CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Bangladesh is a major fish producing nation that is endowed with vast coastal and marine resources along the northern Bay of Bengal (Barua *et al*., 2014). The country has a marine area of 1,65,887 km^2 along with 710 km long coastline expanding from the tip of Teknaf in the Southeast to the west coast of Satkhira (Hossain, 2004). Due to the geographical position and climatic condition, Bangladesh also has the advantage of being as one of the highly productive coastal areas. The coast harbors a number of soft substrate ecosystem that are highly productive and provides ecologically critical habitats like mangroves, salt marshes, sandy beach and mudflats (Kabir, 2000). This coastal water of the Bay of Bengal has a high potential for fish production. Fisheries sector is now playing a significant role in the economy of the country, with an outstanding ratio of capture and culture production. By providing healthy and quality animal protein, this sector contributes highly to food safety. About 60% of our daily protein intake is being supplemented by different kinds of fishes. This sector provides 3.57% to our national GDP and around 25.30% to the agricultural GDP. According to the Yearbook of fisheries statistics 2017-18, the total fisheries production was 42.77 lakh MT in FY 2017-18, of which around 44% was obtained from capture fishery (DoF, 2017-18).

Being a coastal rich country, coastal fish and fisheries portrait one of the major parts of the total country fisheries production. According to Bangladesh Bureau of Statistics 2004, the coastal zone of Bangladesh consists of 32% (47,201 km^2) of the total landmass of the country with 19 coastal districts of which 11 meets the sea or lower estuary directly and among the districts four belong to Chattogram division and solely owns 10,407 km^2 (approximately 22%) of the total coastal area. As a leading coastal district, Chattogram plays a crucial role in the commercial industry of fishing. This district is closely connected to the Bay of Bengaland provides a large proportion of the marine area's capture rate. A significant number of commercially important fish species are found in the coastal harbor of Chattogram region (DoF, 2017-18). However, inspite of being a rich ecosystem the coastal waters of Bay of Bengal are probably one of the most least studied areas in the world. Even though, this is one of the potential areas for stock improvement, no recent and comprehensive knowledge is available on different biological and ecological aspects of the coastal and marine fisheries, which, to some extent limit the utilization and management of the resources (Islam, 2003). Reports on experimental studies on specific aspects of biology and life history of commercially important fish species are rarely available.

1.2 Morphological systematic

Identification of a species is a preliminary step towards any research work and it also plays a major role for the behavioral study. Morphological characteristics are mainly useful for identifying a species and taxonomic study (Brraich and Akhter, 2015). Furthermore, understanding the function of a morphological feature is a foundation for practical use in taxonomy and ecology. Morphological systematic is a term that defines the identification of any specimen using morphometric measurements and meristic counts (Nayman, 1965). Whereas morphometric characters are the measurable characters and meristic characters are the countable characters of a fish. These morphological measurements, meristic counts, shape and size provide different kinds of data that are useful for taxonomic status (Ihssen *et al*., 1981). Generally, fish are more susceptible to environmentally induced morphological variations and elucidates greater variances in morphological traits both within and between species than other vertebrates.

Morphometrics is the study of quantitative analysis of living organisms such as size and shape, which can be attained by using linear measurements and these studies are also necessary for understanding the taxonomy as well. Therefore, within the species, morphometric studies are strong tools for measuring discreetness (Naeem and Salam, 2005), essential for delimitation of diverse populations within species in same geographical area (Mahfuj *et al*., 2019), and useful aspects of the fisheries conservation, management and evolutionary context (Turan *et al*., 2005). In addition to, the meristic characters of a fish are occurred in series which are mostly used for differentiation of species as well as populations. The relationship between different morphological characters are considered obligatory for estimating various physiological and morphological aspects such as length and age structure, growth rate and other important parameters of fish population dynamics (Kolher *et al*., 1995).

1.3 Length-weight relationship

When any fish family or population is studied, the growth of species is considered as an important parameter. In fisheries studies the length weight data are used to estimate the growth rate and the length-weight relationship (LWR) is considered as a very important parameter for understanding the growth dynamics of a fish population (Bintoro *et al*., 2019). By using the knowledge, the growth pattern of a particular species can be determined and the growth pattern reflects the condition of the species in a region. The length-weight relationship plays a significant role in fishery resource management and for comparing morphological aspects and life history of fish populations inhabiting in different regions (Martin, Kuppan and Kalaichelvi, 2016). In both fisheries biology and fisheries management, length-weight relationship is widely used (Froese and Pauly, 2006) and it is essential in order to stabilize the taxonomic characters of the species (Pervin and Mortuza, 2008).

1.4 Importance of morphological analysis

Both the morphometric and meristic features can be altered under the environmental parameters impact and the cause of alteration may range from the intraspecific to variability. These morphological traits and their relationships between body parts of fish can be used to assess the condition of individuals and to identify possible varieties between different unit stocks of same species. Anatomical and physiological characters of an organism could be changed by various environmental and genetic factors that are liable for reflecting the phenotypic plasticity through a certain time (Barlow, 1961).

Under the basic notion of evaluation, every species is believed to be passing through micro and macro evolutionary process resulting in the expression of significant genetic variations at the levels of the species-specific chromosome morphology or structure, gene-controlled protein structure and polygene controlled morphometrics and metrics (Ayala and Keiger, 1980). The anatomy of fish has traditionally been the key source of taxonomic and evolutionary studies. Often, as an order, specimens originating from different locations vary from one another in morphology. The variation in its traits or characters may be related with the habit and habitat among the variants of this species (Cavalcanti *et al*., 1999), and the shape and structures are singular to the species, which is determined by the evolutionary background of the fish and the physical and chemical characteristics of water. For the management of many stocks, it is necessary to have information on the sub-stock structure in fish populations.

1.5 Significance of this research:

The main focus of this study has been the family sharing species of Hilsha, the national fish of Bangladesh under the Clupeidae family. This family is the most valuable fish family of food fishes around the world due to its high demand in human consumption (Rajan, 2018). Clupeidae is a principle family of the order Clupeiformes and contains at least 66 genera and 222 species worldwide with several popular species supporting large commercial fisheries (Ditty, Farooqi and Shaw, 2006). A study shows that around 20 species of Clupeidae family consisting most commonly *Gudusia chapra*, *Corica soborna*, *Sardinella sp, Tenualosa toli*, *Tenualosa ilisha* and *Hilsha kelee* are found in the marine waters of Bangladesh (Fishbase) . Bangladesh has an annual production of *Tenualosa ilisha*of 12.09% among the production from inland and marine fisheries combined (FRSS, 2018), with an estimated annual production of 517,198 tons. This provides 1.0% to the national GDP to support the livelihoods of 1.2 million Hilsha fishers in Bangladesh (FRSS 2018). As this family of fish species provides a significant harvest percentage, we need to ensure a proper management concern to this family. There are some researches and survey conducted on Hilsha production and abundance around the country but till now no scientific study has done regarding the whole family of Clupeidae. Also, in Bangladesh there is no recent data set or no scientific study has been done on the availability of the species of Clupeidae family in the Chattogram coastal area and their distribution and diversity along the coastal region. A large portion of fish species in the coastal belt of south-eastern Bangladesh remain without systematic assessment due to insufficient scientific information and research. There is no continuous stock structure information available for Clupeidae family of Bangladesh. To fulfill the research gap and to initiate other related studies on Clupeidae fish family in the coastal region, the present research was very crucial.

1.6 Aims and objectives:

This study aims at investigating the morphological approach to identify the fish species from Clupeid family and determine their structure, diversity and abundance of stock along the Chattogram coast. It will experimentally test the variation among different morphological characteristics to update the stock information. The main objectives of this research addressed here in the study are as follows:

- ✓ To identify all the available species under Clupeidae family determining their morphometric and meristic characters
- ✓ To determine the seasonal variation of availability and the regional distribution of the species under Clupeidae family

CHAPTER TWO

REVIEW OF LITERATURE

Before conducting a research and for better understanding the whole procedure, it is quite essential to study the previously conducted related research. The motive of this chapter is to review the past researches related to the present study. Different relevant works has been done on the morphometric and meristic analysis of the fish species both in Bangladesh and worldwide. But little was done on Clupeidae family in Bangladesh coast. The present study is aimed to determination the morphological variation among the different fish species under the Clupeidae family including their distribution and diversity in the Chattogram coastal region.

