# CHAPTER ONE

# INTRODUCTION

## 1.1 Background of the study

Bangladesh is one of the world's driving fish delivering nations with a total production of 42.77 lakh MT in FY 2017-18, where aquaculture sector contributes 56.24 percent of the absolute fish production. The average growth execution of this area is 5.26 percent throughout the previous 10 years. Aquaculture shows solid and reliable growth, average growth rate is just about 10 percent during the equivalent time span. It is accepted that if the expanding pattern of fish production proceeds, it will be conceivable to accomplish the projected production focus of 45.52 lakh MT by 2021 in similarity with the objectives of Vision-2021 of the current Government. Following 46 years of autonomy, Bangladesh turns into an independent nation in fish production, with a for every capita fish utilization of 62.58 g/day against the set objective of 60 g/day (DoF, 2017-18).

Morphological characters are generally significant in the identification and scientific categorization of fishes, and the solitary known realities about numerous fishes. Notwithstanding understanding, the capacity of a morphological structure is a fortress for reasonable use in scientific categorization furthermore (Bohlen, 2008). It is a broadly utilized apparatus in the investigation of ichthyological systematics or scientific classification which looks the quantifiable parts of fish anatomy such as body parts and blades and their proportion of body length. This method is extremely helpful for testing and graphically shows the distinctions in shape.

Patterns of morphometric variety in fishes may show contrasts in development and development rates since body structure is a result of ontogeny. Morphometric landmark strategies contain one of the two significant classifications of morphometric examination, the other being outline techniques (Stransky, 2013). The qualification between the two is that landmark strategies examine information got from discrete morphometric points, direct distances among points, and mathematical connections among points, while outline techniques manage border shapes. Starting with Huxley and Teissier's spearheading work on bivariate allometry of shellfish and finfish during the 1920s (Huxley, 1932; Teissier, 1960), stock recognizable proof examinations have assumed a focal part in the advancement of traditional landmark strategies.

The improvement of computerized imaging frameworks and advances in scientific strategies reformed the investigation of morphometric variety and have expanded the intensity of morphometric examination (Cadrin and Friedland, 1999). In any case, the use of advanced geometric techniques as applied to stock recognizable proof lingers behind applications to other organic fields, for example, scientific categorization and biomedical examination (Cadrin, 2000).

Meristic characters, for example, fin spines and rays are countable structures of fishes that are created in a sequential design (Waldman, 2005). Meristic generally alluded to structures relating to body fragments, for example, various fin rays or vertebrae. Notwithstanding, the term is presently frequently applied to any countable structure, for example, various scales, gill rakers, branchiostegal rays, or cephalic pores (Helfman *et al*., 1997). Meristic highlights can be inward or outer yet in one or the other case, they can be obviously defined and measured which makes them helpful characters for looking at examples.

Meristic characters are helpful for contemplating stock segregation since they can show that early advancement happened in discrete territories or under various conditions. Meristic tallies are halfway controlled by hereditary qualities and somewhat by ecological conditions during egg and larval turn of events (Swain *et al*., 2005). Contrasts in temperature, saltiness, disintegrated oxygen, CO2, and photoperiod cause variety in meristic attributes (Hubbs, 1922; Vladykov, 1934; McHugh, 1954; Lindsey, 1988). Vertebral, fin beam, and scale considers will, in general, expand water temperature diminishes (Jordan's standard). Vertebral and pectoral beam includes in certain types of salmonids and plaice curve lower at the middle of the road temperatures than they are at either sequential temperatures (Barlow, 1961). Ecological components can modify the arrangement of meristic characters in the event that they cause anomalies are being developed, and factors, for example, raising thickness have additionally been appeared to impact meristic under specific conditions (Leary *et al*., 1991).

Since meristic structures are for the most part simple to notice and check since the nineteenth century they have been utilized broadly as an apparatus to segregate stocks

(Heincke, 1898) are as yet utilized effectively. Some new stock structure contemplates that have used meristic characters have analyzed species, for example, *Clupea harengus* (Turan. 2000), *Trachurus mediterraneus* (Turan, 2004), *Pomatomus saltatrix* (Turan *et al*., 2006), *Ammodytes personatus* (Kim *et al*., 2008), *Scomber japonicus* (Erguden *et al*., 2009).

The species *Eleutheronema tetradactylum* (Shaw, 1804) is typically known as Indian Salmon or four fingers threadfin in English and Rishi Kuchi or Tailla in Bengali. Ordinarily, it is found in the coastal shallow water of the Bay of Bengal of the Indian Sea at the profundity of 20-100 m. It is likewise written about the Hooghly estuarine framework, India, and its feeders. Around the world, this species is broadly disseminated along the shores of South Africa, Madagascar, Pakistan, China, Taiwan, Malaysia, Indonesia, Thailand, Philippines, Hong Kong, and Queensland. Being Polynemids animal varieties, they are flesh-eating in nature with the attributes of predaceous, ravenous, and cannibalistic (Abu Hena *et al*., 2011). In the youthful stage, they feed on tiny fish like copepods, nauplii, and amphipods with their filter-feeding of the system. As they develop, their food changes steadily to somewhat bigger tiny fish like mysids, megalopa hatchlings, little prawns, and fish hatchlings. The food of the grown-ups comprises polychaetes, decapodes, stomatopods, and fish. Malhotra saw that *E. tetradactylum* shows diverse conduct at various length viz., size bunch I (7-30 mm) took care of solely on copepods and mysids and periodically on lucifers; size bunch II (30-60 mm) benefited from planktonic shellfish, hatchlings, and post-hatchlings of teleostean fish and size III (60 mm or more) benefited from scavengers and fish in marine climate and polychaetes in the estuaries (Malhotra, 1953).

Upper sides of head and trunk with a slight darkish silver hint, getting lighter on lower sides; foremost edges of first and second dorsal fins blackish, outstanding part s clear and somewhat blackish, separately; pectoral fin striking yellow (shadowy yellow in huge examples over around 350 mm standard length); pectoral fibers white; the front edge of pelvic fin yellow, different parts white; the base of butt-centric fin yellow, different parts yellowish white; the base of caudal fin yellowish, different parts blackish (Malhotra, 1953).

This species contributes a decent fishery in the Cove of Bengal estuarine framework. This species is an amazing food fish and moves higher up the waterways than any of the other polynemids. Mature *E. tetradactylum* goes into the estuary for reproducing when the salinity of water begins rising. Youthful ones are found in plenitude in the lower spans of the estuaries of the Bay of Bengal (Abu Hena *et al*., 2011). Therefore it can be hypothesized that there may be some morphological differences between marine or estuarine inhabitants of Tailla populations. For that, we collected fish from three different sources in consideration of spawning migration. The aim of this study was to determine the morphological differences between three different sources of *E. tetradactylum* populations. This fish has an incredible interest among the people groups of waterfront locale. The interest for *E. tetradactylum* in the public business sectors is high and developing quick.

### 1.2 Objectives of the study:

The goals of the proposed research are as per the following:

- ❖ To determine possible morphological differences between separate unit stocks of the *E. tetradactylum* species
- ❖ To visualize monthly variation of morphometric characters within the identical species

# CHAPTER TWO

# REVIEW OF LITERATURE

Various techniques have been utilized for examining hereditary inconstancy. The utilization of meristic, morphometric, and milestone attributes to consider the variety among loads of fish species is a typical marvel on the planet. Numerous examinations have been done on the natural parts of various fish species in Bangladesh. This part is a definite audit of the morphological investigations carried on various fish species at home and abroad.

The morphometric study of *E. tetradactylum* analyzed in the Persian Gulf based on the truss network and showed significant differences among the samples in the *E. tetradactylum* populace in the two zones of examining (Jaferian *et al*., 2010).

A large variety of Rohu (*Labeo rohita*) and Mrigal (*Cirrhinus cirrhosus*) populaces investigated in Bangladesh depends on the morphometric and meristic information of the populaces. This study recommended that incubation center populaces of Rui and Mrigal may have veered off from their source and morphological characters of these species could be utilized for the assurance of virtue of the species (Hasan *et al*., 2007).

Morphometric characters and their relationship in *Notopterus notopterus* contemplated and found that the standard length, pectoral blade length, body tallness, and head length(dependent factors) are exceptionally connected with the complete length (free factors), while the eye distance across and interorbital width (subordinate factors) are profoundly associated with the head length (autonomous factors) (Prakash and Verma , 1982).

Milestone-based morphometric characters alongside support network estimations and meristic checks were analyzed to assess the populace status of the jeopardized carp, Kalibaus (*Labeo calbasu*) from two disengaged streams (the Jamuna and the Halda) and an incubation facility and noticed critical contrasts in four (most extreme body tallness, pre-orbital length, peduncle length, and maxillary free weight length) of 12 morphometric estimations, two (pectoral blade beams and scales over the horizontal line) of 9 meristic tallies, and four (8 to 9, 3 to 10, 2 to 10, and 1 to11) of 22 bracket network estimations among the stocks (Hossain *et al*., 2010).

An ordered correlation inside five populaces of climbing roost; *Anabas testudineas* gathered from five locales of Bangladesh and found a normal complete length, standard length, postorbital length, eye length, and length of the base of the dorsal balance of the number of inhabitants in Khulna area higher than those of the other four populaces (Hasan *et al*., 2005).

*Liza abu* stocks from the Orontes, Euphrates, and Tigris waterways to know the hereditary and morphometric structure. Simultaneously, allozyme electrophoresis for hereditary examination and the bracket network framework for morphometric correlation were applied to a similar example set and discovered profoundly huge morphological contrasts between the 3 *Liza abu* stocks and subsequently confined Tigris stock from the other two stocks (Turan *et al*., 2004a).

The support framework utilized for the recognizable proof of incubator and wild populaces of Coho salmon (*Oncorhynchus kisutch*) and discovered a huge morphometric variety (Swain *et al*., 1991).

Morphological characters of four Italian population of *Lebias fasciata* examined to survey the degree of separation among populaces. Fourteen meristic and 23 morphometric characters, comparative with the skull, vertebral segment, and the beams of the dorsal and butt-centric blades were inspected. The morphological outcomes demonstrated an imperative separation among the four populaces which mirrored their serious level of disengagement yet their morphological separation can't be deciphered biogeographically (Ferrite *et al*., 2003).

Morphometric characters with the bracket network framework utilized to know the populace status of anchovy (*Engraulis encrasicolus L.*) in Turkish earthly waters and noticed a serious level of difference among the anchovy tests and subsequently recognized as isolated stocks (Turan *et al*., 2004b).

Morphological characters were depicted of developing and non-developing *Labeo rohita*. They contemplated nine morphometric and eight meristic characters of 44 developing and 72 non-developing fishes. Body profundity, pre-dorsal, pre-pectoral, pre-ventral, pre-butt-centric, and head demonstrated direct associations with complete length while eye breadth and nose length indicated straight associations with head length. A slight variety was recorded in the meristic characters (Islam *et al*., 1983).

