance of Cladocera according to frequency of occurrence method in the gut of Hilsha collected from the Chattogram coastal area of Bangladesh

4.4 Abundance of plankton according to month:

Bacillariophyceae, Chlorophyceae, Cyanophyceae, Dinophyceae, Pyrrophyceae represented phytoplankton. Bacillariophyceae were found to occurence maximum in April(45.12%) and minimum in August (40.30%) according to point method and Chlorophyceae was found to occurence maximum in March (24.87%) and minimum in September (20.15%) (Table 4). On the basis of point method, Rotifera was observed to occur maximum in July (6.9%) and minimum in February (4.09%) and Copepoda were observed to occur maximum in July (5.4%) and minimum in (1.53%) (Table 4). Monthly changes in total plankton were shown in figure 17.

Table NO. 4: Percentage of total points of different food categories of Hilsha Shad by point's method according to month :

Average	January	December	November	September	August	May	April	March	February	Month		
10	10	10	10	10	10	10	10	10	10	No.Of fish examined		
41.93	43.44	41.86	41.25	40.50	40.30	41.09	45.12	41.48	42.22	Bacillariophyceae (%)	Phytoplankton	Items collected from stomach of Hilsha
22.25	24.85	22.70	21.00	20.15	21.25	20.56	22.16	24.87	22.58	Chlorophyceae (%)		
7.15	6.20	5.50	6.20	6.63	8.83	8.57	6.04	7.23	6.83	Cyanophyceae (%)		
9.08	10.00	9.20	10.70	10.60	9.50	7.78	10.50	10.96	12.05	Dinophyceae (%)		
6.75	5.42	6.40	6.50	5.50	6.88	8.26	7.48	6.23	7.60	Pyrrophyceae (%)		
87.16	89.91	85.66	85.65	83.38	86.76	86.20	91.30	90.77	91.28	Total Phytoplankton (%)		
3.92	2.50	4.2	5.4	5.8	3.5	5.0	3.16	2.41	1.53	Copepoda (%)	Zooplankton	
3.97	4.21	3.8	4.8	3.92	3.6	3.31	3.0	1.9	3.1	Cladocera (%)		
4.95	5.38	6.4	6.15	6.9	6.14	5.49	2.54	4.92	4.09	Rotifera (%)		
100	100	100	100	100	100	100	100	100	100	Total (%)		

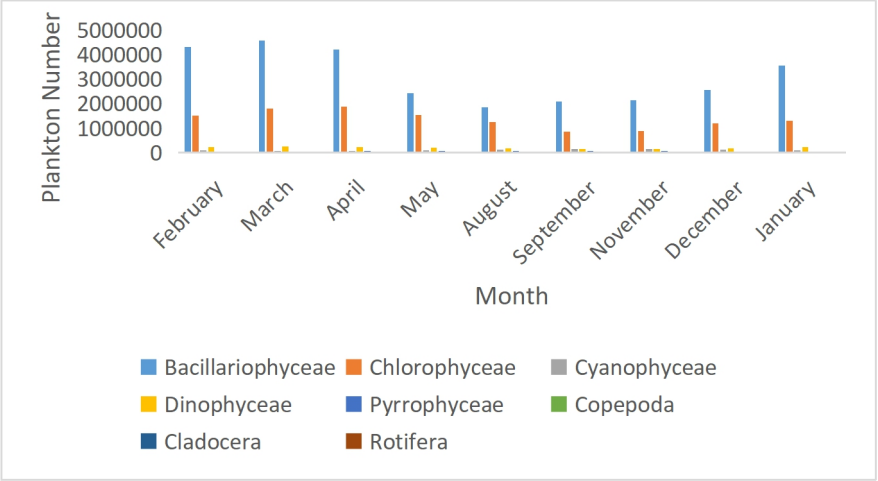

Figure 17: Abundance of plankton according to month

4.5 Relationship between Plankton and weight group:

The gut content analysis was done by correlation and regression analysis to understand its relationship with weight. The weight was measured by gram (g). In that analysis, the whole sample divided into 8 groups (101-200 g, 201-300 g, 301-400 g, 401-500 g, 501-600 g, 601-700 g, 701-800 g, 801-900 g). The correlation and regression analysis showed that plankton and weight group had R2 linear value of 0.260 which meant R2 value was low and acceptable. The low R-squared graph showed that even noisy, high-variability data had a significant trend. The trend indicated that the predictor variable still provided information about the response even though data points fall further from the regression line. (401-500) g and (301-400) g had consumed highest amount of plankton. That means, in their growth stage, their feeding diet increased. But (801-900) g had fed lowest amount of plankton. That means, their feeding diet decreased in their mature stage.