2.1 Morphological analysis of *Tenualosa sp.*:

A lot of work has been done on the morphometric and meristic analysis of *Tenualosa sp.* worldwide. Das *et al.* (2020) carried out a land mark based morphometric with truss measurements together and meristic variations in two congeneric Hilsha populations, *Tenualosa ilisha* and *Tenualosa toli* from Bangladesh water bodies, which provide useful information about the morphological differentiation which will be helpful in further investigation.

Vaisakh *et al.* (2020) found significant morphological variations among three distinct tropical habitat,i.e; rivers, estuary and resevoir in West Bengal, where the populations of *Tenualosa ilisha* were geographically isolated. On the other hand morphometric measurements between the two species of *Tenualosa* sp. were carried out by Tint, Ko and Oo (2019) to ascertain the possibility of morphological diversification in Malaysia.

The morphometric, meristic and proximate composition between freshwater and marine Hilsa fish were studied by Ara *et al.* (2019) to compare the marine and freshwater Hilsa. Jassim, Ahmed and Ali (2012) collected some young Hilsha Shad, *Tenualosa ilisha* from three different sites and carried out some statistical analysis. The result showed insignificant differences in the ratio of some statistical analyses except some morphometric ratio. Narejo, Lashari and Jafri (2008) carried out a comparative study of morphometric and meristic differences between two types of *Tenualosa ilisha* from river Indus in Pakistan. Significant intertype differences in six morphometric measurements and seven meristic characters were found in the study.

2.2 Length-weight relationship of *Tenualosa sp.*:

The length-weight relationship of clupeid fish from Iran was studied by Dizaj *et al.* (2020). The result of the study showed that the maximum value of slope 'b' is 3.48 for *Tenualosa ilisha* which indicated the length-weight relationship was highly correlated and significant.

The length-weight relationship of *Tenualosa ilisha* on season-wise was studied by Bhakta *et al.* (2019). The result showed that the species had positive allometric growth in moonson and negative allometric growth in winter. The values of the relationship were highly significant.

A research on the length-weight relationship of Hilsha Shad, *Tenualosa ilisha* was conducted by Machrizal *et al.* (2019) in bilah river, Indonesia. The result showed that the length-weight relationship was negatively allometric, i.e., the b value was less than 3 and the growth pattern was firmly related with light penetration.

Flura *et al.* (2015) held a research on Length-weight relationship of hilsa, *Tenualosa ilisha* fishes in Meghna river, Bangladesh. All the length-weight relationship were found highly correlated. The study of Narejo, Lashari and Jafri (2008) also revealed differences between summer and winter types of *T. ilisha* in length-weight relationship, condition factor values and GSI values.

Ahmed, Sharif and Latifa (2008) held a research on age, growth and mortality of *Tenualosa ilisha*. The calculated length-weight relationship for combined sexes indicated negative allometric growth of the species. Amin *et al.* (2005) studied on Length-weight relationship of *Tenualosa ilisha* in Bangladesh water. The result of the study indicated that there was highly significant relationship between length and weight and the species had positive allometric growth pattern in the Bangladesh water.

2.3 Morphological analysis of other Clupeidae fish species:

There was less knowledge on the morphometric variability, though *Amblygaster clupeoides* is a reef-associated oceanic species and having long-standing socioeconomic as well as ecological importance. Due to this reason Hanif *et al.* (2019) choosed to study the morphometric variability of *Amblygaster clupeoides*. They employed the truss network technique. The investigation demonstrated that the population of the east coast was morphometrically different from other populations. Their study area was the Bay of Bengal coast in Bangladesh.

Hata and Motomura (2019) described a new species of sardine that was *Sardinella pacifica*, on the basis of 21 specimens collected from the Philippines. The variations in the morphometric and meristic characteristics among five populations of *Sardinella lemuru* from waters of Bali Strait, northern and southern-east Java and their relation to the environment.

A study suggested that environment factors play an important role in controlling the variety of fish phenotypes, which was carried out by Sartimbul *et al.* (2018). Echem (2016) conducted a research on the shape variation of *Sardinella lemuru* where the geometric morphometric analysis was used. During that study, total 120 samples were used, sexes were determined by direct gonadal examination. The specimen responded and adapted to environmental change by modifying their morphology and behavior, probably for their phenotypic plasticity.

The morphometrics of the Indian Oil Saredine, *Sardinella longiceps* by Sukumaran *et al.* (2016) to found out the implication of adaptive variation. Shah *et al.* (2014) investigated 14 morphometric characters of 917 specimens to conduct biometric analysis of *Sardinella longiceps* along Ratnagiri coast of Maharashtra.

Aisyah and Syarif (2018) studied with an aim to analyze and determine the differences in morphometric and meristic character of *Anodontostoma sp.* between Kelabat Bay and Tukak Strait. The results showed 52.17% similarities in the 23 morphometric multivariance analysis of Selangat fish. No significant difference was found in meristic characteristics between two stocks.

Research work of morphometric and meristic characters on *Gudusia chapra* and *Gonalosia manmina* were done by Azadi and Rahman (2008) to detect the plastic and non-plastic characters. They found highly significant ($P<0.001$) linear relationshipd in all cases between different morphometric characters. From their study they suggested to restrict the identification manuals for the fishes to smaller geographical regions which opinion was also given by Johal *et al.* (1989).

Turan (2000) studied on the *Clupea harengus* in the North-East Atlantic. This study investigated the morphological structure on the basis of 2 sets of phenotypic markers, otolith shape and meristics of herring populations. The detection of the pattern of phenotypic discreteness with meristics and analysis of otolith shape suggested a direct relationship between the extent of phenotypic divergence and the geographic separation of the populations, which was actually indicated that geographic separation limits migration between the populations.

2.4 Length-weight relationship of other Clupeidae fish species:

A research on *Sardinella longiceps* from Baluchistan Coast, Pakistan was conducted by Baset *et al.* (2020). The estimated value of slope b was 2.25 which indicated the negative allometric growth of the experimented species.

Binotro *et al.* (2019) studied on analysis of population dynamics of *Sardinella fimbriata* from Indonesia. The study indicated the negative allometric growth for length-weight relationship. The lower counts of lateral scales, pseudo branchial filaments, and post pelvic scutes and a shorter lower jaw helped in distinguishing the new species.

Abdussamad *et al.* (2018) carried out a research on systematics of *Escualosa thoracata*. The estimated 'b' value from length-weight relationship for unsexed population showed that the growth pattern was allometric.

Ahirwal *et al.* (2017) conducted a research on biometric analysis of *Sardinella longiceps* from Mumbai coast. The result of the length-weight relationship revealed positive allometric growth for male, female and pooled data.

A study on growth parameter of *Sardinella fimbriata* was carried out by Rilani, Mulyanto and Setiohadi (2017). The range of b value was 2.62750-2.69449 and

2.63959-2.72040 for male and female respectively which showed the negative allometric growth pattern.

Biometric analysis of white sardine, *Escualosa thoracata* was carried out by Gurjar *et al.* (2017). The result showed that in case of male, female and combined sex the 'b' value was less than 3 which indicated the allometric growth pattern of the species.

Kudale, Rathod and R (2016) studied on length-weight analysis of *Sardinella fimbriata* from karwar coast. The length-weight relationship revealed negative allometric growth for both male and female fishes in the coast.

Length-weight relationship from a coastal artisanal fishery, southern Bangladesh was investigated by Siddik *et al.* (2016). According to the finding of the study *Anodontostoma chacunda* had isometric growth and it's length and weight was significantly correlared.

Johny (2016) investigated two indigenous freshwater species, *Dayella malabarica* and *Hyporhamphus limbatus* both of which are of great demand as food fish as well as in ornamental fish industry. The work was intended to study the length-length relationship and meristic characteristics. The conducted study helped in revealing more about stock for conducting sustainable fisheries in ornamental fish industry.