Morphometric characters and their relationship in *Gudusia chapra* and found that the fork length, dorsal balance length, pectoral balance length, pelvic balance length, body profundity and head length of the fish have exceptionally corresponded with its all-out length. While the looked at breadth, nose length, and post-orbital head length are exceptionally connected with the head length of the fish (Hoque and Rahman, 1985).

The morphometric characters of the catfish, *Rita rita* (Hamilton) examined from the stream Yamuna in North India. Perceptions were made based on absolute length, fork length, standard length, and head length, the profundity of the body at the pectoral balance base and at the caudal peduncle. They found that guys and females indicated heterogeneity in characters. Standard length and profundity of the body at pectoral balance base were diverse at 1% while the forked length and head length were distinctive at 5% degree of centrality. A straight relationship was gotten between body characters and all-out length (Devi *et al*., 1991).

Morphometric characters of red tilapia (freak *O. mossambicu* sand *O. niloticus*) were examined and found that the standard length, pelvic blade length, pectoral balance length, dorsal balance length, butt-centric balance length, and head length of the two fishes profoundly corresponded with the absolute length of the fish (Kohinoor *et al*., 1995).

Morphometry of *Labeo bata* from Kaptai repository and remarked that the connection between the reliant factors for example standard length, fork length, head length, predorsal distance, length of the dorsal balance, the profundity of dorsal balance, preanal distance, length of pectoral balance, length of the pelvic blade, least body width, most extreme body width, the distance among pectoral and pelvic balance, the distance among pelvic and butt-centric balance, length of caudal peduncle and length of caudal balance. This study discovered to correspond with the autonomous variable (the absolute length of fish) essentially at 0.1 % (Azadi and Naser, 1996).

A huge positive connection among's heterozygosity and variety inside the morphological boundaries on account of *Clarias gariepinus* were founded (Grobler *et al*., 1997). Two gatherings recognized among the *Clarias gariepinus* populaces, one containing Nilo-Sudanian populaces and the other remembering Lake Victoria and southern African populaces for the premise of morphological and allozyme varieties (Rognon *et al*., 1998).

Morphometric and meristic characters of *Gudusia chapra*, gathered from Keenjhar Lake (Pakistan), examined and found no huge morphological distinction between the genders. Relapses of length-weight didn't digress fundamentally from the 3D square law showing isometric development (Narejo *et al*., 2000).

The meristic and morphometric highlights of *G. giuris* populace from Mymensingh stock were examined (Mollah *et al*., 2012). An examination on scale morphology of *G. giuris* from Makran bowl of Iran and announced that ctenoid and cycloid scales were available on the head and body locale, individually. The nonattendance of the lepidonts on the peak of circuli and the course of action of cteni on the size of this fish could be utilized as significant ordered characters (Reza *et al*., 2009).

Two new types of family *Glossogobius* depicted from southern New Guinea and third related animal categories from northeastern Australia. *G. bellendenesisis* particularly in having decreased predorsal scale and balance beam tally where *G. robertsisis* unmistakable in balance beam and scale check that species has been mistaken for *G. giuris*, which by and large happens in lower scopes of the waterway (Hoese and Allen, 2009).

The significance of meristic and morphological trademark information have been utilized in the ID of fish stock (Murta, 2000; Saborido and Nedreaas, 2000), decide scientific classifications and even to recognize companion of solitary animal categories.

A serious level of variety was seen in morphological attributes among three unique stocks (the Meghna, Padma, and Ichamoti) of *Rhinomugil corsuladue* to their ecological variety and separate geological area (Hossain *et al*., 2015).

Morphometric and meristic characters were utilized to separate two congeneric archerfish species *Toxotes chatareus* and *Toxotes jaculatrix* possessing Malaysian beachfront waters (Simon *et al*., 2010).

The relative investigation of two sorts of Palla, *Tenualosa ilisha* from Waterway Indus, Pakistan uncovered huge intertype contrasts in six morphometric estimations (all-out length, standard length, fork length, head length, eye width, and circumference) and seven meristic characters (absolute number of scutes, pre pelvic scutes, post pelvic scutes, dorsal balance beams, pectoral balance beams, pelvic balance beams, and butt-centric blade beams) (Narejo *et al*., 2008).

# CHAPTER THREE

# MATERIALS AND METHODS

The methodology is a key and necessary piece of any exploration. In logical research, the worthiness of the outcomes relies upon an extraordinary expectation of a suitable approach. This part manages the strategies that are followed and materials that are utilized to accomplish the goals of the investigation. In this investigation, a logical and legitimate philosophy has been trailed by the researcher. This examination depends on sample assortments from various natural surroundings and information are gathered and examined for the understanding of results.

## 3.1 Study area

The investigation territory for this research was the Chattogram coast as it is the biggest and major sea side district of Bangladesh. The geographical location of the studied area is latitude 22.3569$^0$N and longitude 91.7832$^0$E (Fig. 01).

For the sampling reason, the investigation was separated into three distinctive inspecting stations. These stations are three primary landing stations of the waterfront locale of Chattogram region. The landing centers were chosen as inspecting stations so an assortment of fish samples could be simpler. The sampling stations were:

1) Sampling station 1 (Patenga, Chattogram): In the hub of Chattogram the new Fishery ghat region is the place of available fish species having geographical location as the latitude 22°32 97.36"N and longitude 91°84'58.20"E. This station covers a wide area of Chattogram coast including Patenga sea beach region, Pathoarghata, Fishery ghat (New and old), other adjacent fish landing sites of Chattogram.

2) Sampling station 2 (Kattoli coast, Chattogram): Adjacent to Sagorika beach, Halishohor, Chattogram including Foillatoli bazar, Bectech bazar, Kornell hat bazar were investigated under this sampling station 2. The positioning of this station is latitude 22°34'46.15"N and longitude as 91° 77'87.25" E.

3) Sampling station 3 (Cox's Bazar): It includes the region of BFDC landing center, coastal sites of CVASU field station, and other adjacent coasts of Cox's Bazar. The geographical location of station 3 is 21° 44' 53.36"N latitude and 91° 97'35.1"E longitude.

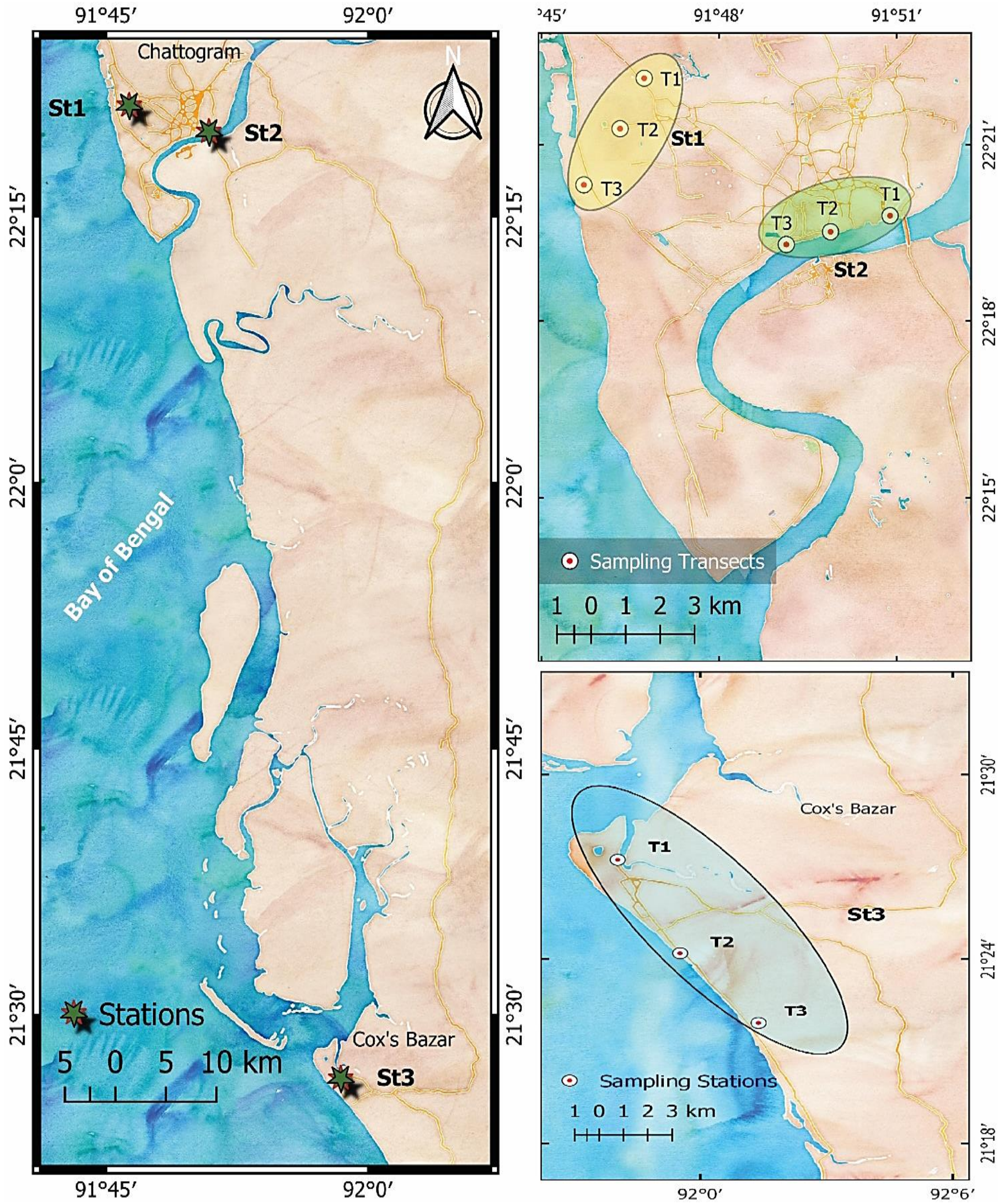


**Figure 1:** Map of sampling area (sampling station 1: Patenga, Chattogram; sampling station 2: Kattoli coast, Chattogram; sampling station 3: Cox's Bazar)

### 3.2 Collection of samples

The species *E. tetradactylum* depended on the morphological assessment and examination utilizing at least 60 specimens gathered from the selected three stations. Sampling was done using the "Simple Random Sampling" method. At first, the larger sized fish specimen with a new appearance and having all weighted and scale were defined. At that point, the random specimen were gathered from the available fishes.

The specimens consistently collected from all the inspecting stations. The samplings were done in each month maintaining the full moon cycle.


**Figure 2:** Collection of samples (a. Cox's Bazar; b. Cox's Bazar; c. Patenga; d. Kattoli coast)

### 3.3 Sample transportation

The gathered specimens were shipped in the Oceanography Lab of Chattogram Veterinary and Animal Sciences University by preserving them in an icebox. In the icebox, the proportion of ice to the fish was 1:2. In any case, the proportion could be changed by circumstances, for example, temperature, distance, gridlock and so on (Aleman, 1982).