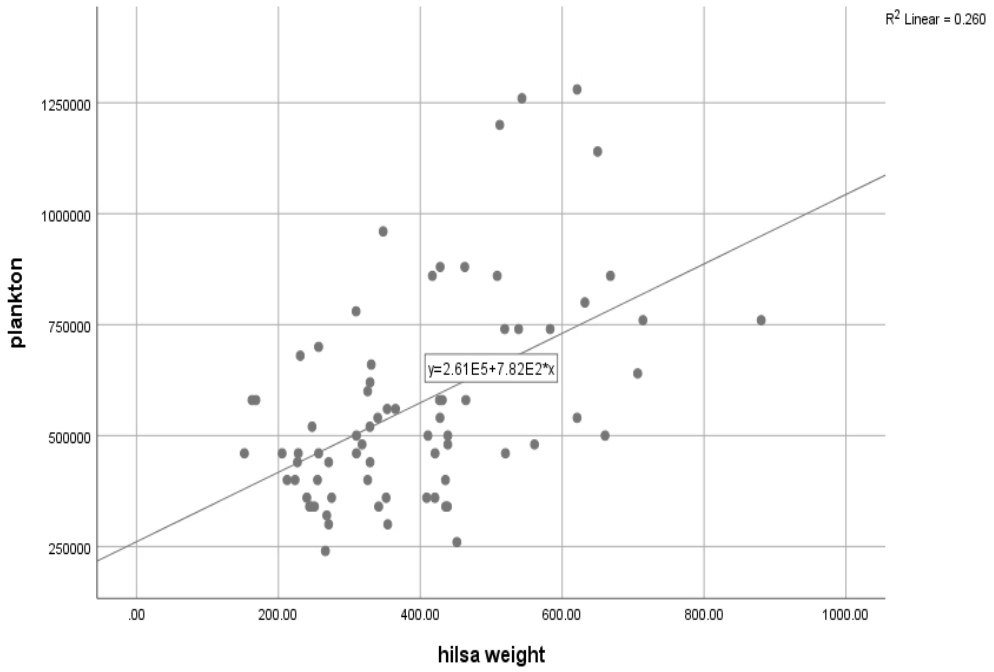

Figure 18: Simple scatter of Plankton by Hilsha weight

4.6 Composition of Plankton according to Length group:

According to their length group, the whole length was grouped into 3 classes (21- 30 cm, 31-40 cm, 41-50 cm). The relationship between the length and feeding based on the food categories according to One way Anova method.

Size Group-1 (21-30 cm):

In the size group of 21-30 cm, Bacillariophyceae and Chlorophyceae had shown as dominant food than other class. Their feeding rate had increased. There are highly significant variation ($p<0.001$) among the plankton of Bacillariophyceae, Chlorophyceae, Dinophyceae, Cladocera and Rotifera.