Dar *et al.* (2015) conducted a research on length-weight relationship of Clupeidae from Mumbai Coast. The value of b was 3.23, 2.95 and 1.99 for the *Escualosa thoracata, Sardinella longiceps, Anodontostoma chacunda* respectively. The correlation between length and weight was significantly positive which indicated that throughout the life those species maintained their shape. Al-Jufaili (2014) studied on reproductive biology of *Sardinella longiceps* and the length–weight relationship equations analyzed by the study confirmed the the growth pattern of the species was allometric in the study area.

A research on population biology of *Gudusia chapra* in the Old Brahmaputra River of Bangladesh was held by Ahamed *et al.* (2014). This study showed the growth pattern of the species was negatively allometric, while the analysis of covariance showed significant differences ($p<0.001$) in slope and intercept between the sexes.

CHAPTER THREE

MATERIALS AND METHODS

In this section, the general research design and the procedures followed for the data collection and analysis of the experiment are described in detail.

3.1 Study area and sampling stations: The research was mainly based on the availability of fish species from Clupeidae family in Chattogram coastal area. For this reason Chattogram coastal area was the main focused area of the research. To make the sample collection easier the whole study area was segmented into three selective sampling stations.

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 $22^0$32'97.36"N and longitude $91^0$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.

Sampling station 2 (Kattoli coast, Chattogram): Adjacent to Sagorika beach, Halishohor, Chattogram including Foillatoli Bazar, Bectech Bazar, Kornel Hat Bazar were investigated under this sampling station 2. The positioning of this station is latitude $22^0$34'46.15"N and longitude as $91^0$77'87.25"E.

Sampling station 3 (Cox's Bazar): Sampling station 3 includes the region of BFDC Landing Center, coastal sites of CVASU field station and other adjacent coats of Cox's Bazar. The geographical location of station 3 is $21^0$44'53.36"N latitude and $91^0$97'35.1"E longitude.

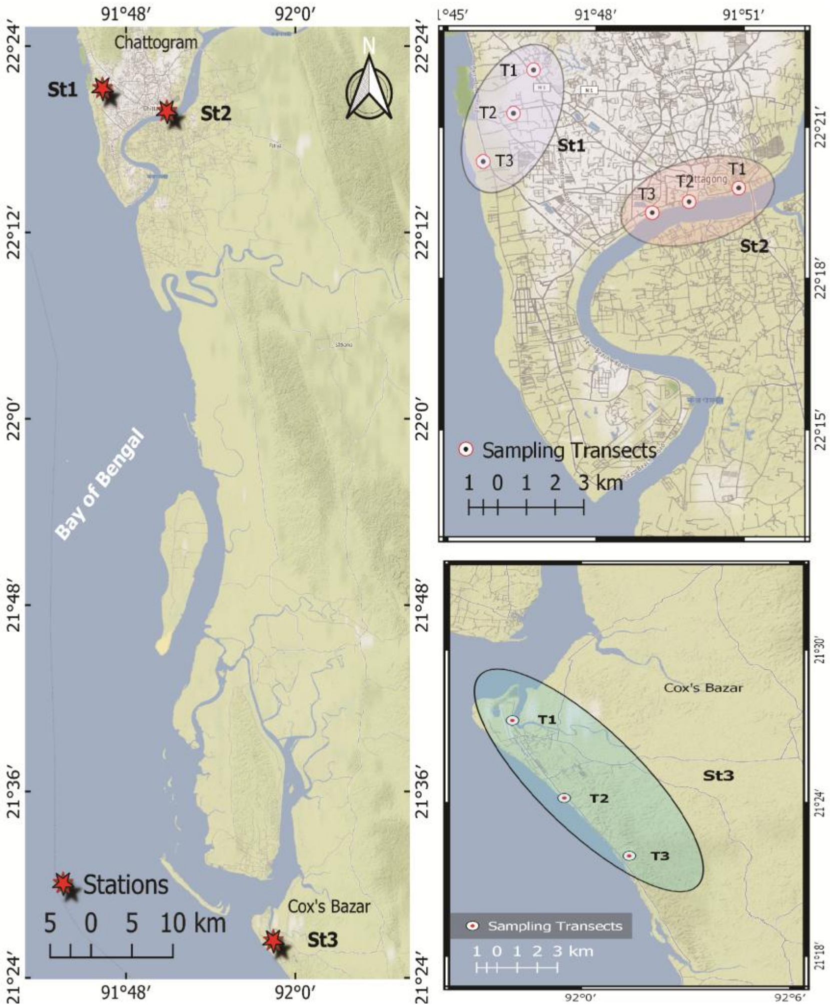


Figure 1: Sampling stations

3.2 Sampling period and sampling frequency: The sampling of fish was carried out for a period of one year from February 2019 to January 2020 by regular visits to the sampling stations at monthly intervals. Sampling from each sampling station was done at the same date of every month. All samplings of a month were also done maintaining 1-2 days interval from one sampling to another sampling.

3.3 Collection of fish samples: The fish specimens were collected by following "Simple random sampling" method. Fishes which showed the basic phenotypic characteristics of the Clupeidae family were considered as sample species. During sampling the fishes with fresh appearance and having all fins and scales were taken as samples. 3-5 individuals of each species were collected in each sampling.

Basic phenotypic characteristics of Clupeidae family which were considered during sample collection:

- Torpedo shaped body
- Laterally compressed
- Dark shading on back and bright silvery sides
- Ventral keel of scutes
- Single dorsal fin
- Teeth usually absent or very weakly developed
- Fins have no spine
- Forked caudal fin

Figure 2: Sample collection

3.4 Sample transportation: After collecting all the specimens were immediately preserved in ice box. In the ice box, and ice to fish ratio of 1:2 was generally maintained. But the ratio could be changed according to the situations such as temperature, distance, traffic jam ect. The samples were then transported to the Oceanography Laboratory of Faculty of Fisheries of Chattogram Veterinary and Animal Sciences University where morphometric and meristic analysis was carried out.

Figure 3: Samples preserved in ice box

Figure 4: Ice box

3.5 Laboratory analysis: All the collected fish specimens were analyzed in fresh condition immediately after arriving at the laboratory. At first the total length and weight of each sample was measured and recorded. The weight was measured in gram by electric weighing machine. A total of 18 morphological characters were measured and recorded including 10 morphometric measurements, 6 meristic counts and 2 apparent body characteristics.

Figure 5: Samples for laboratory analysis

Figure 6: Length and weight measurement of the sample

3.6 Morphometric measurements: The ten morphometric characters were measured by using measuring board and digital slide calipers. Total length, forked length and standard length was determined by measuring board consisting essentially of a wooden piece with a central scale. The fish body was straightened along the central scale and the reading was taken from the scale. The other morphometric characters were measured by digital slide calipers. All the morphometric measurements were recorder in centimeter.