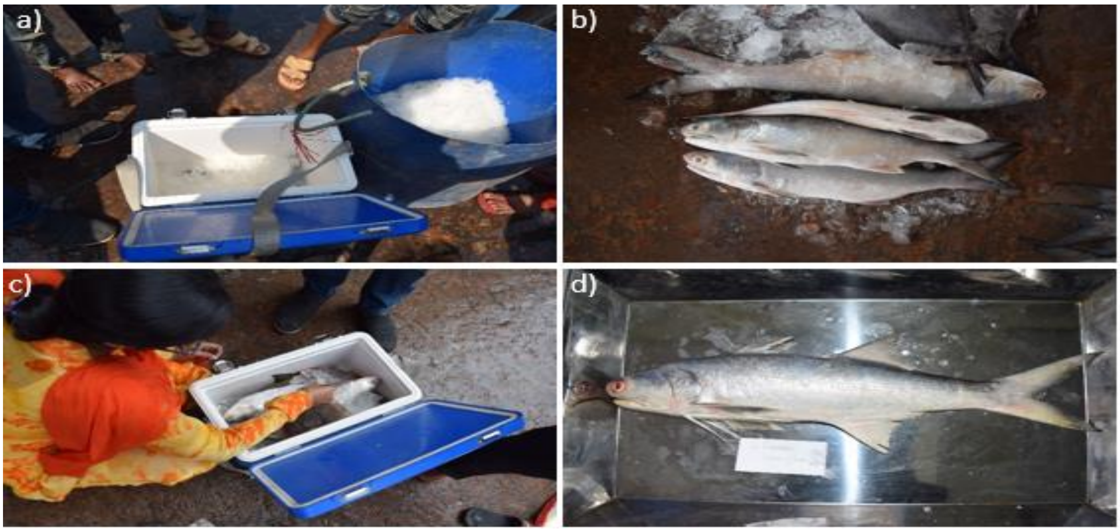


**Figure 3:** Sample transportation (a. Filled icebox with ice; b. Fish in the fish market; c. Preserving fish; d. Fish in the laboratory)

### 3.4 Laboratory analysis

At the point when the specimens were shown up at the research center from the outset the forked length and weight of each example were estimated and recorded in the record sheet (Figure 4).


**Figure 4:** Laboratory analysis (a. Mouth pattern observation; b. Estimation of forked length and weight)

#### 3.4.1 Measurement of morphometric characteristics

Nine general morphometric characters were measured (Figure 05) from each sample fish following the conventional method described by Hubbs and Lagler (1958).

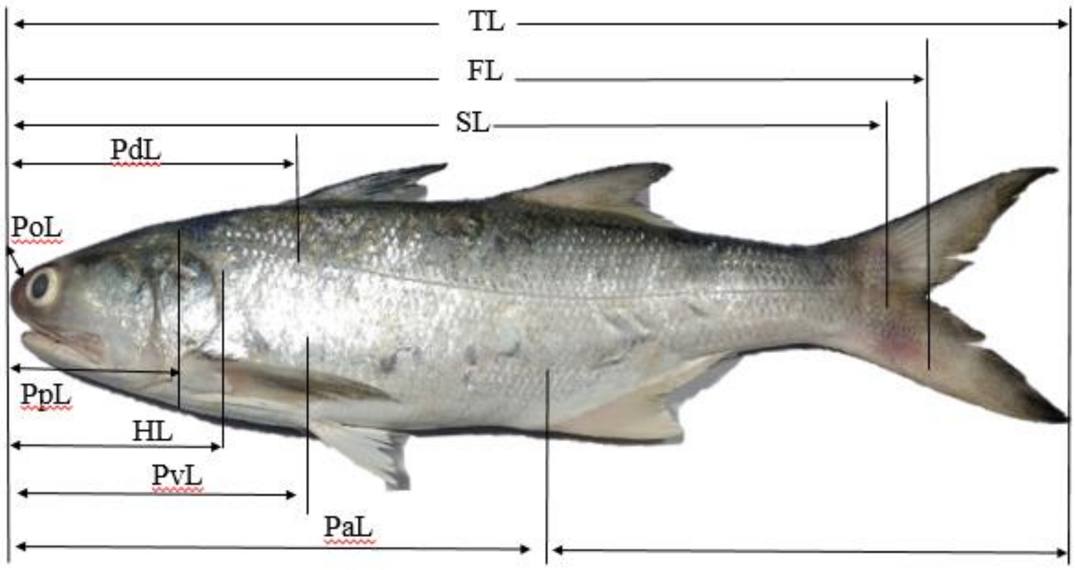


**Figure 5:** Overview of different morphometric indices of *Eleutheronema tetradactylum*

The morphometric characters were assessed with a precision of 0.05 mm with the assistance of Slide calipers and Metric scale. Table 02 shows the intentional morphometric characters used in this test for morphological assessment with their depictions.

**Table 01:** General morphometric characters and their descriptions used for the analysis

| SL. No | Characters | Description |
|---|---|---|
| 01 | Standard length (SL) | From the tip of the snout to the end of the vertebral column |
| 02 | Total length (TL) | From the tip of the snout to the longest caudal fin ray |
| 03 | Fork Length (FL) | From the tip of the snout to the middle part of the fork of the tail |
| 04 | Head Length (HL) | From the tip of the snout to the end of the most posterior portion of the operculum |
| 05 | Pre-orbital Length (PoL) | From the tip of the snout to the anterior of eye |
| 06 | Pre-dorsal fin length (PdL) | From the snout tip to the origin of the dorsal fin |
| 07 | Pre-Pelvic fin length (PvL) | Front of the upper lip to the origin of the pelvic fin |
| 08 | Pre-Pectoral fin length (PpL ) | Front of the upper lip to the origin of the pectoral fin |
| 09 | Pre-anal fin length (PaL) | Front of the upper lip to the origin of the anal fin |

### 3.4.2 Measurement of meristic characteristics

Five meristic characters like Dorsal Fin Rays (DFR), Anal Fin Rays (AFR), Caudal Fin Rays (CFR), Pectoral Fin Rays (PcFR) and Pelvic Fin Rays (PvFR) of each sample were counted from each fish and used for comparative analysis using magnifying glass.

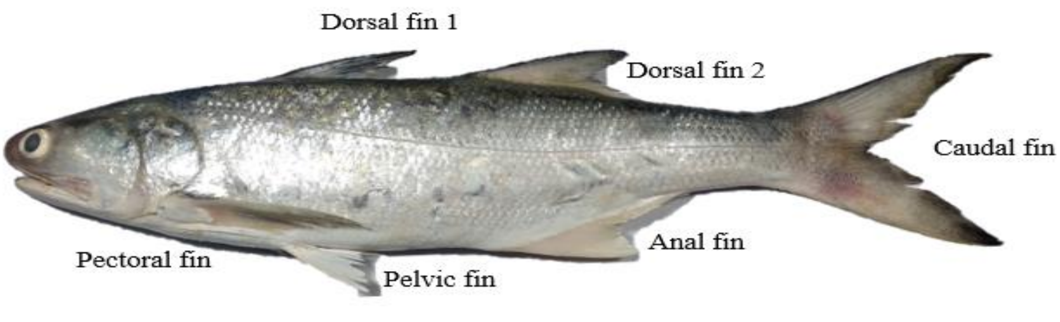


**Figure 6:** General indications of different meristic characters observed in *Eleutheronema tetradactylum*

### 3.4.3 Statistical analysis

Prior to the analysis, size effects from the data set were eliminated. An allometric formula (Elliott *et al*., 1995) with slight modification was used to remove the size effect from the data set.

$$M_{adj} = M\,(Ls/Lo)^{b}$$

Where,

$M_{adj}$: size adjusted measurement,

M: original measurement,

Ls: overall mean of standard length for all fish from all samples in each analysis

Lo: total length of fish

Parameter b was estimated for each character from the observed data as the slope of the regression of logM on logLo using all fish in all groups. The efficiency of the size adjusted values was then correlated with the TL and the transformed values.

## 3.5 Formula development

In general, the meristic characters are explicit for each species. These characters are among the characteristics of most regularly utilized for the separation of species and populations. So by utilizing the meristic characters a particular equation was produced for every species. This recipe is known as the meristic equation. The equation assists with recognizing species.

## 3.6 Final identification

At last distinguishing proof of the species were done using literature reviews as well as relevance books and logical papers were utilized as the source of perspective. Based on the particular characters and meristic method each specimen was recognized finally.

## 3.7 Documentation

Subsequent to recognizing a fish specimen, the image of the distinguished sample was caught in the photograph lab with its species name (Fig 7). The distinguishing characters, morphometric and meristic information and the image of each example were recorded in the archive for the further uses.

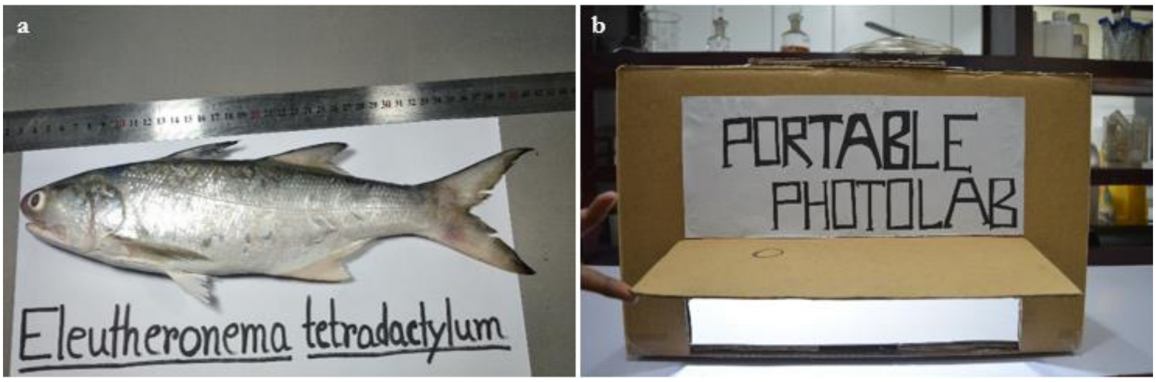


**Figure 7:** Documentation (a. Sample with its species name; b. Portable photo lab)

### 3.8 Preservation

All the recognized species were preserved in the Oceanography Lab of Department of Marine Bioresource Science under the Faculty of Fisheries, Chattogram Veterinary and Animal Sciences University maintaining the following technique.

Stage 1: A solution of 20% formalin was infused into the various parts of the fish body.

Stage 2: The fish was absorbed into formalin for 24 hours.

Stage 3: The fish was at last protected by the additive arrangement which contains a particular extent of distilled water, formalin, glycerin and ethanol solution.

# CHAPTER FOUR

# RESULTS

This section is the systematic descriptive part of the analysis on morphological features of *E. tetradactylum* collected from three different stations of Bangladesh along the northern Bay of Bengal. This study investigated the details of systemic analytical observations of the morphology based on statistical approaches.