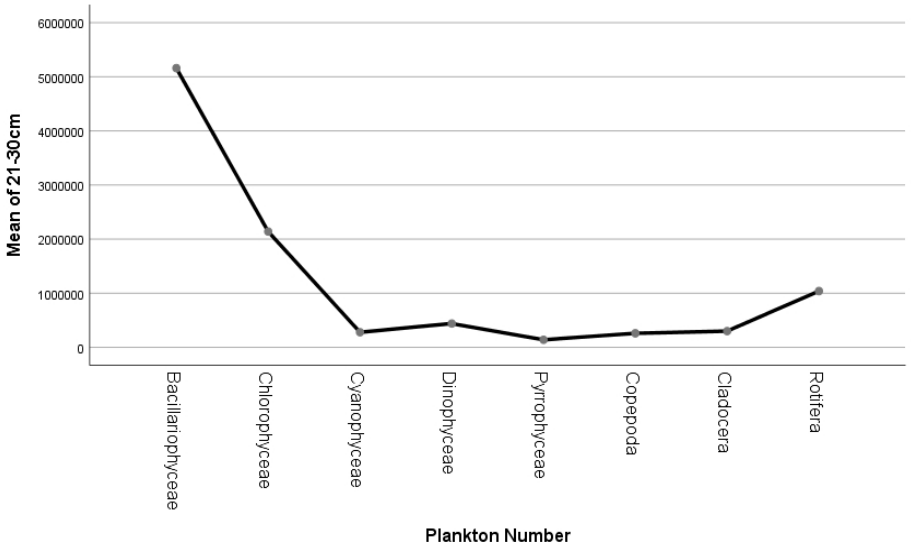

Figure No.19: Abundance of plankton according to size group 1 in the gut of Hilsha collected from the Chattogram coastal area of Bangladesh

Size Group-2 (31-40 cm):

In the size group of 31-40 cm, Bacillariophyceae and Chlorophyceae had shown as dominant food than other class. Their feeding rate had increased. There are highly significant variation ($p<0.001$) among the plankton of Bacillariophyceae, Chlorophyceae, Dinophyceae, Copepoda and Rotifera.

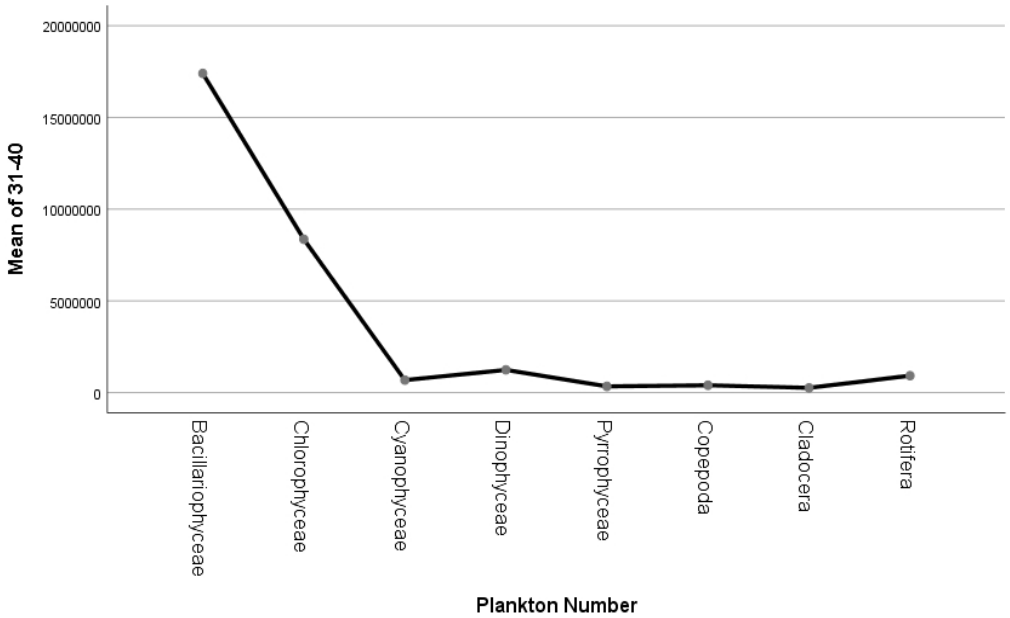

Figure No.20: Abundance of plankton according to size group 2 in the gut of Hilsha collected from the Chattogram coastal area of Bangladesh

Size Group-3 (41-50 cm):

In the size group of 41-50 cm, Bacillariophyceae and Chlorophyceae had shown as dominant food than other class. Their feeding rate had increased. There are highly significant variation ($p<0.001$) among the plankton of Bacillariophyceae, Chlorophyceae, Dinophyceae.