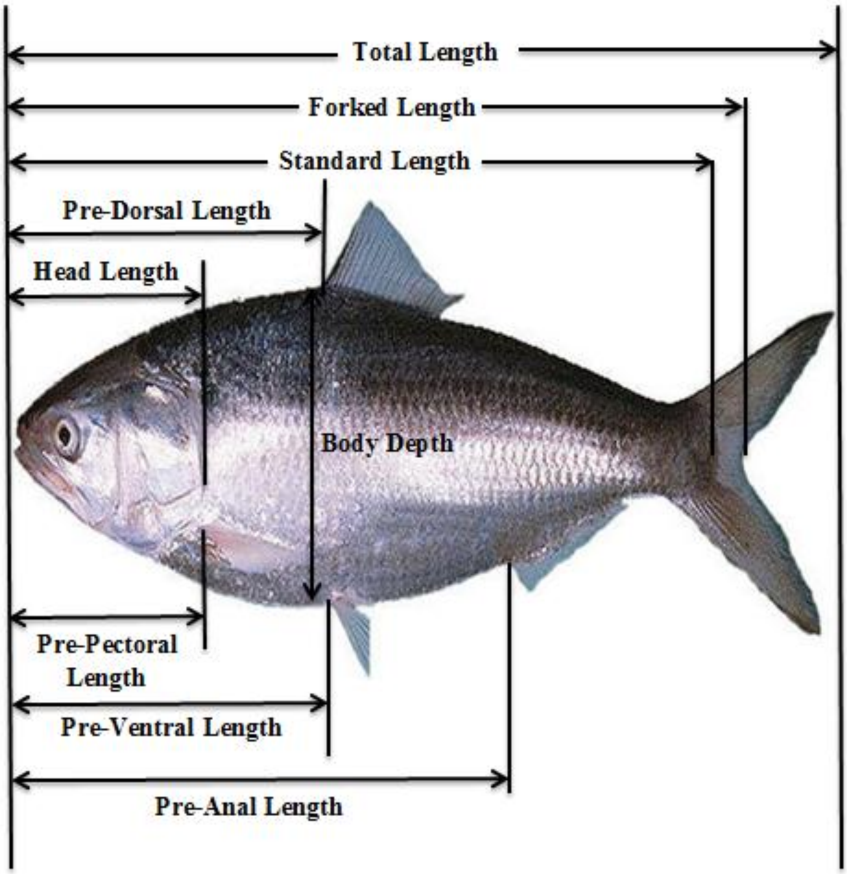


Figure 7: Overview of different morphometric indices

The following morphometric characters were taken into consideration for the study-

- Total Length (TL): Distance from the tip of the mouth to the ending point of the caudal fin.
- Standard Length (SL): Distance from the tip of the mouth to the base of the caudal fin.
- Forked Length (FL): Distance from the tip of the mouth to the point of bifurcation of caudal fin.
- Head Length (HL): Distance from the tip of the mouth to the rear end of the operculum.
- Body Depth (BD): Maximum distance from the dorsal part to the ventral part of fish body.
- Pre-orbital Length: Distance from the tip of the mouth to the front margin of the eye orbit.

- Pre-dorsal Length: Distance from the tip of the mouth to the origin of the dorsal fin.
- Pre-pectoral Length: Distance from the tip of the mouth to the origin of the pectoral fin.
- Pre-pelvic Length: Distance from the tip of the mouth to the origin of the pelvic fin.
- Pre-anal Length: Distance from the tip of the mouth to the origin of the anal fin.

Figure 8: Measuring board

Figure 9: Digital slide calipers

Figure 10: Determination of morphometric data

3.7 Meristic counts: The six meristic characteristics of each specimen were counted by setting up the characters against incoming light direction in the room with the help of needles and small pins. Large fin rays were counted manually. For counting the small fin rays magnifying glass was used to ease the counting and to ensure the accuracy.

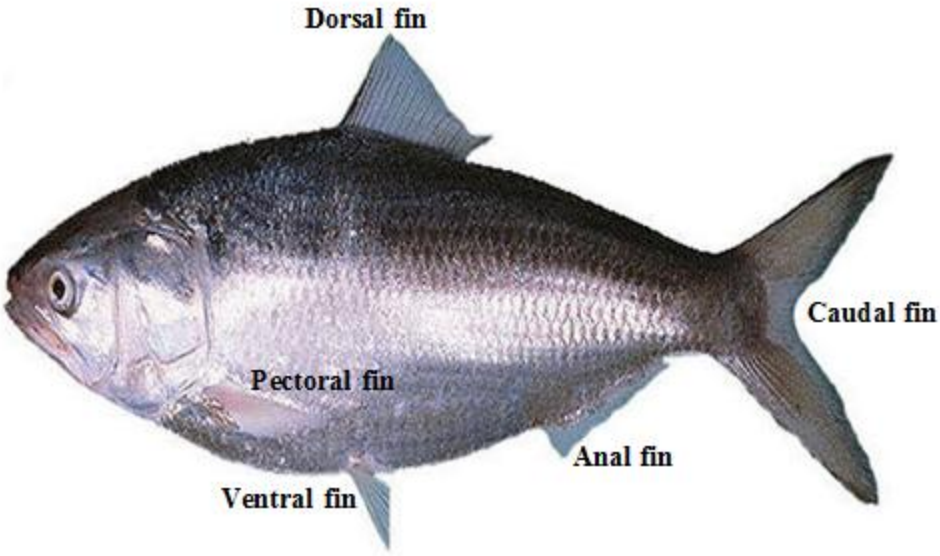


Figure 11: General indications of different meristic characters

The six counted meristic characteristics were as follows-

- Dorsal Fin Ray: Total number of rays in the dorsal fin.
- Pectoral Fin Ray: Total number of rays in pectoral fin.
- Pelvic Fin Ray: Total number of rays in pelvic fin.
- Anal Fin Ray: Total number of rays in anal fin.
- Caudal Fin Ray: Total number of rays in caudal fin.
- Scales on Lateral Line: Total number of scales along the lateral line.

Figure 12: Counting of fin rays

Figure 13: Counting of scales

Generally the meristic characters are specific for every species and don't change with growth. So by using the meristic characters a specific meristic formula was developed for every species. The formula helped to identify fish species.

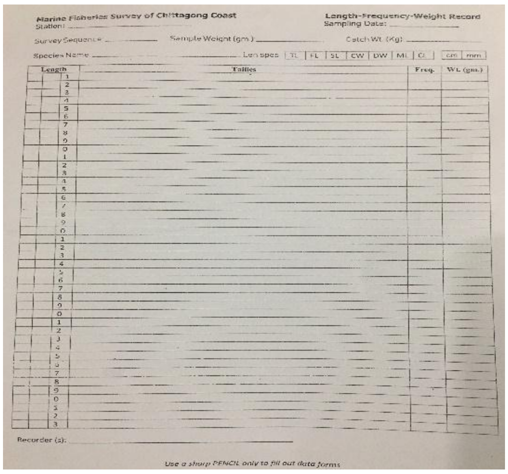
3.8 Apparent body characteristics: Two apparent body characteristics such as scale type and mouth pattern were taken into consideration for the study.

Figure 14: Observation of mouth pattern

Figure 15: Observation of scale type

3.9 Species identification: By using phenotypic characters and meristic formula, the fish species were identified according to the reference books.

3.10 Data collection and record: The collected weight, morphometric measurements, meristic counts and apparent body characteristics of each specimen was recorded in a form where sampling station, sampling number and date were also recorded for the specimen. All the raw data were then gathered in MS Excel- 13 for further statistical analysis. For capturing the image of every fish species, the species was cleaned in fresh running tap water and placed with it's name on the platform of the portable photolab. The images of the species were captured by a digital camera.



Marine Fisheries Survey of Chittagong Coast
Station:
Length-Frequency-Weight Record
Sampling Date:
Survey Sequence
Sample Weight (gm.)
Catch Wt. (Kg):
Species Name
Len spec TL FL SL CW DW ML CL cm mm

Length	Tallies	Freq.	Wt. (gm.)

Recorder (s):
Use a sharp PENCIL only to fill out data forms

Figure 16: Data collection form

Figure 17: Portable photolab

Figure 18: Captured picture of a sample in the portable photolab

3.11 Preservation: All the identified species were preserved at room temperature in the Oceanography laboratory of Chattogram Veterinary and Animal Sciences University by the following method.

Step 1: A solution of 20% formalin was injected in the different parts of the fish body.

Step 2: The fish was soaked in formalin for 24 hours.

Step 3: The fish was finally preserved in the preservative solution which contains specific proportion of distilled water, formalin, glycerin and ethanol (For 10 liter solution, 7.5 L DW+2.5 L formalin+250ml glycerin+250ml ethanol).

Figure 19: Preserved samples

3.12 Statistical analysis:

For the purpose of some statistical analysis, size effects were eliminated from the data set. All individual morphometric measurements were standardized according to the following formula given by Elliott et al. (1995):

$M_s = M_0 (L_s/L_0)^b$

Where,

M_s = Standardized measurement

M_0 = Original measurement

L_s = Overall mean of standard length for all fish samples of a species

L_0 = Standard length of the fish sample

Parameter 'b' for each measurement was estimated as the slope of the regression of $\log M_0$ on $\log L_0$ using all fishes in all groups.