### 4.1 Analysis of meristic counts

Meristic counts of all samples of *E. tetradactylum* collected from three different habitats ranged from 8 spines for first dorsal fin rays with 1 spine, 16-17 for second dorsal fin rays with 1 spine, 6 for pelvic fin rays including a spine, 4 for pectoral filaments, 16-17 for pectoral fin rays, and 17-19 for anal fin rays with 2 spines, 16-18 for caudal fin rays and 70-78 for scales on lateral lines. The number of anal fin rays, dorsal fin rays, pelvic fin rays, pectoral fin rays and caudal fin rays were not statistically significant ($p>0.05$) among the specimen from three different sampling stations.

Formula: $D_1$ VIII; $D_2$ I/15-16; $P_1$ 16-17+4; $P_2$ I/5; A II/15-17; C 16-18.

**Table 2(A):** Mean and standard deviation of meristic counts ($D_1$= First dorsal fin rays, $D_2$= Second dorsal fin rays, $P_1$= Pectoral fin rays, $P_2$= Pelvic fin rays, A= Anal fin rays, C= Caudal fin rays)

| Meristic Characteristics | $D_1$ | $D_2$ | $P_1$ | $P_2$ | A | C |
|---|---|---|---|---|---|---|
| Mean | 8.00 | 16.60 | 16.37 | 6.00 | 18.03 | 16.20 |
| Std. Deviation | .000 | .855 | .490 | .000 | .320 | .610 |

The meristic characteristics of the collected specimen varied in different transects of three sampling locations. Among different meristic parameters the first dorsal fin rays, pectoral fin rays and pelvic fin rays were not changed in the investigated samples. On the other hand, second dorsal fin rays, pectoral fin rays, anal fin rays and caudal fin rays were found as 16.60±0.86, 16.37±0.49, 18.03±0.32 and 16.20±0.61 respectively which indicates a small variation among these samples. In addition, scales on lateral line was observed as 72.70±1.8 indicates a moderate variation among these specimen (Table 02).

### 4.2 Analysis of morphometric counts

The morphometric counts of the specimen varied in different transects of three sampling locations. Among different morphometric parameters the total length, standard length, fork length, head length, pre-orbital length, pre-dorsal length, pre-pectoral length, pre-pelvic length and pre-anal length were found as 34.46±5.59, 26.00±4.19, 32.23±0.39, 8.15±.0.09, 1.13±0.08, 10.06±0.16, 7.54±0.20, 10.82±0.24 and 15.57±0.86 respectively all three stations (Table 02(B)).

**Table 2(B):** Mean and Standard deviation of morphometric characteristics

| Characters | Mean | Std. Deviation | N |
|---|---|---|---|
| TL | 34.458 | 5.5862 | 90 |
| SL | 25.980 | 4.2113 | 90 |
| FL | 32.232 | .3942 | 90 |
| HL | 8.1451 | .08592 | 90 |
| PoL | 1.1301 | .08189 | 90 |
| PdL | 10.0624 | .15713 | 90 |
| PpL | 7.5397 | .19563 | 90 |
| Pvl | 10.8211 | .23879 | 90 |
| PaL | 15.5693 | .86072 | 90 |

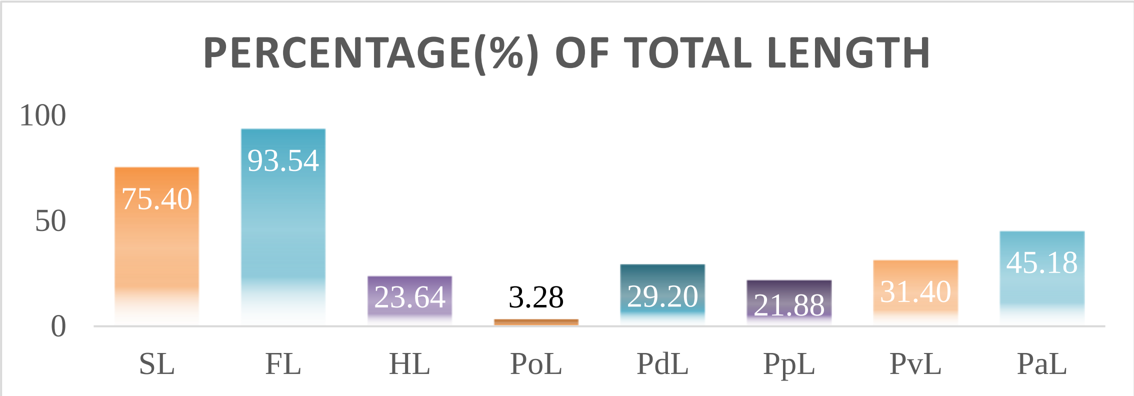


**Figure 8:** Morphological measurements expressed as percentage of total length.

All the morphological measurement were considered for different analysis. There was significant correlations ($p>0.05$) between the morphological values. Morphological measurements (Standard length, fork length, head length, pre-orbital length, pre-dorsal length, pre-pectoral length, pre-pelvic length and pre-anal length) expressed as percentage of total length in the Fig 8.

Percentages of standard length, fork length, head length, pre-orbital length, pre-dorsal length, pre-pectoral length, pre-pelvic length and pre-anal length were 75.40, 93.54, 23.64, 3.28, 29.20, 21.88, 31.40 and 45.18 respectively according to the total length. The fork length (93.54%) had higher percentage and the pre-orbital length (3.28%) had lower percentage with the total length (Figure 8).

### 4.2.1 Correlation

Different morphological measurements (Weight, total length, fork length, head length, pre-orbital length, pre-dorsal length, pre-pectoral length, pre-pelvic length and pre-anal length) were considered for correlation.

The correlations in the main diagonal (cells Wt vs Wt, TL vs TL, FL vs FL, HL vs HL, PoL vs PoL, PdL vs PdL, PpL vs PpL, PvL vs PvL and PaL vs PaL) were all equal to 1. Weight and other morphometric characters (total length, fork length, head length, pre-dorsal length, pre-pectoral length, pre-pelvic length, and pre-anal length, moderately related and pre-orbital length) had a statistically significant linear relationship (r=0.90, 0.91, 0.91, 0.67, 0.91, 0.88, 0.87, 0.89 and $p < 0.01$). The direction of the relationship was positive (i.e., weight and total length were positively correlated), meaning that these variables tend to increased together (i.e., greater weight was associated with greater total length). The strongest correlation was cells TL vs FL, TL vs HL, FL vs HL and HL vs PdL where r = 0.99 and its 2-tailed significance, p = 0.000 (Table 3).

**Table 3:** Correlation among samples of morphometric measurements from three different stations. Degree of significance were presented as **p<0.01.

| Morphometric characters | Wt | TL | FL | HL | PoL | PdL | PpL | PvL | PaL |
|---|---|---|---|---|---|---|---|---|---|
| Wt | 1 | | | | | | | | |
| TL | .90** | 1 | | | | | | | |
| FL | .91** | .99** | 1 | | | | | | |
| HL | .91** | .99** | .99** | 1 | | | | | |
| PoL | .67** | .72** | .71** | .69** | 1 | | | | |
| PdL | .91** | .98** | .98** | .99** | .68** | 1 | | | |
| PpL | .88** | .95** | .94** | .95** | .63** | .95** | 1 | | |
| PvL | .87** | .96** | .96** | .96** | .63** | .94** | .93** | 1 | |
| PaL | .89** | .86** | .86** | .87** | .63** | .85** | .80** | .88** | 1 |
| **. Correlation is significant at the 0.01 level (2-tailed). | | | | | | | | | |

### 4.2.2 Regression

Regression was presented between different morphometric measurements with total length. The fork length was explained as $R^2 = 0.984$ by the linear relationship with total length in the graph (Fig: 9(A)). According to that, 98.2%, 51.1%, 96.1%, 90.4%, 91.6%, 74.1% and 81% of the variation was observed in head length, pre-orbital length, pre-dorsal length, pre-pectoral length, pre-pelvic length, pre-anal length and weight respectively predicted by the linear relationship with total length (Fig: 9(B-H)).

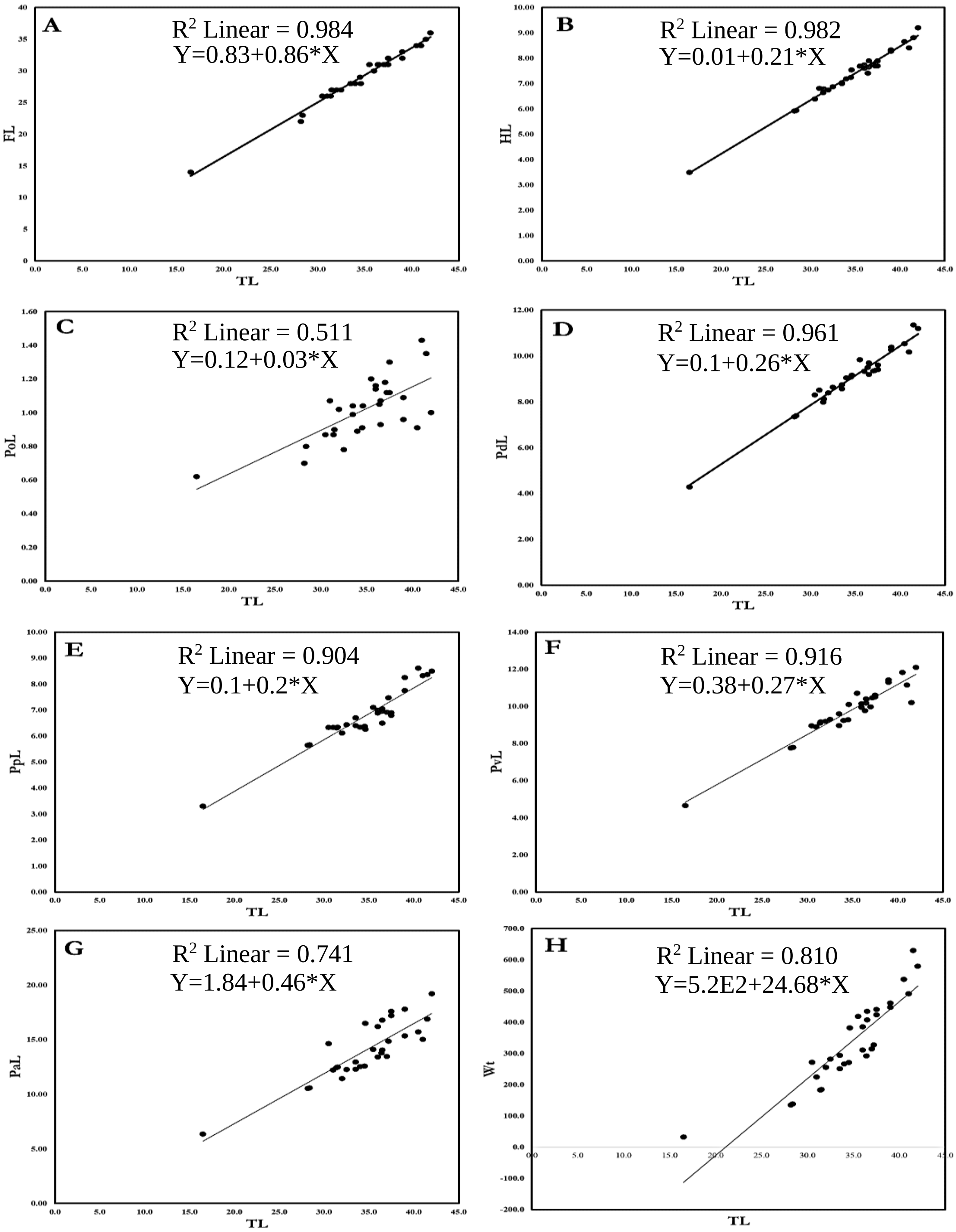


**Figure 9 :** Regression line of (A-H) length on total length (A=Fork, B=Head, C=Pre-orbital, D=Pre-dorsal, E=Pre-pectoral, F=Pre-pelvic, G=Pre-anal, H=weight)