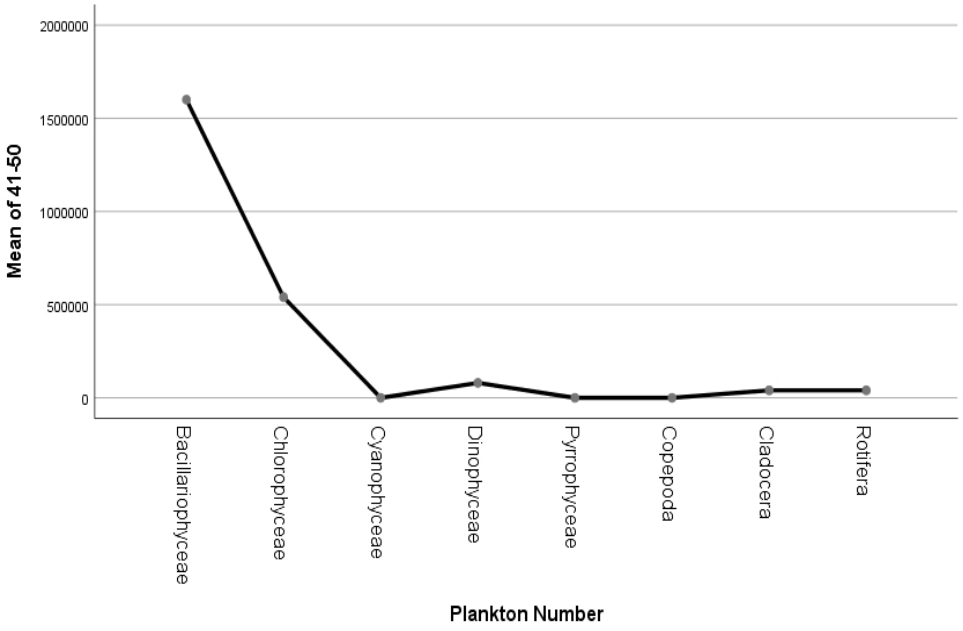

Figure No.20: Abundance of plankton according to size group 3 in the gut of Hilsha collected from the Chattogram coastal area of Bangladesh

4.6 Relationship between size and fullness of stomach of Hilsha based on average index of fullness and average points:

A total of fish 90 individuals species belong to 3 size groups were examined. The size groups were-

1. Size Group - 1 (21-30) cm
2. Size Group- 2 (31-40) cm
3. Size Group- 3(41-50) cm

These size groups were studied to determine the relationship between size of fish and feeding pattern. The results based on percentages of empty stomach and percentages index of fullness were represented in table in table 5.

Table 5 : Relationship between size and fullness of stomach of Hilsha:

Items	(21-30) cm Group 1	(31-40) cm Group 2	(41-50) cm Group 3
No. Of fish Examined	51	33	6
Average index of fullness	3.47	3.76	3.25
No Fish with empty stomach	0	0	0
Percentage of empty stomach	0	0	0
Degree of fullness	3/4 Full	3/4 Full	3/4 Full

The degree of fullness method observed the intensity of feeding. In the table, the degree of fullness of the stomach indicated stomach containing food, along most of its length, but inner surface was longitudinally pleated and well felt thick and hard

Chapter 5
Discussion

The qualitative and quantitative estimation of feeding diet of Hilsha in Chattogram coast was the main purpose of the study. The one year (February, 2019- January, 2020) study period mainly focused on improving the knowledge about Hilsha and this knowledge will help the for researchers and fishermen to identify the feeding biology of different sizes of Hilsha.

5.1 Plankton compositions as food items in the gut:

The study of gut content analysis identified that Hilsha consumed mainly on phytoplankton (93%) and zooplankton (7%). Hasan et al. (2016) found that Hilsha fed mainly on phytoplankton (98.08%) with a small quantity of zooplankton (1.92%).

The present study analysis of Hilsha revealed 58 genera of phytoplankton, including Bacillariophyceae (26 genera), Chlorophyceae (15 genera), Cyanophyceae (5 genera), Dinophyceae (8 genera), Pyrrophyceae (4 genera) and 13 genera of zooplankton were identified in the analysis of Hilsha gut, including Copepoda (4 genera), Cladocera (4 genera), Rotifera (5 genera). This study observed a greater generic abundance of plankton, both phytoplankton and zooplankton, in the Hilsha gut than the Rahman et al. (1992) study, who identified only 39 genera; 27 phytoplankton and 12 zooplankton. On the other hand, Hasan et al, (2016) found that the gut content analysis of Hilsha from the early stages (fry and juvenile) to adult indicated 51 genera of phytoplankton: Bacillariophyceae (18 genera), Chlorophyceae (20 genera), Cyanophyceae (9 genera), Euglenophyceae (2 genera), Xanthophyceae (1 genus) and Dinophyceae (1 genus). It also found 17 genera of Zooplankton: Copepoda (4 genera), Rotifera (7 genera), Cladocera (5 genera) and Protozoan (1 genus).