The relationship between the total length and body weight of every fish species was estimated using the following equation:

$W = aL^b$

Where,

W = Body weight of fish in gm

L = Total length of fish in cm

a = Constant (Intercept)

b = Growth exponent

The statistical part of the study mainly emphasized on the morphological parameters of available Clupeidae family fishes along Chattogram coast. Initially for measuring the normality of the distribution of data set, first of all Kolmogorov-Smirnov (KS) test was performed. To check out the basic statistics such as mean, standard deviation, range and median the descriptive statistics and boxplot was executed. In form of trait relationship like length-length and length-weight relationship percentage and power curve was drawn. To estimate the association among the morphometric characters of available species correlation was done. A graphical presentation and PCA biplot was established to check the variation among stations and monthly variation was determined by cluster analysis. All statistical analysis of the investigation was carried out by Statistical Packages for Social Sciences (SPSS version-25), Microsoft office excel, 2010 and R statistical software.

CHAPTER FOUR

RESULT

The core part of the thesis is discussed in this result section. To fulfill the purpose of the investigation stepwise statistical analysis of all the recorded data was carried out. Here all the findings of the investigation are presented briefly with the specific and relevant statistical analysis. The data and statistical analysis of the morphometric and meristic characters of the fish species collected through monthly sampling are demonstrated in this part.

4.1 Monthly species availability:

During the study a total of 375 specimens were collected from three sampling stations throughout the sampling period and after examining and analyzing them 6 species were identified as the member of Clupeidae fish family. Among the 375 specimens 75 were identified as *Tenualosa ilisha*, 60 as *Escualosa thoracata*, 60 as *Sardinella fimbriata*, 60 as *Sardinella longiceps*, 60 as *Hilsa kelee* and 60 as *Anodontostoma chacunda*. How many species of Clupeidae fish family were found in each month was shown in the Fig. 1. Most species was found in the month of January, February, March and October. During these four months five different fish species were collected in every month. The second highest number of species was found in April; four species were collected in this month. Among the identified species *Tenualosa ilisha* was the most dominant fish species in the Chattogram coastal region. Almost in every month this investigation on different species of this group was conducted and specimen collected for further analysis.

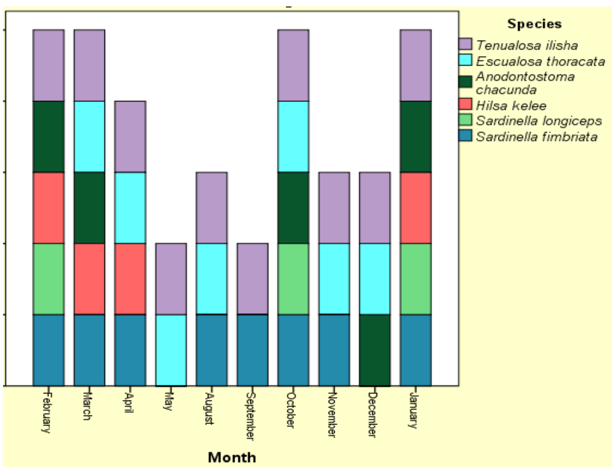


Figure 20: Monthly species availability

4.2 Analysis of meristic traits:

For the purpose of the research six meristic characters of each specimen were determined. The meristic counts were considered to confirm the identification of the species. Through the analysis of meristic counts, it was observed that every meristic character of a species remained within a certain range and range didn't vary with the size and growth of fish and also with the different months and sampling stations. By using the meristic counts a taxonomic formula was developed for every species. The taxonomic formulas of the identified fish species were given in the Table 1.

Table 1: Taxonomic formula

Species name	Taxonomic formula
Tenualosa ilisha	D_{16-18} P_{14} V_{8} A_{18-20} C_{20} Sl_{45-48}
Escualosa thoracata	D_{15} P_{10} $V_{6}A_{16-18}$ C_{20} Sl_{32-36}
Sardinella fimbriata	$D_{13-19}P_{14}V_{8}A_{18-24}C_{22}Sl_{32-40}$
Sardinella longiceps	D_{16} P_{14-15} V_{8-9} A_{14-16} C_{20-22} Sl_{45-50}
Hilsa kelee	$D_{16-19}P_{14}V_{7}A_{18-20}C_{20-22}Sl_{40-42}$
Anodontostoma chacunda	D_{16-18} P_{14} V_{8} A_{18-20} C_{20-22} Sl_{32-36}

4.3 Analysis of morphometric traits:

The analysis of the morphometric measurements of the fish species was completed by the following steps-

- Kolmogorov-Smirnov (KS) test
- Descriptive statistics and Box and Whisker plot
- In percentage of total body length
- Correlation
- Station wise variation
- Cluster analysis

- Principal Component Analysis (PCA)

4.3.1 Kolmogorov-Smirnov (KS) test:

For the statistical analysis of the morphometric measurements at first Kolmogorov-Smirnov (KS) test was done with the measured values. The result of the KS test was shown in the appendix A (A(I) for *Tenualosa ilisha,* A(II) for *Escualosa thoracata,* A(III) for *Sardinella fimbriata,* A(IV) for *Sardinella longiceps,* A(V) for *Hilsa kelee* and A(VI) for *Anodontostoma chacunda*). The significance of the KS test revealed that the test distribution was normal for all species. After that further statistical tests was carried out.

4.3.2 Descriptive statistics:

The observed descriptive data such as maximum and minimum value, average range as well as standard deviation of all the morphometric characters for all species were elaborated in the appendix B (B(I) for *Tenualosa ilisha,* B(II) for *Escualosa thoracata,* B(III) for *Sardinella fimbriata,* B(IV) for *Sardinella longiceps,* B(V) for *Hilsa kelee* and B(VI) for *Anodontostoma chacunda*).

The total length of *Tenualosa ilisha* ranged from 23.0-41.5cm during the investigation period with the mean value of 34.04cm and standard deviation 4.56cm. The standard length was from 19.-35.50cm with average value and standard deviation as 28.39 cm and 3.79cm respectively. The mean value of the head length was 7.94±1.09cm, whereas body depth recorded as 8.47±1.35cm [Appendix B(I)]. On the other hand, total length of *Escualosa thoracata* varied from 7.2-10.2cm with the average value of 8.97±0.89cm. The head length varied from 1.20-1.70cm and body depth was reported as 2.23± 0.3cm [Appendix B(II)].

For the whole specimens set of *Sardinella fimbriata* the maximum and minimum value of standard length was 7.10cm and 16.20cm respectively. The mean value of head length was 3.04cm with standard deviation 0.44cm. The pre-dorsal length of the species ranged between 3.50cm and 6.90cm with the mean value 5.34±1.05cm [Appendix B(III)]. The analysis of morphometric measurements of *Sardinella longiceps* indicated that the range for total length and forked length was 21.50-24.40cm and 19.20-22.00cm respectively. The mean value of pre-orbital length, pre-dorsal length, pre-pectoral length, pre-ventral length and pre-anal length was

1.65±0.06cm, 9.10±0.44cm, 5.52±0.31cm, 10.45±0.44cm and 15.38±1.32cm respectively [Appendix B(IV)].

In the case of *Hilsa kelee*, the forked length varied from 10.00-20.00cm; head length 2.60-5.80cm; pre-orbital length, 0.70-1.70cm; pre-dorsal length, 4.00-8.90cm; pre-pectoral length, 2.60-5.60cm; pre-anal length, 7.00-16.10cm. The mean value of body depth was 4.98cm with standard deviation 1.70cm [Appendix B(V)]. The samples of *Anodontostoma chacunda* ranged in total length from 9.80cm to 18.60cm. The mean head length of the species was 2.88±0.64cm. The value of body depth ranged between 2.50cm and 6.20cm with mean value 4.70±1.44cm. The pre-orbital length ranged between 0.50cm and 1.00cm with mean value 0.70±0.21cm [Appendix B(VI)].