### 4.2.3 Cluster analysis

Cluster analysis (Similarity) was carried out for month wise average values of morphometric measurements to understand the relationship among various months. Month wise morphometric measurements formed four major clusters. This is the indication of the variation over a period of 1 year resembles four periodical clusters. The first cluster was formed by four months such as August, September, January and November. In the first cluster, morphometric characters of August and September were very similar than other months. The second cluster was formed by three months and these were May, December and October. Third cluster was consisted by the months of April which appeared to be quite different from any of the other months. Last cluster was formed by February and March which were also substantially different from all of the other months at a higher level. The morphometric measurements had changed throughout the year (Figure 10).

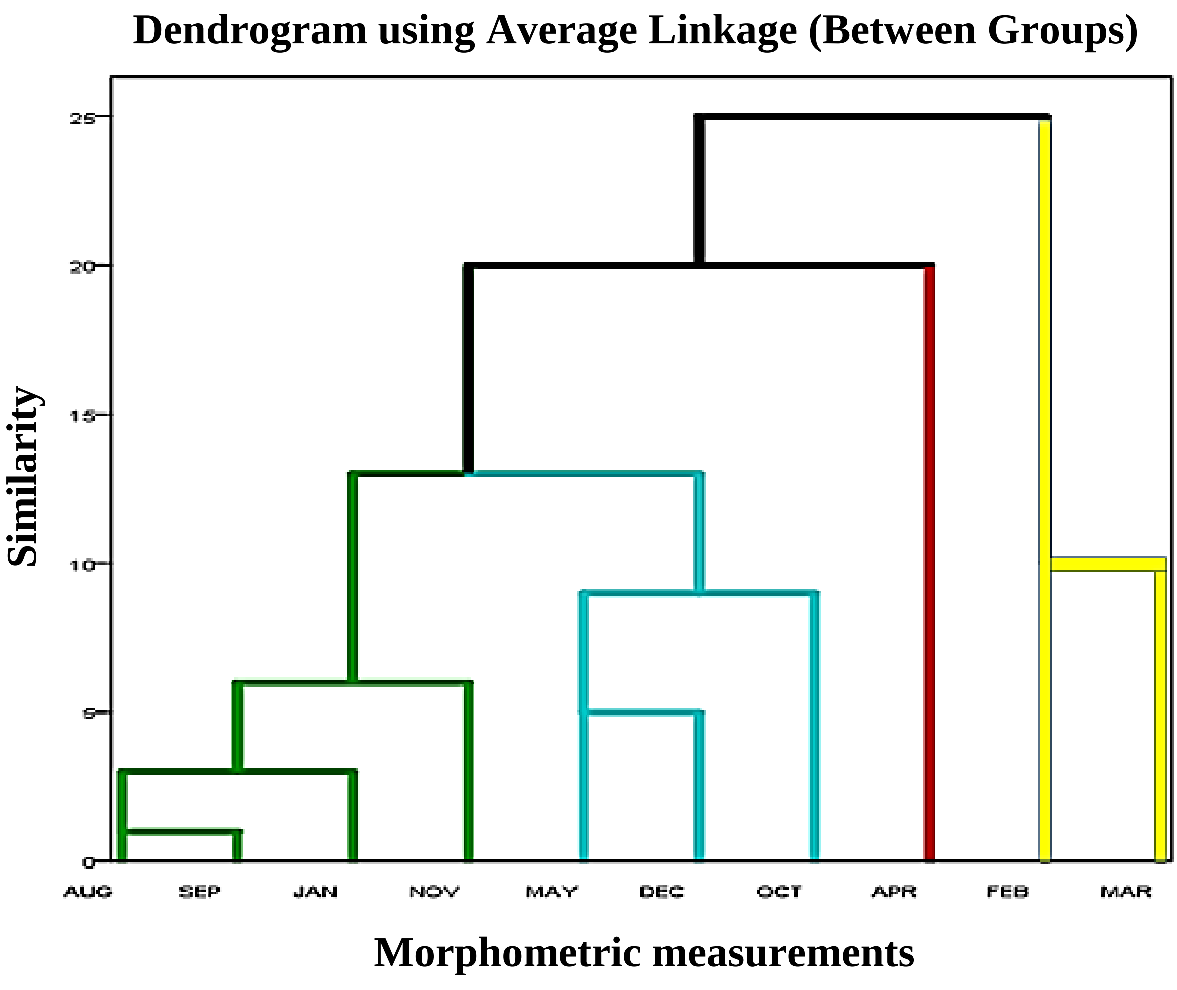


**Figure 10:** Dendrogram showing the Month wise similarity of various morphometric measurements

### 4.2.4 Univariate analysis (ANOVA)

There was no significant correlations ($p>0.05$) between the standard length and adjusted morphological values which indicates that the size effects were successfully removed with the help of allometric transformations. Therefore all the morphological measurement were considered for Univariate analysis (ANOVA). Univariate analysis showed that only pre-pelvic length (PvL) of nine morphometric measurements was significantly different in $p<0.05$ degrees among three groups of populations.

**Table 4:** Univariate statistics (ANOVA) among samples of *E. tetradactylum* from nine morphometric measurements from three different habitats. Degree of significance were presented as *$p<0.05$.

| Morphometric characters | Wilks' Lambda | F | df1 | df2 | Sig. |
|---|---|---|---|---|---|
| TL | .99 | 0.03 | 2 | 87 | 0.97 |
| SL | .99 | 0.03 | 2 | 87 | 0.97 |
| FL | .96 | 1.96 | 2 | 87 | 0.15 |
| HL | .99 | 0.18 | 2 | 87 | 0.83 |
| PoL | .98 | 1.03 | 2 | 87 | 0.36 |
| PdL | .96 | 1.79 | 2 | 87 | 0.17 |
| PpL | .93 | 3.17 | 2 | 87 | 0.04* |
| PvL | .99 | 0.21 | 2 | 87 | 0.82 |
| PaL | .99 | 0.54 | 2 | 87 | 0.59 |

Discriminant Function Analysis (DFA) produced two sets of discriminant functions (DF1 and DF2) for morphometric measurements. The first DF analysis resolved 85.0% and the second DF accounted for 15.0% group variability and together they explained 100% of the total variability for morphometric measurements (Table 4).

Pooled within-groups correlations between discriminating variables and discriminant functions revealed that among the nine morphometric measurements, three measurements of pre-pectoral length (PpL), fork length (FL) and pre dorsal length (PvL) dominantly contributed to the first DF, while the remaining six [pre orbital length (PoL), pre-anal length (PaL), pre-pelvic length (PvL), head length (HL), standard length (SL), total length (TL)] contributed to the second DF (Table 05).

**Table 5:** Pooled within-groups correlations between discriminating variables and discriminant functions in case of general morphometric characteristics.

| Morphometric Characters | DF1 | DF2 |
|---|---|---|
| PpL | .632* | -.124 |
| FL | .497* | -.063 |
| PdL | .455* | -.339 |
| PoL | .115 | .814* |
| PaL | -.209 | -.369* |
| PvL | .055 | -.360* |
| HL | .094 | -.284* |
| SL | -.030 | .138* |
| TL | -.010 | .135* |

In discrimination space, morphometric measurements of fish sample from the Patenga, Kattoli and Cox's Bazar coast were not fully separated. On the basis of morphometric measurement 60%, 36.7% and 23.3% of original group cases were correctly classified in case of Patenga, Kattoli and Cox's Bazar samples respectively and a total of 40% of original group cases correctly classified for all three stations (Table 06). This suggested that *E. tetradactylum* of Patenga, Kattoli and Cox's Bazar populations were not fully separated (Figure 11) which was revealed by canonical discriminant functions.

**Table 6:** Showing classification results of canonical discriminant function based on all morphometric measurement classification results

<table>
<tr><td></td><td></td><td rowspan="2">Station</td><td colspan="3">Predicted Group Membership</td><td rowspan="2">Total</td></tr>
<tr><td></td><td></td><td>Patenga, Chattogram</td><td>Kattoli coast, Chattogram</td><td>Cox's Bazar</td></tr>
<tr><td rowspan="6">Original</td><td rowspan="3">Count</td><td>Patenga, Chattogram</td><td>18</td><td>7</td><td>5</td><td>30</td></tr>
<tr><td>Kattoli coast, Chattogram</td><td>15</td><td>11</td><td>4</td><td>30</td></tr>
<tr><td>Cox's Bazar</td><td>14</td><td>9</td><td>7</td><td>30</td></tr>
<tr><td rowspan="3">%</td><td>Patenga, Chattogram</td><td>60.0</td><td>23.3</td><td>16.7</td><td>100.0</td></tr>
<tr><td>Kattoli coast, Chattogram</td><td>50.0</td><td>36.7</td><td>13.3</td><td>100.0</td></tr>
<tr><td>Cox's Bazar</td><td>46.7</td><td>30.0</td><td>23.3</td><td>100.0</td></tr>
</table>