By consisting their main preferable food items in Hilsha gut, the plankton group were Bacillariophyceae (Coscinodiscus, Cyclotella, Nitzschia, Pleurosigma, Pseudo-nitzschia, Thallasionema), Chlorophyceae (Chlorella, Microspora, Oscillotaria, Ulothrix, Zygonema, Closterium), Cyanophyceae (Anabaena, chrooccus, Trichodesmium), Dinophyceae (Alexandrium , Amphidinium, Ceratium, Gonyaulax, protopteridinium), Pyrrophyceae (Bacteriostrum and Pyrocystis), Copepoda (Copepods, Cyclops), Cladocera (Sida, Bosmina, Daphnia), Rotifera (Asplancha, Hexarthra). But Pillay and Rao (1962) observed different groups of phytoplankton

such as Spirogyra, Oscillatoria, Microcystis and Merismopedia in the gut contents of *T. ilisha.*

Halder (1968) identified the food items such as Cyclotella, Melosira, Gyrosigma, Microcystis, Aphanocapsa, Oscillatoria and Spirogyra in Hilsha stomachs in the 120 to 160 millimetre and 180 to 200mm size ranges in the Hooghly estuarine system. On the other side, Narejo et al. (2005) reported that Hilsha selected some genera of phytoplankton such as Bacillariophyta (Cyclotella, Cymbella, Gyrosigma, Melosira and Navicula species), Cyanophyta (Aphanocapsa, Chroococus, Lyngbya, Merismopedia, Microcystis, and Oscillatoria) and Chlorophyta (Odogonium, Rhizoclonium and Scendesmus). Hilsha is a plankton feeder and does not show any selectivity in feeding with its closely-set sieve-like gill rakers (Hora, 1938; Jones and Sujansingani, 1951). Generally, the items which are preponderant are crustaceans (particularly copepods), diatoms, green and blue algae; organic detritus, mud and sand have also been recorded (Hora, 1938; Hora and Nair 1940; Chacko and Ganapati, 1949; Pillay and Rao, 1962; Halder, 1968 and 1971: Quereshi, 1968).

According to present study, Bacillariophyceae (57%) found the most frequent one among the various groups of phytoplankton, Chlorophyceae (29%), Dinophyceae (4%), Cyanophyceae (2%), Pyrrophyceae (2%) and with a small quantity of Zooplankton, Copepoda (2%), Cladocera (1%), Rotifera (4%) were found. As opposed to, Chlorophyceae appeared with the highest percentage (58.04%) among phytoplankton, followed by Bacillariophyceae (38.57%), Cyanophyceae (1.24%), Euglenophyceae (0.1%), Xanthophyceae (0.03%) and Dinophyceae (0.1%). Among zooplankton, Cladocera (0.77%) dominated in the gut contents, followed by Rotifera (0.56%), Copepoda (0.52%) and Protozoa (0.06%) (Hasan et al,, 2016). Similar results were observed by Rahman et al. (1992), who stated that Hilsha were predominantly a planktonic filter feeder, although sand and debris were also seen in their guts. A few studies on the food and feeding habits of Hilsha indicate that Hilsha shad is a filter feeder and feeds on plankton (Hora, 1938; Jones and Sujansingani, 1951).

5.2 Feeding biology of Hilsha in different size groups:

The present study analyzed the whole length grouped into 3 classes; (21-30 cm, 31-40 cm, 41-50 cm) and the weight group of Hilsha divided into 8 groups; (101-200) g, (201-300) g, (301-400) g, (401-500) g, (501-600) g, (601-700) g, (701-800) g, (800-900) g. In the diet study of Hilsha, Bacillariophyceae, Chlorophyceae,

Dinophyceae, Rotifera were dominated in size group of 1 (21-30 cm) and (31-40 cm) and Bacillariophyceae, Chlorophyceae, and Dinophyceae were dominated in size group 3 (41-50 cm). In the feeding habit of Hilsha, (300-400) g and (401-500) g were fed highest amount of plankton but (801-900) g was fed lowest amount of plankton.