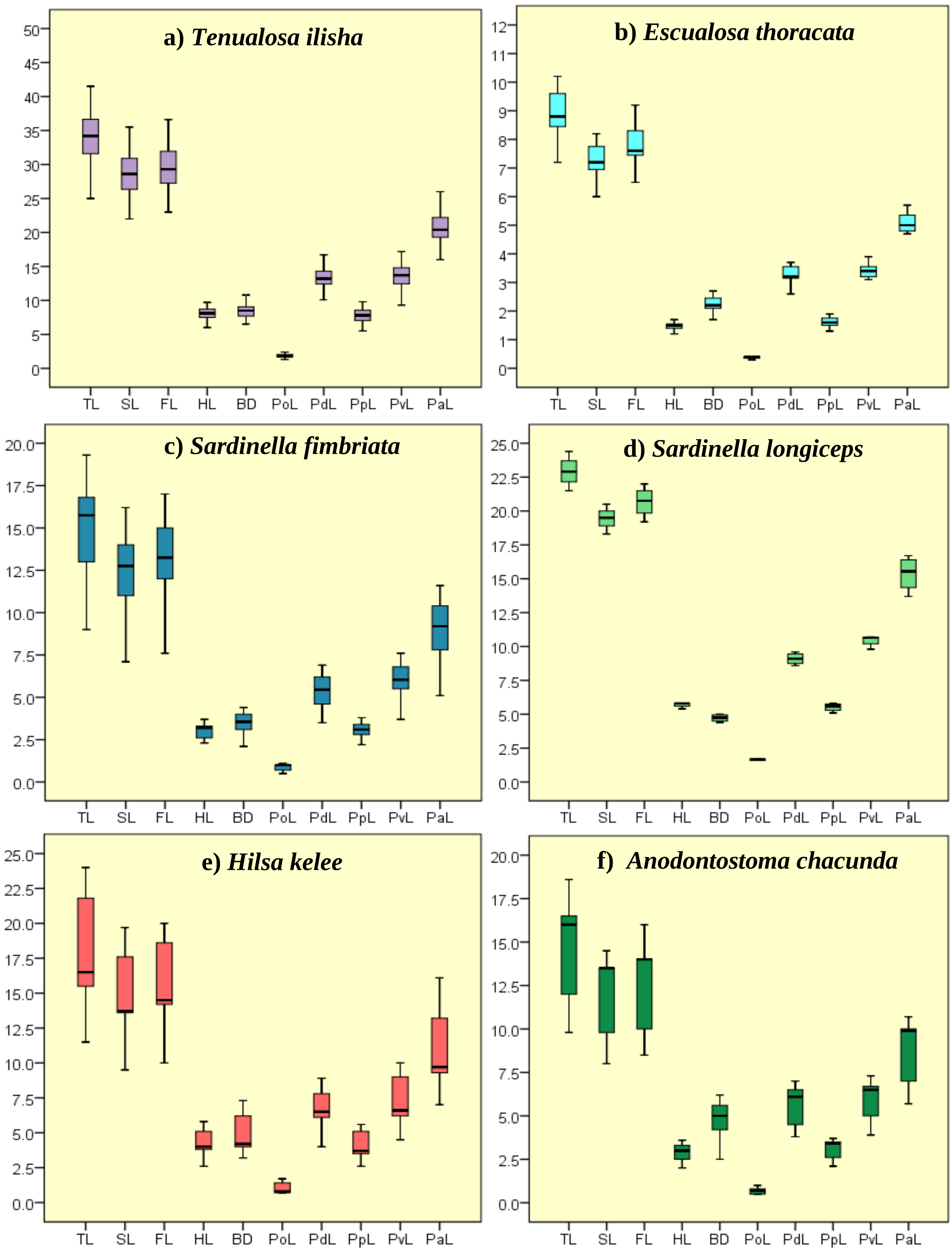


Figure 21: Box and Whisker plot showing the maximum and minimum value, quartiles and median (TL= Total length, SL= Standard length, FL= Forked length, HL= Head length, BD= Body depth, PoL= Pre-orbital length, PdL= Pre-dorsal length, PpL= Pre-pectoral length, PvL= Pre-ventral length, PaL= Pre-anal length)

4.3.3 In percentage of total body length:

The morphometric measurements were expressed as the percentage of total length in the following Figure 22(a-f). In all specimens, the forked length had highest percentage and the pre-orbital length had lowest percentage. The percentage of forked length ranged from 85.73% to 90.19%. In *Sardinella longiceps*, the forked length was 90.19% of the total length which was the highest among all species. The pre-orbital length of *Escualosa thoracata* was reported as 4.15% of total length which was the lowest percentage. Among the head length of all species, the highest percentage was for *Sardinella longiceps* (24.86%). The percentage of body depth varied from 20.61-32.23% and the highest value reported from the *Anodontostoma chacunda*. In *Tenualosa ilisha*the pre-dorsal length was 38.94% of the total length whereas it was 35.93% in *Sardinella fimbriata.* In case of *Hilsa kelee* the pre-anal length was 61.93% of the total length.

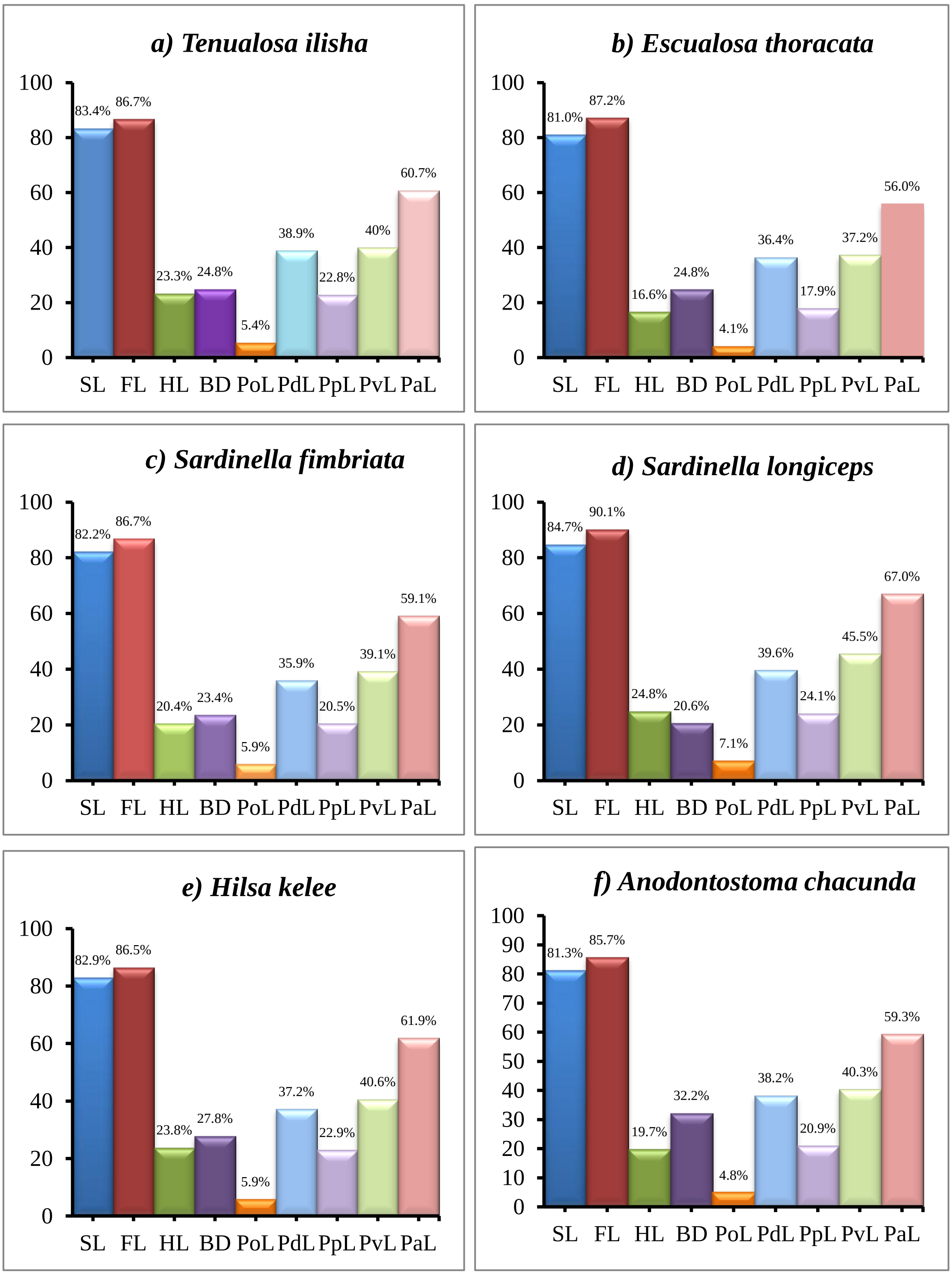


Figure 22: Morphometric measurements expressed as percentage of total length (TL= Total length, SL= Standard length, FL= Forked length, HL= Head length, BD= Body depth, PoL= Pre-orbital length, PdL= Pre-dorsal length, PpL= Pre-pectoral length, PvL= Pre-ventral length, PaL= Pre-anal length)