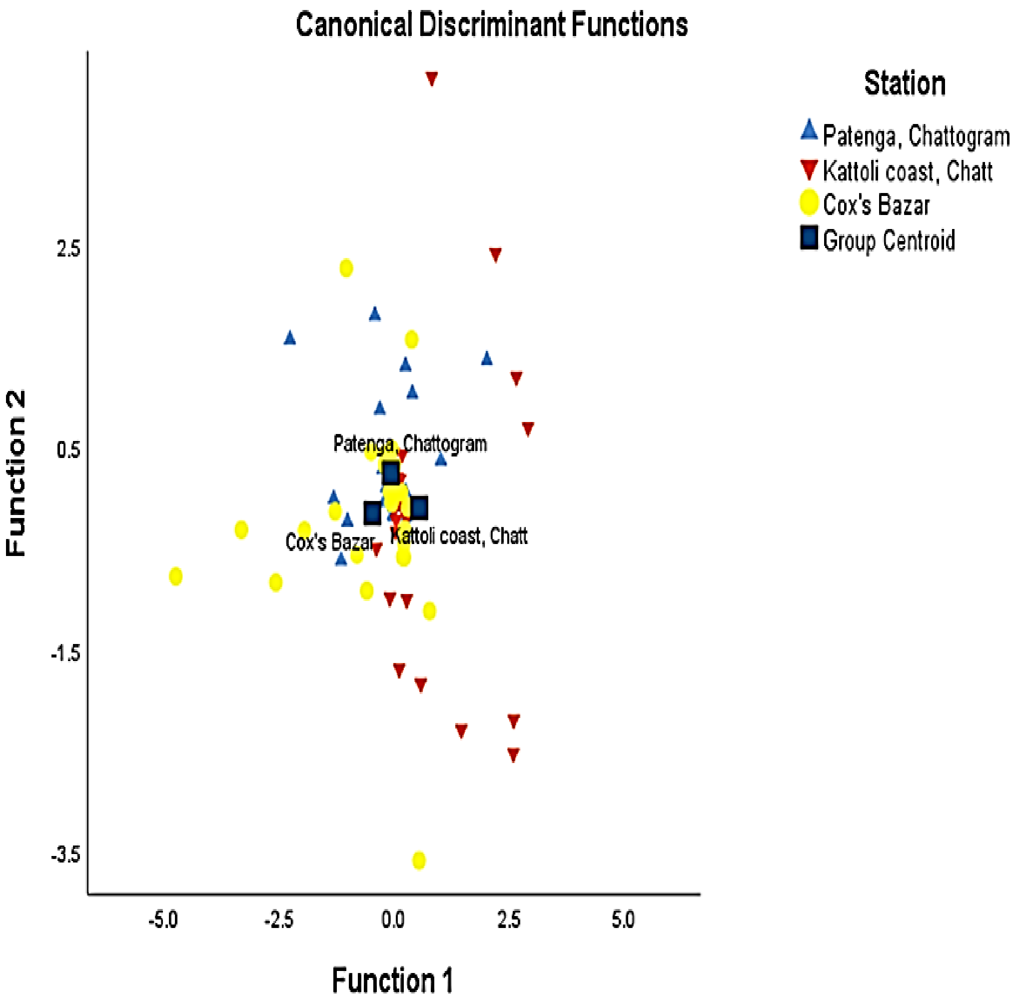


**Figure 11:** Canonical discriminant functions for morphometric characters of *E. tetradactylum* collected from the Patenga, Kattoli and Cox's Bazar coast.

### 4.3 Principal component analysis (PCA)

The significant traits (Morphometric and meristic measurements) were used for principal component analysis (PCA). In this study, characters that were significant at a high level ($p < 0.05$) were considered for principal component analysis (PCA). In our present study, significant factors considered only those factors with loadings greater than 0.5.

The first three principal components (PC1, PC2 and PC3) had eigenvalues greater than 1. These three components explained 83.17% of the variation in the data. The scree plot showed that the eigenvalues started to form a straight line after the third principal component. As 83.17% was an adequate amount of variation explained in the data, then the first three principal components had used (Fig: 12).

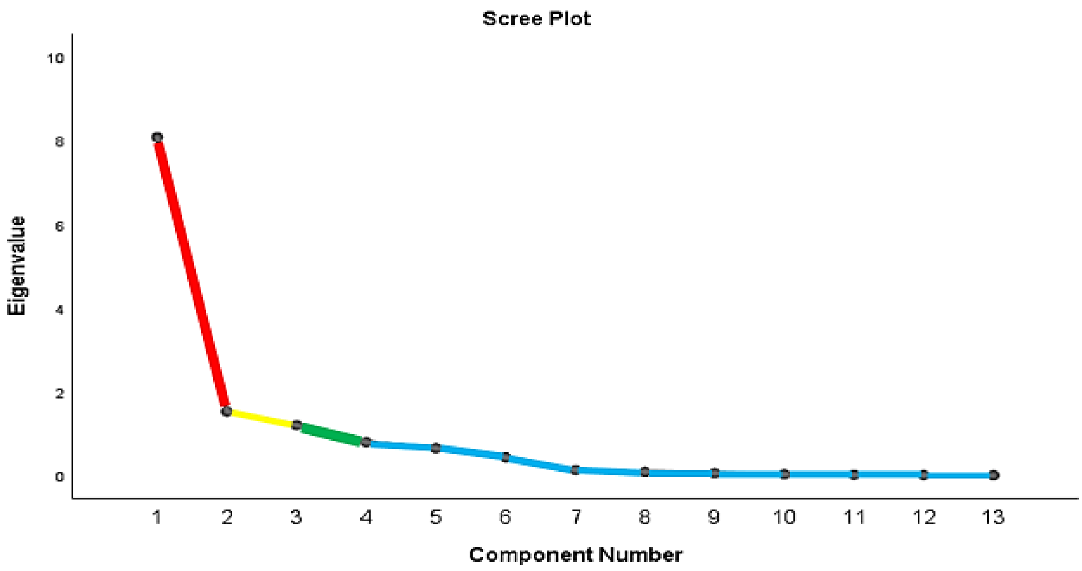


**Figure 12:** Scree plot showed the first three principal components had greater variation

Principal Component Analysis (PCA) based on the morphometric and meristic measurement of *E. tetradactylum* from three different habitats shows the value of KMO for overall matrix was 0.78 and the Bartlett's Test of Sphericity also significant ($P<0.01$). The results of KMO and Bartlett's Sphericity test suggest that the sampled data is appropriate to proceed with a factor analysis procedure. The PCA based on thirteen characteristics retained three components with Eigen values more than 1. The first (PC1), second (PC2) and third (PC3) principal components accounted for 62.17%, 11.75% and 9.25% of the total variance in turn. Some of the thirteen morphometric and meristic measurements had significant loadings on PC1, PC2 and PC3 were significant (Table 7).

The first principal component (PC1) was strongly correlated with nine of the original variables. The first principal component (PC1) increased with increasing head length, total length, forked length, pre-dorsal length, pre-pelvic length, pre-pectoral length, weight, pre-anal length, pre-orbital length scores (0.99,0 .99, 0.99, 0.98, 0.97, 0.95, 0.94, 0.91 and 0.74 respectively). This suggests that these nine criteria of morphometric measurements varied together. If one increased, then the remaining ones tend to increase as well. Furthermore, the first principal component correlated most strongly with the head length, total length, forked length (0.99) (Table 7).

**Table 7:** Component loadings of the first there principal components derived from PCA for the morphometric and meristic measurements of *E. tetradactylum* from three different stations.

| Morphometric and Meristic Measurements | Component | | |
|---|---|---|---|
| | PC1 | PC2 | PC3 |
| Head length | **.99** | | |
| Total length | **.99** | | |
| Forked length | **.99** | | |
| Pre-dorsal length | **.98** | | |
| Pre-pelvic length | **.97** | | |
| Pre-pectoral length | **.95** | -.12 | .23 |
| Weight | **.94** | | |
| Pre-anal length | **.91** | .25 | -.11 |
| Pre-orbital length | **.74** | | -.16 |
| Caudal fin ray | | **.81** | .21 |
| Anal fin ray | | **.68** | .22 |
| Pectoral fin ray | -.31 | **-.55** | .35 |
| Scales on lateral line | | | **-.94** |
| Eigen-values | 8.08 | 1.53 | 1.2 |
| % of variance | 62.17 | 11.75 | 9.25 |
| Cumulative variance % | 62.17 | 73.92 | 83.17 |

The second principal component (PC2) increased with three of the values, caudal fin ray, anal fin ray and decreasing pectoral fin ray (0.81, 0.68 and -0.55 respectively). The third principal component (PC3) increased with only one of the values, decreasing scales on lateral line (Table 7).

# CHAPTER FIVE

# DISCUSSION

The phenotypic versatility is extremely high in fish and the morphometric and meristic studies give valuable outcomes to recognizing fish stocks (Hossain *et al*., 2010; Ihssen *et al*., 1981). In this experiment, morphometric and meristic characters have been used to analyze the potential differentiation of *Eleutheronema tetradactylum* collected from different habitats of Bangladesh. To elucidate the differences, Correlation, Regression, Cluster Analysis, ANOVA (Analysis of Variance), and (Discriminant Function Analysis) with Principal Component Analysis (PCA) were performed in this experiment.

## 5.1 Variation of meristic counts

Though no significant difference was observed in the case of meristic counts among the populations of *E. tetradactylum* from three habitats and significant morphometric differences were found. There were no significant differences observed in meristic characters such as rays of dorsal, pectoral, pelvic, and anal fins of the population in the present investigation. These outcomes propose that ecological varieties have no impact on these meristic characters. Similarly, there was no variation found in the meristic characters of the populations of *Clupea harengus* sampled from different environmental conditions in the Baltic Sea and *Arius jella* collected from different estuaries of Sri Lanka (Jorgensen *et al*., 2008;Gunawickrama, 2007). These outcomes recommend that varieties emerging in meristic characters may take extensive stretches of development.

## 5.2 Variation of morphometric counts

A (Pearson) correlation was a number between -1 and +1 that indicated to what extent 2 quantitative variables were linearly related. Correlation showed between nine morphometric characters that the correlations in the main diagonal (cells Wt vs Wt, TL vs TL, FL vs FL, HL vs HL, PoL vs PoL, PdL vs PdL, PpL vs PpL, PvL vs PvL and PaL vs PaL) were all equal to 1. The correlations on the main diagonal were the correlations between each variable and itself -which was why they were all 1 and not interesting at all. The Pearson correlation coefficient between morphometric measurements had a statistically significant linear relationship. For example, Weight had a statistically significant linear relationship with other morphometric characters (total length, fork length, head length, pre-dorsal length, pre-pectoral length, pre-pelvic length, and pre-anal length, moderately related and pre-orbital length) (r=0.90, 0.91, 0.91, 0.67, 0.91, 0.88, 0.87, 0.89 and $p < 0.01$). The direction of the relationship was positive, meaning that these variables tend to increase together (i.e., greater weight was associated with greater total length). The strongest correlation was cells TL vs FL, TL vs HL, FL vs HL and HL vs PdL where r = 0.99 and its 2-tailed significance, p = 0.000.

Regression is a straight methodology for displaying the connection between two factors. The dependent variable were different morphometric measurements (weight, fork length, head length, pre-orbital length, pre-dorsal length, pre-pectoral length, pre-pelvic length and pre-anal length) and the independent variable was the total length. A regression was presented between different morphometric measurements with total length. The fork length, head length, pre-orbital length, pre-dorsal length, pre-pectoral length, pre-pelvic length, pre-anal length and weight were explained as 98.4%, 98.2%, 51.1%, 96.1%, 90.4%, 91.6%, 74.1% and 81% respectively predicted by the linear relationship with total length. All the morphometric characters were highly explained by the regression line of total length.