Increasing the size in adult stage of Hilsha, they decreased their feeding diet. In pre-adult stage they used to eat comparatively good portion of zooplankton (7.04%) and phytoplankton (92.96%) but in adult stage they fed phytoplankton (95.12%) and zooplankton (4.88%). The present study revealed that on the basis of index of stomach fullness method, 3 size groups (21-30 cm, 31-40 cm, 41-50 cm) represented 3/4 full degree stomach containing food, along most of its length, but inner surface was longitudinally pleated and well felt thick and hard.

Mazid and Islam (1991) reported that the respectively large but immature Hilsha chose phytoplankton to zooplankton and that jatka had voracious appetite which backing the present study. Southwell and Prashad (1918) inferred from the large number of empty stomachs that adult Hilsha do not feed while ascending the river. Hora (1938 and 1940) recorded that the young Hilsha between 20 mm and 40 mm in length, feed mostly on diatoms and sparingly on crustaceans, and that slightly larger specimens up to 100 mm were found to feed on smaller crustaceans and also on insects and polyzoa.

The present study also showed monthly variation of Hilsha feeding diet. The study was presented by 9 months (except June, July and October due to ban period). The analysis found that during the month of January to April, Hilsha were eaten highest amount of plankton. But, no fishes with empty stomach found in Hilsha. Hora and Nair (1940) found that algae constituted the bulk of the food eaten during February-March, while diatoms formed the main item during the nor' westers (March-April). Pillay and Rao (1962) identified that from January to March feeding was fairly intensive and from June to November there was no specimen with more than a little food in the stomach that supports the present findings. From all the discussion, it is summed up that the Hilsha feeding higher in the pre-adult stage but decreases in grown up stage for spawning seasons.

Chapter 6
Conclusions

The diet of Hilsha showed no clear pattern of feeding with respect to various size groups but it was evident that the fish increased feeding on phytoplankton (93%) and zooplankton (7%) gradually with the increase of size. But in mature stage they decreased their diet due to migration, spawning and other issues. Bacillariophyceae (57%) found the most frequent one among the various groups of phytoplankton, Chlorophyceae (29%), Dinophyceae (4%), Cyanophyceae (2%), Pyrrophyceae (2%) and with a small quantity of Zooplankton, Copepoda (2%), Cladocera (1%), Rotifera (4%) were found. The gut analysis found that, their diet pattern changes with month. Specially during January to April, their feeding diet was mainly include Bacillariophyceae, Chlorophyceae, Dinophyceae and Rotifera. Coscinodiscus, Cyclotella, Pseudo-nitzschia, Nitzschia, Thallasinema, Diatoma, Pleorosigma, Navicula, Biddulphia, Microspora, Oscillotaria, and Ulothrix were the most dominant genera in the diet study. In the diet study of Hilsha, Bacillariophyceae, Chlorophyceae, Dinophyceae, Rotifera were dominated in size group of 1 (21-30 cm) and 2 (31-40 cm) and Bacillariophyceae, Chlorophyceae, and Dinophyceae were dominated in size group 3 (41-50 cm). In the feeding habit of Hilsha, (300-400) g and (401-500) g were fed highest amount of plankton but (801-900) g was fed lowest amount of plankton. Increasing the size in adult stage of Hilsha, they decreased their feeding diet.

Chapter 7

Recommendations and Future Prospects

This study of feeding biology of Hilsha provide detailed and updated knowledge about Hilsha. Utilizing information from this study in Hilsha feeding biology are :

- Increasing Hilsha production,
- Learning about Hilsha characters,
- Reducing capture costs,
- Increasing exports,
- Maintaining fish quality,
- Controlling overfishing in wildlife, and
- Saving endangered species

After a brief evaluation of the existing study on important features of the Hilsha feeding biology in coastal waters of Chattogram, It is beneficial to coastal people who are directly and indirectly involve in Hilsha Fishery. It also helps to develop their socioeconomic conditions and their livelihood. It greatly helpful for economical sector in Bangladesh, at the national, bilateral and multilateral levels.