4.3.4 Correlation: In the table-2, table-3 and table-4 the correlation coefficient between ten morphometric characters of *Tenualosa ilisha*, *Sardinella fimbriata* and *Hilsa kelee*were presented respectively. The values of all the correlation coefficients were close to 1 which indicated that all the morphometric characters had high positive correlation with each other and all the correlation was significant.

Table 2: Correlations between different morphometric measurements of *Tenualosa ilishsa*(TL= Total length, SL= Standard length, FL= Forked length, HL= Head length, BD= Body depth, PoL= Pre-orbital length, PdL= Pre-dorsal length, PpL= Pre-pectoral length, PvL= Pre-ventral length, PaL= Pre-anal length)

Parameters	TL	SL	FL	HL	BD	PoL	PdL	PpL	PvL	PaL
TL	1									
SL	.98**	1								
FL	.98**	.99**	1							
HL	.96**	.95**	.95**	1						.
BD	.85**	.85**	.85**	.82**	1					
PoL	.89**	.87**	.88**	.90**	.77**	1			.	
PdL	.98**	.96**	.96**	.96**	.86**	.92**	1			
PpL	.96**	.94**	.95**	.97**	.79**	.92**	.96**	1		
PvL	.98**	.97**	.97**	.95**	.86**	.91**	.97**	.97**	1	
PaL	.98**	.96**	.97**	.96**	.86**	.91**	.97**	.95**	.98**	1

**. Correlation is significant at the 0.01 level (2-tailed).

Table 3: Correlations between different morphometric measurements of *Sardinella fimbriata*(TL= Total length, SL= Standard length, FL= Forked length, HL= Head length, BD= Body depth, PoL= Pre-orbital length, PdL= Pre-dorsal length, PpL= Pre-pectoral length, PvL= Pre-ventral length, PaL= Pre-anal length)

Parameters	TL	SL	FL	HL	BD	PoL	PdL	PpL	PvL	PaL
TL	1									
SL	.99**	1								
FL	.99**	.99**	1							
HL	.90**	.91**	.91**	1						
BD	.89**	.90**	.91**	.92**	1					
PoL	.87**	.84**	.84**	.87**	.80**	1				
PdL	.99**	.98**	.98**	.91**	.90**	.84**	1			
PpL	.90**	.90**	.90**	.96**	.94**	.84**	.90**	1		
PvL	.98**	.98**	.99**	.89**	.87**	.82**	.98**	.87**	1	
PaL	.99**	.99**	.99**	.92**	.88**	.87**	.98**	.90**	.99**	1

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4: Correlations between different morphometric measurements of *Hilsa kelee*(TL= Total length, SL= Standard length, FL= Forked length, HL= Head length, BD= Body depth, PoL= Pre-orbital length, PdL= Pre-dorsal length, PpL= Pre-pectoral length, PvL= Pre-ventral length, PaL= Pre-anal length)

Parameters	TL	SL	FL	HL	BD	PoL	PdL	PpL	PvL	PaL
TL	1									
SL	.99**	1								
FL	.99**	.99**	1							
HL	.99**	.99**	.99**	1						
BD	.98**	.97**	.96**	.97**	1					
PoL	.94*	.91*	.90*	.92*	.98**	1				
PdL	.98**	.99**	.99**	.99**	.95*	.88*	1			
PpL	.99**	.99**	.99**	.99**	.98**	.95*	.97**	1		
PvL	1.00**	.99**	.99**	.99**	.98**	.95*	.98**	1.00**	1	
PaL	.98**	.98**	.97**	.98**	.99**	.96**	.96**	.98**	.99**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

The correlation among the morphometric variables of *Escualosa thoracata* was presented in the table-5. Out of ten morphometric characters 9 characters showed high positive correlation, only the pre-orbital length showed low value of correlation coefficient. For this species, expect 8 correlations (PoL-TL, PoL-SL, PoL-FL, PoL-BD, PoL-PdL, PoL-PpL, PoL-PvL and PoL-PaL) all the correlations among the morphometric characters were significant. The pre-orbital length had only significant correlation with the head length.

In the case of *Sardinella longiceps*, only 5 correlatins came out as significant and they were TL-SL, TL-FL, SL-FL, HL-PvL and PdL-PaL. The value of correlation coefficient was negative between pre-orbital length and body depth which was –0.314. According to the value of correlation coefficient there was no correlation between pre-orbital length and pre-dorsal length. The highest value of correlation coefficient (0.994) was found between total length and standard length. (Table-6)

Table-7 representing the correlation among the morphometric measurements of *Anodontostoma chacunda* revealed that all the measurements were significantly correlated except the pre-orbital length. The pre-orbital length had no significant correlation with any other measurement. The correlation coefficient was 1.00 between standard length and pre-anal length.

Table 5: Correlations between different morphometric measurements of *Escualosa thoracata* (TL= Total length, SL= Standard length, FL= Forked length, HL= Head length, BD= Body depth, PoL= Pre-orbital length, PdL= Pre-dorsal length, PpL= Pre-pectoral length, PvL= Pre-ventral length, PaL= Pre-anal length)

Parameters	TL	SL	FL	HL	BD	PoL	PdL	PpL	PvL	PaL
TL	1									
SL	.97**	1								
FL	.97**	.98**	1							
HL	.75**	.72*	.74**	1						
BD	.77**	.75**	.72*	.90**	1					
PoL	.10	.02	.06	.68*	.54	1				
PdL	.94**	.92**	.91**	.84**	.91**	.31	1			
PpL	.75**	.74**	.73**	.90**	.92**	.59	.87**	1		
PvL	.92**	.90**	.92**	.91**	.84**	.39	.94**	.87**	1	
PaL	.94**	.93**	.92**	.88**	.87**	.34	.95**	.90**	.96**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 6: Correlations between different morphometric measurements of *Sardinella longiceps* (TL= Total length, SL= Standard length, FL= Forked length, HL= Head length, BD= Body depth, PoL= Pre-orbital length, PdL= Pre-dorsal length, PpL= Pre-pectoral length, PvL= Pre-ventral length, PaL= Pre-anal length)

Parameters	TL	SL	FL	HL	BD	PoL	PdL	PpL	PvL	PaL
TL	1									
SL	.99**	1								
FL	.98*	.984*	1							
HL	.80	.85	.84	1						
BD	.50	.43	.58	.30	1					
PoL	.65	.70	.57	.57	-.31	1				
PdL	.68	.67	.78	.75	.82	.00	1			
PpL	.51	.58	.60	.91	.26	.28	.75	1		
PvL	.83	.87	.88	.99**	.40	.53	.81	.90	1	
PaL	.76	.76	.85	.84	.75	.15	.98*	.81	.89	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 7: Correlations between different morphometric measurements of*Anodontostoma chacunda* (TL= Total length, SL= Standard length, FL= Forked length, HL= Head length, BD= Body depth, PoL= Pre-orbital length, PdL= Pre-dorsal length, PpL= Pre-pectoral length, PvL= Pre-ventral length, PaL= Pre-anal length)

Parameters	TL	SL	FL	HL	BD	PoL	PdL	PpL	PvL	PaL
TL	1									
SL	.99**	1								
FL	.99**	.99**	1							
HL	.99**	.97**	.97**	1						
BD	.97**	.95**	.95*	.98**	1					
PoL	.75	.81	.79	.66	.64	1				
PdL	.98**	.99**	.99**	.95*	.93*	.85	1			
PpL	.98**	.99**	.98**	.96**	.95*	.83	.99**	1		
PvL	.99**	.99**	.99**	.98**	.98**	.76	.98**	.99**	1	
PaL	.98**	1.00**	.99**	.96**	.95*	.82	.99**	.99**	.99**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

4.3.5 Station wise variation: The variation of morphometric characters of the species between stations was represented in the Figure 23. Using the average morphometric parameters of every station, single graph was created for each species. According to the figure, the pre-orbital length of all species was approximately equal whatever the other lengths were small or large. In case of all species except *Hilsa kelee* it was seemed that if the total length of any sample was large for a station then all the lengths of the sample for that station was comparatively larger. An exception was found in case of *Hilsa kelee*. The total length of this species was bigger in station 1 than station 3 but the body depth, pre-orbital length and pre-anal length of station 3 was bigger than station 1.