Analysis of Variance (ANOVA) showed that out of nine morphometric measurements only pre-pelvic length (PvL) was significantly different in $p<0.05$ degrees among three groups of populations. Thirteen characteristics found among the samples that showed significant differences in the *E. tetradactylum* population in the two zones of Persian Gulf Based on the truss network (Jaferian *et al*., 2010). also Variations found in morphological differences in diverse populations from different habitats in *Liza abu*, *Rhinomugil corsula*, *Eutropiichthys vacha*, *Labeo calbasu* and in *Heteropneustes fossilis* respectively (Turan *et al*., 2004a; Hossain *et al*., 2015; Parvej *et al*., 2014; Hossain *et al*., 2010; Rahman *et al*., 2014).

The morphological variations among the populations of *E. tetradactylum* were not significant due to their closely related geographical location. It is well known that morphological characteristics can show high plasticity in response to differences in environmental conditions (Swain *et al*., 1991). Therefore, the distinctive environmental conditions of these habitats may underlie the morphological differentiation among the populations from different locations. Such kind of discrimination has been reported among six populations of *Capoeta capoeta gracilis* located in the Aras, Sefidrud, Shirud, Tonekabon, Haraz and Gorganrud river systems in Iran (Samaee *et al*., 2006).

Generally, fish show greater variances in morphological characters both within and between populations than any other vertebrates and are more vulnerable to environmentally induced morphological variations (Allendorf *et al*., 1987; Wimberger 1992). As the phenotypic plasticity of fish is very high, they modify their physiology and behavior to adapt quickly to environmental changes which ultimately change their morphology (Stearns *et al*., 1983). Therefore it might be impossible to detect small morphological differences in fish that are created due to small environmental differences by analyzing only gross morphometric and meristic characters.

Discriminant Function Analysis (DFA) could be a suitable method to differentiate between separate stocks of the same species, which could be of concern to stock management programs (Karakousis *et al*., 1991). This discrimination was ensured by canonical discriminant functions, where pictorial analysis for every specimen was observed. Both discriminant function analysis (DFA) and canonical discriminant functions suggested that the populations of *E. tetradactylum* have a lower degree of phenotypic distinction in the three stations in the case of morphometric characters. Canonical discriminant functions based on morphometric measurements suggested that *E. tetradactylum* populations were similar to the fish samples of three different stations. This inter-population similarity may be attributed due to a closely related geographical location (Allendorf, 1988; Swain *et al*., 1991; Wimberger, 1992). Non-diversity showed in the *E. tetradactylum* population in the two zones of Persian Gulf based on the truss network (Jaferian *et al*., 2010).

In this experiment, DF analysis was conducted to determine the variations among the three stocks of *E. tetradactylum*. The canonical discriminant functions in DFA showed an overlapped in the Patenga, Kattoli and Cox's Bazar stocks of *E. tetradactylum*. In the case of morphometric measurement, the first DF accounted for much more (85.0%) of the among group variability than did the second DF (15.0%). From these observations, it was obvious that the second DF explained much less of the variance than did the first DF. Therefore, the second DF was much less informative in explaining differences among the stocks.

Cluster analysis (Similarity) was carried out for month-wise average values of morphometric measurements of *E. tetradactylum* to understand the relationship among various months. Month-wise morphometric measurements formed four major clusters. The first cluster was formed by four months such as August, September, January, and November. In the first cluster, morphometric characters of August and September were very similar to other months. The second cluster was formed by three months and these were May, December, and October. The third cluster was consisted by the months of April which appeared to be quite different from any of the other months. The last cluster was formed in February and March which were also substantially different from all of the other months at a higher level. The morphometric measurements had changed throughout the year. These differences among the habitats might be happened due to environmental variations. A dendrogram dependent on information of the morphological characters appeared in the number of inhabitants in Japanese charr, *Salvelinus leucomaenis* (Nakamura, 2003); Mullet, *Rhinomugil corsula* (Hossain *et al*., 2015); *Eutropiichthys vacha* (Parvej *et al*., 2014); *Labeo calbasu* (Hossain *et al*., 2010) from various territories uncovered separate stocks were potential because of ecological condition, the separate environment just as hereditary varieties. Therefore, the distinctive environmental conditions of these months may underlie the morphological differentiation among the populations from different locations.

### 5.3 Identification of principle components

The significant traits (morphometric and meristic measurements) were used for principal component analysis (PCA). In this study, characters that were significant at a high level ($p < 0.05$) were considered for principal component analysis (PCA). To examine the suitability of the data for PCA, Bartlett's Test of Sphericity and the Kaiser–Meyer-–Olkin (KMO) measurement was performed. The Bartlett's Sphericity tests hypothesized that the values of the correlation matrix equal zero and the KMO measure of sampling adequacy tests, whether the partial correlation among variables is sufficiently high (Yakubu *et al*., 2011). The KMO insights change somewhere in the range of 0 and 1 and the qualities more prominent than 0.5 are satisfactory (Yakubu *et al*., 2011). The morphometric and meristic characters with an Eigen value above 1 were included in this analysis. It is worth mentioning that a factor loading more than 0.30 is considered significant, 0.40 is considered more significant, and factor loadings 0.50 or above are considered very significantly (Lombarte *et al*. 2012). In our present study, significant factors considered only those factors with loadings greater than 0.5. The first three principal components (PC1, PC2 and PC3) had eigenvalues greater than 1. These three components explained 83.17% of the variation in the data. The scree plot showed that the eigenvalues started to form a straight line after the third principal component. As 83.17% was an adequate amount of variation explained in the data, then the first three principal components had used. . The first (PC1), second (PC2) and third (PC3) principal components accounted for 62.17%, 11.75% and 9.25% of the total variance in turn. Some of the thirteen morphometric and meristic measurements had significant loadings on PC1, PC2 and PC3 were significant. This data clearly confirmed significant differences between these three components where PC1 consisted with morphometric measurements on the other hand PC2 and PC3 consisted with meristic measurements.

Principal Component Analysis (PCA)based on the morphometric and meristic measurement of *E. tetradactylum* from three different habitats shows the value of KMO for overall matrix was 0.78 and the Bartlett's Test of Sphericity also significant ($P<0.01$). The results of KMO and Bartlett's Sphericity test suggest that the sampled data is appropriate to proceed with a factor analysis procedure. The PCA based on thirteen characteristics retained three components with Eigen values more than 1. Yakubu and Okunsebor (2011) found morphometric difference between two Nigerian fish species (*Oreochromis niloticus* and *Lates niloticus*) using principal components and discriminant analysis.

From the above demonstration it is clearly revealed that, the populations of *E. tetradactylum* is morphologically similar and morphological characters slightly varied according to the month in the Chattogram coast.

# CHAPTER SIX

# CONCLUSIONS

Fish and fisheries are the indispensable pieces of Bangladesh. In Bangladesh, fish assumes a focal part in dietary patterns, occupations, and culture. Fish is the most regularly consumed creature source food across all populace gatherings. Yet, this area is confronting an expanding danger due to overfishing, habitat degradation, contamination in the waterways and the unpredictable utilization of agrochemicals, presentation of exotic species, absence of appropriate territory, decreased fecundity, etc. To satisfy the interest of its expanding pressure, feasible and proficient stock administration is important.

For appropriate conservation and management of any population, it is had to think about their biology and populace structure. It is likewise crucial for select hereditarily prevalent stocks alongside better features for, both successful aquaculture and open-water management. This investigation has given significant morphological data that can be utilized to separate this *E. tetradactylum* all the more decisively among groups and species. This examination was not intended to explore the real reason because of which morphological variety happens in various supplies of similar species and to decide if the morphological varieties are earth prompted or because of hereditary components or both. Examination in such a manner might be started based on the current discoveries. The discoveries of the study would fill in as primary information of stock management and enable efficient management strategies for the particular supplies of *E. tetradactylum* populaces to make its fishery sustainable and create suitable protection plans in the not-so-distant future. The authors trust that the data got from the current investigation will be useful for fisheries, scholars, and taxonomist concerned about these intriguing fish species.

# CHAPTER SEVEN

## RECOMMENDATIONS AND FUTURE PERSPECTIVES

Since the identification of populaces and their availability between one another is a significant point for sustainable management and protection of species, the utilization of morphological characters as benchmark data seems promising in this area. The current examination manages the cost of rudimentary data about the variety of *Eleutheronema tetradactylum* populaces in various water territories of Bangladesh and it suggests that the utilization of morphometric characters and support estimations create dependable data for stock separation of *E. tetradactylum*.

Notwithstanding, the current examination had a few impediments regarding a predetermined number of individuals and populations. The aftereffect of the current examination may be utilized as a rule for additional investigation with more examples and for more explanation and adaptation. Lastly, the following focuses may be considered for sustaining *E. tetradactylum* species in Bangladesh.

a) Systematic investigation may be directed with more individuals from various areas.

b) DNA level work (RAPD, RFLP, microsatellite, and so on) may be led to more explanation and compliance of hereditary variety.

c) Breeding ground of *E. tetradactylum* species ought to be secured.

d) Sperm cryopreservation of *E. tetradactylum* species ought to be drawn closer for both preservation and hydroponics.

e) Finally, legitimate preservation plans ought to be formed.