Chapter 8

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Appendix A

Pictures of plankton found in the gut content of Hilsha:

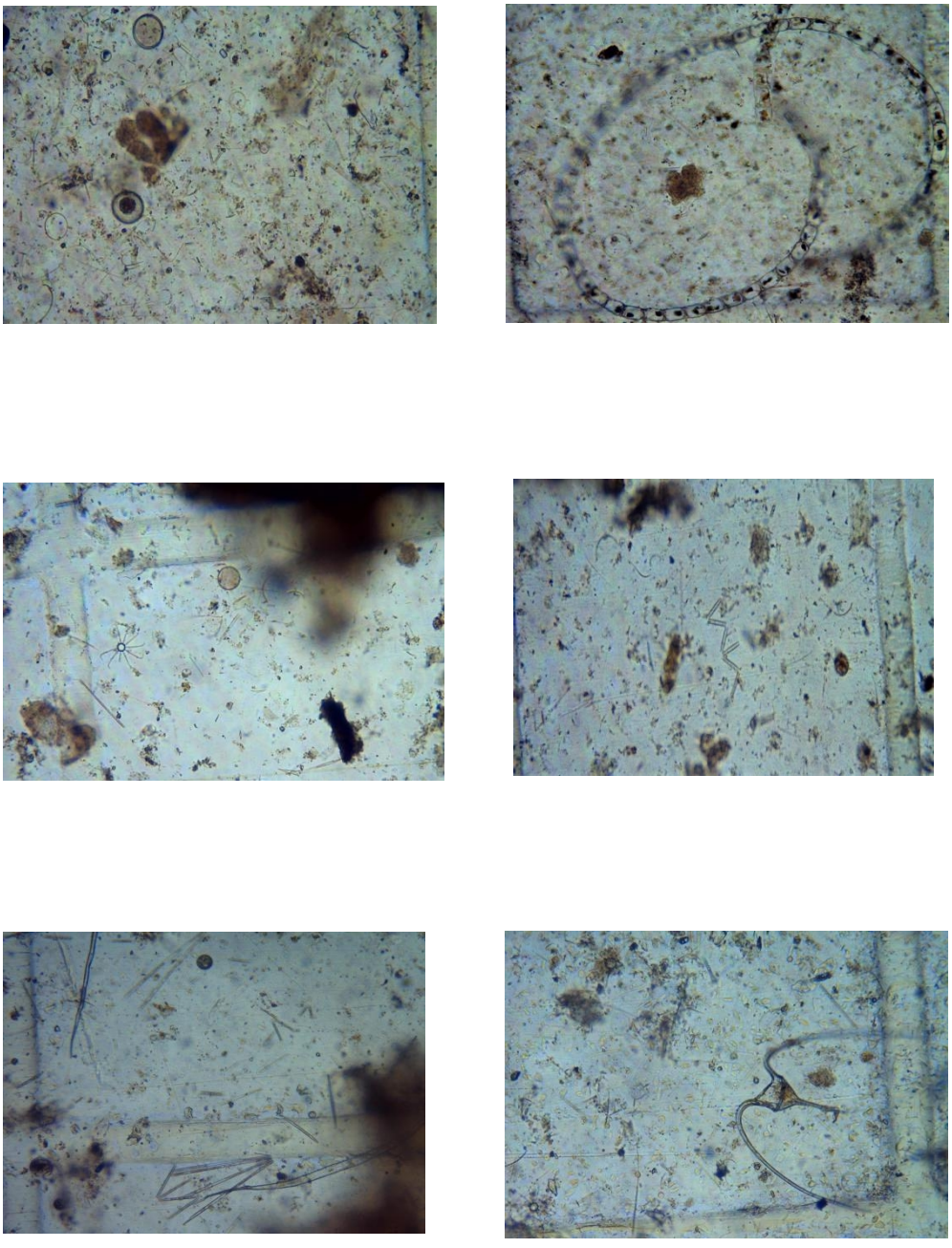

Figure 21 (a): Pictures of plankton found in the gut content of Hilsha

Pictures of plankton found in the gut content of Hilsha:

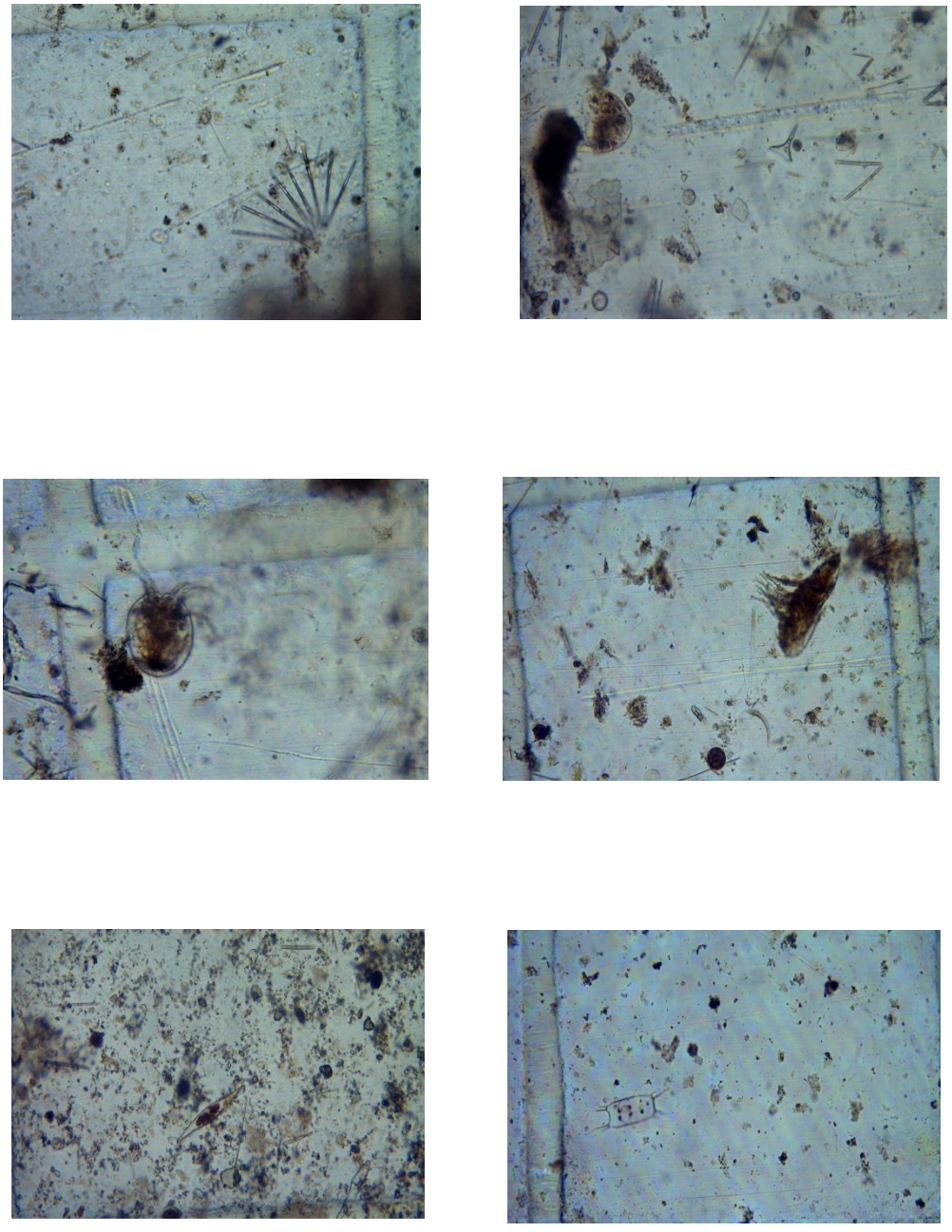

Figure 21(b): Pictures of plankton found in the gut content of Hilsha

Appendix B

Some pictures of lab activities:

Figure 22: Some pictures of lab activities

Brief Biography

Mashhura Hossain Anchol, Daughter of Md. Mobarok Hossain and Jannatul Fardush from Mymensingh Sadar upazilla, under Mymensingh District of Bangladesh. She paased Secondary School Certificate (SSC) and Higher Secondary School certificate (HSC) examination from Cantonment Public School and College. Then, she completed her B.Sc in Fisheries (Hon's) from the Faculty of Fisheries of Chattogram Veterinary and Animal Sciences University (CVASU), Chattogram, Bangladesh in 2018. Now, she is the candidate for the MS in Marine Bioresource Science under the Depertment of Marine Bioresource Science. She has immense interest to work in the field of Marine Science.