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# APPENDICES

**Comparative studies on *Eleutheronema tetradactylum* collected from three (03) different station for morphometric characters**

### A. Mean and Standard deviation of morphometric characteristics

| Characters | Mean | Std. Deviation | N |
|---|---|---|---|
| TL | 34.458 | 5.5862 | 90 |
| SL | 25.980 | 4.2113 | 90 |
| FL | 32.232 | .3942 | 90 |
| HL | 8.1451 | .08592 | 90 |
| PoL | 1.1301 | .08189 | 90 |
| PdL | 10.0624 | .15713 | 90 |
| PpL | 7.5397 | .19563 | 90 |
| Pvl | 10.8211 | .23879 | 90 |
| PaL | 15.5693 | .86072 | 90 |

### B. Group Statistics for Morphometric Characters

| Station | Characters | Mean | Std. Deviation | Valid N (list wise) | |
|---|---|---|---|---|---|
| | | | | Unweighted | Weighted |
| Patenga, Chattogram | TL | 34.6500 | 2.44636 | 30 | 30.000 |
| | SL | 26.1567 | 1.81273 | 30 | 30.000 |
| | FL | 32.2110 | .19304 | 30 | 30.000 |
| | HL | 8.1384 | .09113 | 30 | 30.000 |
| | PoL | 1.1459 | .06392 | 30 | 30.000 |
| | PdL | 10.0441 | .13977 | 30 | 30.000 |
| | PpL | 7.5249 | .14548 | 30 | 30.000 |
| | PvL | 10.7987 | .16919 | 30 | 30.000 |
| | PaL | 15.5037 | .75282 | 30 | 30.000 |
| Kattoli coast, Chattogram | TL | 34.3533 | 7.43314 | 30 | 30.000 |
| | SL | 25.8767 | 5.60712 | 30 | 30.000 |
| | FL | 32.3397 | .31001 | 30 | 30.000 |
| | HL | 8.1519 | .07447 | 30 | 30.000 |
| | PoL | 1.1288 | .11068 | 30 | 30.000 |
| | PdL | 10.1062 | .19187 | 30 | 30.000 |
| | PpL | 7.6079 | .15873 | 30 | 30.000 |
| | PvL | 10.8367 | .32725 | 30 | 30.000 |
| | PaL | 15.5015 | .67085 | 30 | 30.000 |
| Cox's Bazar | TL | 34.3700 | 5.87168 | 30 | 30.000 |
| | SL | 25.9733 | 4.38036 | 30 | 30.000 |
| | FL | 32.1437 | .56817 | 30 | 30.000 |
| | HL | 8.1450 | .09334 | 30 | 30.000 |
| | PoL | 1.1157 | .06140 | 30 | 30.000 |
| | PdL | 10.0369 | .12814 | 30 | 30.000 |
| | PpL | 7.4863 | .25121 | 30 | 30.000 |
| | PvL | 10.8279 | .19611 | 30 | 30.000 |
| | PaL | 15.7026 | 1.10871 | 30 | 30.000 |

| | | | | | |
|---|---|---|---|---|---|
| Total | TL | 34.4578 | 5.58624 | 90 | 90.000 |
| | SL | 26.0022 | 4.19296 | 90 | 90.000 |
| | FL | 32.2314 | .39412 | 90 | 90.000 |
| | HL | 8.1451 | .08592 | 90 | 90.000 |
| | PoL | 1.1301 | .08189 | 90 | 90.000 |
| | PdL | 10.0624 | .15713 | 90 | 90.000 |
| | PpL | 7.5397 | .19563 | 90 | 90.000 |
| | PvL | 10.8211 | .23879 | 90 | 90.000 |
| | PaL | 15.5693 | .86072 | 90 | 90.000 |

### C. Tests of Equality of Group Means

| Characters | Wilks' Lambda | F | df1 | df2 | Sig. |
|---|---|---|---|---|---|
| TL | .999 | .026 | 2 | 87 | .974 |
| SL | .999 | .034 | 2 | 87 | .967 |
| FL | .957 | 1.957 | 2 | 87 | .148 |
| HL | .996 | .182 | 2 | 87 | .834 |
| PoL | .977 | 1.028 | 2 | 87 | .362 |
| PdL | .960 | 1.794 | 2 | 87 | .172 |
| PpL | .932 | 3.173 | 2 | 87 | .047 |
| PvL | .995 | .205 | 2 | 87 | .815 |
| PaL | .988 | .535 | 2 | 87 | .588 |

### D. Eigenvalues

| Function | Eigenvalue | % of Variance | Cumulative % | Canonical Correlation |
|---|---|---|---|---|
| 1 | .181[a] | 85.0 | 85.0 | .392 |
| 2 | .032[a] | 15.0 | 100.0 | .176 |
| a. First 2 canonical discriminant functions were used in the analysis. | | | | |

### E. Wilks' Lambda

| Test of Function(s) | Wilks' Lambda | Chi-square | df | Sig. |
|---|---|---|---|---|
| 1 through 2 | .820 | 16.455 | 18 | .561 |
| 2 | .969 | 2.623 | 8 | .956 |

### F. Standardized Canonical Discriminant Function Coefficients

| Characters | Function | |
|---|---|---|
| | 1 | 2 |
| TL | 10.557 | -1.037 |
| SL | -10.705 | 1.414 |
| FL | .432 | -.182 |
| HL | -.147 | -.085 |
| PoL | .189 | .872 |
| PdL | .309 | -.128 |
| PpL | .644 | .004 |
| PvL | -.103 | -.007 |

| | | |
|---|---|---|
| PaL | -.108 | -.416 |

**G. Structure Matrix**

| Characters | Function | |
|---|---|---|
| | 1 | 2 |
| PpL | .632* | -.124 |
| FL | .497* | -.063 |
| PdL | .455* | -.339 |
| PoL | .115 | .814* |
| PaL | -.209 | -.369* |
| PvL | .055 | -.360* |
| HL | .094 | -.284* |
| SL | -.030 | .138* |
| TL | -.010 | .135* |

Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions
Variables ordered by absolute size of correlation within function.
*. Largest absolute correlation between each variable and any discriminant function

**H. Functions at Group Centroids**

| Station | Function | |
|---|---|---|
| | 1 | 2 |
| Patenga, Chattogram | -.074 | .247 |
| Kattoli coast, Chattogram | .546 | -.097 |
| Cox's Bazar | -.472 | -.151 |

Unstandardized canonical discriminant functions evaluated at group means

**I. Classification Function Coefficients**

| Characters | Station | | |
|---|---|---|---|
| | Patenga, Chattogram | Kattoli coast, Chattogram | Cox's Bazar |
| TL | -65.909 | -64.687 | -66.579 |
| SL | 78.712 | 77.032 | 79.583 |
| FL | 239.730 | 240.578 | 239.476 |
| HL | 1220.584 | 1219.872 | 1221.647 |
| PoL | 68.290 | 66.062 | 63.137 |
| PdL | -183.192 | -181.679 | -183.654 |
| PpL | 203.466 | 205.549 | 202.117 |
| PvL | -62.993 | -63.247 | -62.811 |
| PaL | -2.156 | -2.068 | -1.915 |
| (Constant) | -8244.253 | -8291.330 | -8229.447 |

Fisher's linear discriminant functions

**J. Classification Results[a,c]**

| Function | Count | Station | Predicted Group Membership | | | Total |
|---|---|---|---|---|---|---|
| | | | Patenga, Chattogram | Kattoli coast, Chattogram | Cox's Bazar | |
| Original | Count | Patenga, Chattogram | 18 | 7 | 5 | 30 |
| | | Kattoli coast, Chattogram | 15 | 11 | 4 | 30 |
| | | Cox's Bazar | 14 | 9 | 7 | 30 |
| | % | Patenga, Chattogram | 60.0 | 23.3 | 16.7 | 100.0 |
| | | Kattoli coast, Chattogram | 50.0 | 36.7 | 13.3 | 100.0 |
| | | Cox's Bazar | 46.7 | 30.0 | 23.3 | 100.0 |
| Cross-validated[b] | Count | Patenga, Chattogram | 14 | 8 | 8 | 30 |
| | | Kattoli coast, Chattogram | 18 | 7 | 5 | 30 |
| | | Cox's Bazar | 18 | 9 | 3 | 30 |
| | % | Patenga, Chattogram | 46.7 | 26.7 | 26.7 | 100.0 |
| | | Kattoli coast, Chattogram | 60.0 | 23.3 | 16.7 | 100.0 |
| | | Cox's Bazar | 60.0 | 30.0 | 10.0 | 100.0 |

a.40.0% of original grouped cases correctly classified.
b. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.
c.26.7% of cross-validated grouped cases correctly classified.

**K. KMO and Bartlett's Test**

| | | |
|---|---|---|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy. | | .797 |
| Bartlett's Test of Sphericity | Approx. Chi-Square | 591.730 |
| | df | 78 |
| | Sig. | .000 |

**L. Total Variance Explained for Morphometric and Meristic Characters**

| Component | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|
| | Total | % Of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 8.082 | 62.172 | 62.172 | 8.082 | 62.172 | 62.172 |
| 2 | 1.527 | 11.746 | 73.918 | 1.527 | 11.746 | 73.918 |
| 3 | 1.202 | 9.247 | 83.165 | 1.202 | 9.247 | 83.165 |
| 4 | .793 | 6.096 | 89.262 | | | |
| 5 | .650 | 4.998 | 94.260 | | | |
| 6 | .432 | 3.324 | 97.584 | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 7 | .129 | .994 | 98.578 | | | |
| 8 | .082 | .634 | 99.212 | | | |
| 9 | .051 | .389 | 99.601 | | | |
| 10 | .028 | .213 | 99.814 | | | |
| 11 | .013 | .098 | 99.912 | | | |
| 12 | .008 | .063 | 99.975 | | | |
| 13 | .003 | .025 | 100.000 | | | |
| Extraction Method: Principal Component Analysis. | | | | | | |

**M. Component Matrix[a] for Morphometric and Meristic Characters**

| Characters | Component | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Head length | .988 | | |
| Total length | .986 | | |
| Forked length | .986 | | |
| Pre-dorsal length | .981 | | |
| Pre-pelvic length | .965 | | |
| Pre-pectoral length | .948 | -.124 | .227 |
| Weight | .942 | | |
| Pre-anal length | .906 | .246 | -.112 |
| Pre-orbital length | .742 | | -.158 |
| Caudal fin ray | | .814 | .207 |
| Anal fin ray | | .676 | .216 |
| Pectoral fin ray | -.308 | -.549 | .346 |
| Scales on lateral line | | | -.936 |
| Extraction Method: Principal Component Analysis. | | | |
| a. 3 components extracted. | | | |

**N. Rotated Component Matrix[a] for Morphometric and Meristic Characters**

| Characters | Component | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Head length | .992 | | |
| Total length | .989 | | |
| Pre-dorsal length | .985 | | |
| Forked length | .985 | | |
| Pre-pectoral length | .969 | | -.150 |
| Pre-pelvic length | .964 | | |
| Weight | .927 | | .190 |
| Pre-anal length | .883 | .220 | .257 |
| Pre-orbital length | .724 | | .216 |
| Caudal fin ray | | .840 | |
| Anal fin ray | | .707 | |
| Scales on lateral line | | -.150 | .930 |
| Pectoral fin ray | -.256 | -.458 | -.492 |
| Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.[a] | | | |
| a. Rotation converged in 4 iterations. | | | |

**O. Component Transformation Matrix**

| Component | 1 | 2 | 3 |
|---|---|---|---|
| 1 | .995 | .006 | .103 |
| 2 | -.029 | .974 | .227 |
| 3 | .099 | .228 | -.969 |
| Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. | | | |

**P. Component Score Coefficient Matrix**

| Characters | Component | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Weight | .108 | .030 | .087 |
| Total length | .128 | -.040 | -.046 |
| Forked length | .124 | -.050 | -.015 |
| Head length | .129 | -.016 | -.061 |
| Pre-orbital length | .079 | -.067 | .128 |
| Pre-dorsal length | .129 | .004 | -.067 |
| Pre-pectoral length | .138 | -.035 | -.189 |
| Pre-pelvic length | .123 | .016 | -.026 |
| Pre-anal length | .098 | .137 | .138 |
| Pectoral fin ray | .001 | -.285 | -.365 |
| Anal fin ray | -.007 | .472 | -.075 |
| Caudal fin ray | .000 | .558 | -.046 |
| Scales on lateral line | -.067 | -.136 | .765 |
| Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Component Scores. | | | |

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