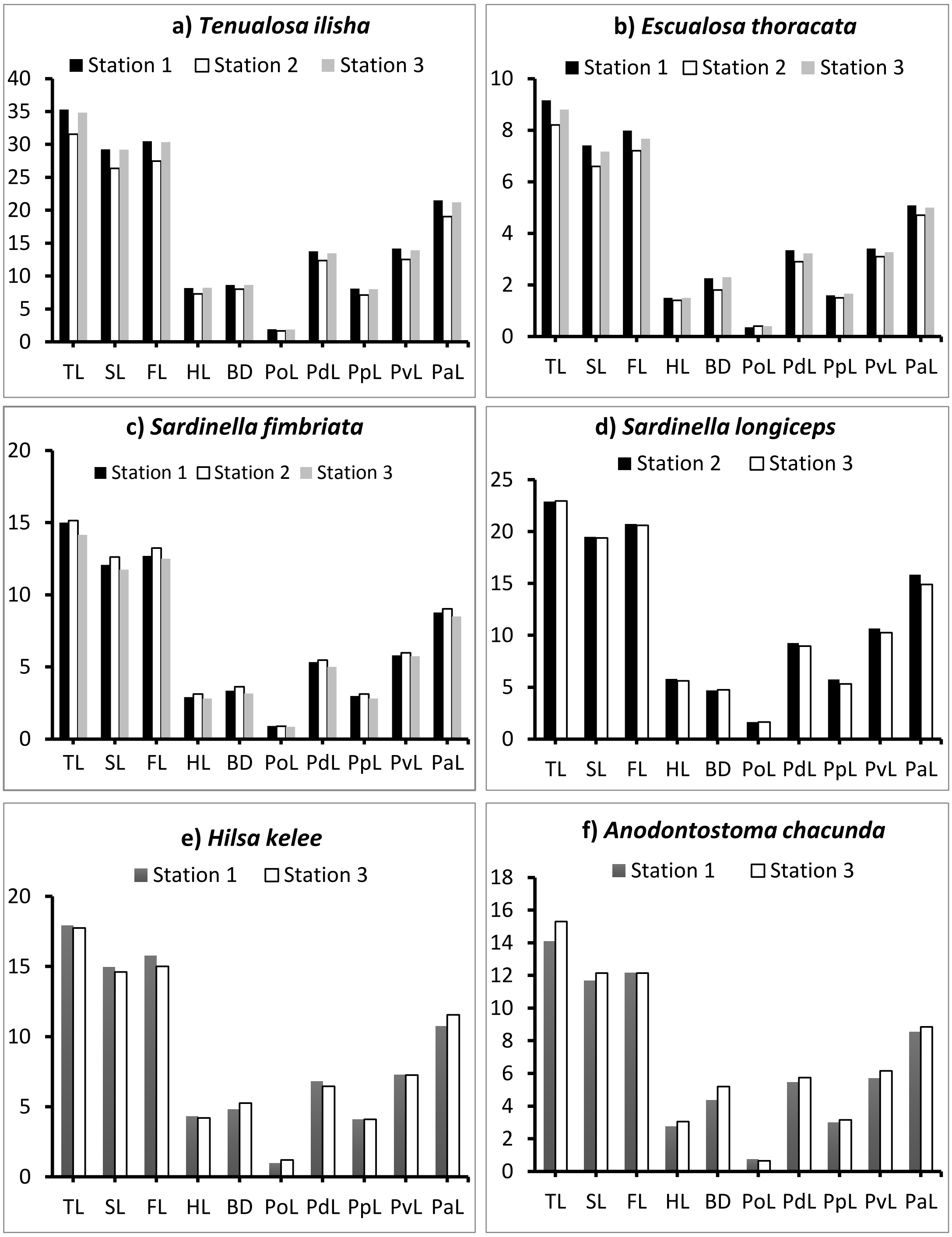


Figure 23: Comparison of morphometric measurements among the stations (TL= Total length, SL= Standard length, FL= Forked length, HL= Head length, BD= Body depth, PoL= Pre-orbital length, PdL= Pre-dorsal length, PpL= Pre-pectoral length, PvL= Pre-ventral length, PaL= Pre-anal length)

4.3.6 Cluster analysis: Cluster analysis was carried out for month wise average values of the morphometric measurements to understand the relationship among different months. For every species single dendrogram was drawn by squared Euclidean distance method which indicated the similarities and dissimilarities between the months.

For *Tenualosa ilisha* thedendrogram using average linkage to determine the relationship between ten months on the basis of morphometric measurements resulted in 3 clusters. The first cluster was formed by the months of May, September, March, August, April, November and February. The second cluster was formed by the months of December and January which combined with the first cluster at the distance less than 5. The month of October individually formed the third cluster (Figure 24).

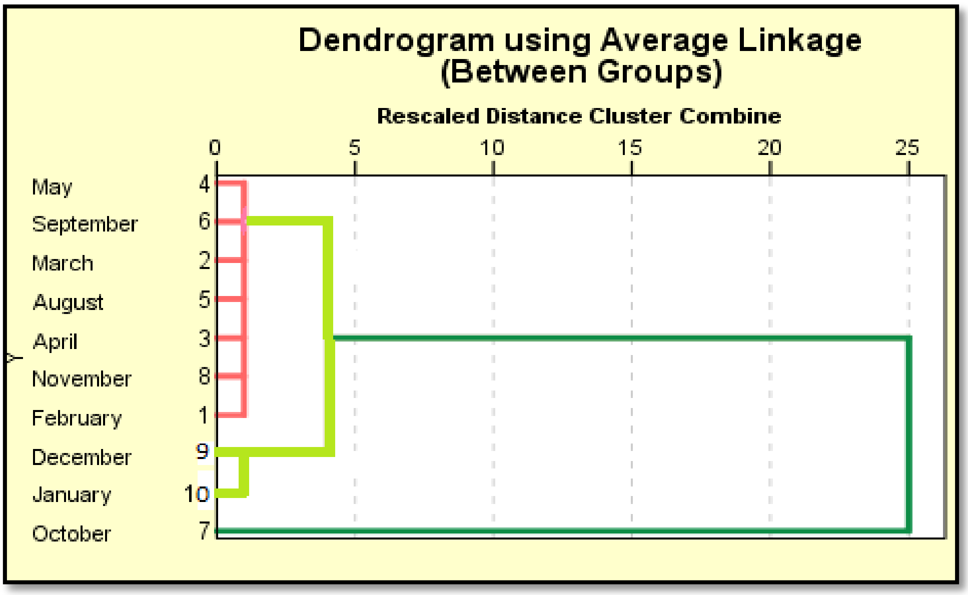


Figure 24: Dendrogram showing the relationships among months based on the morphometric traits of *Tenualosa ilisha*

Cluster analysis applied among the month wise morphometric parameters of Escualosa thoracata, which brought out two significant clusters: cluster 1: November, December, March and August; cluster 2: May, October and April. These two clusters combined at the maximum distance (Figure 25).

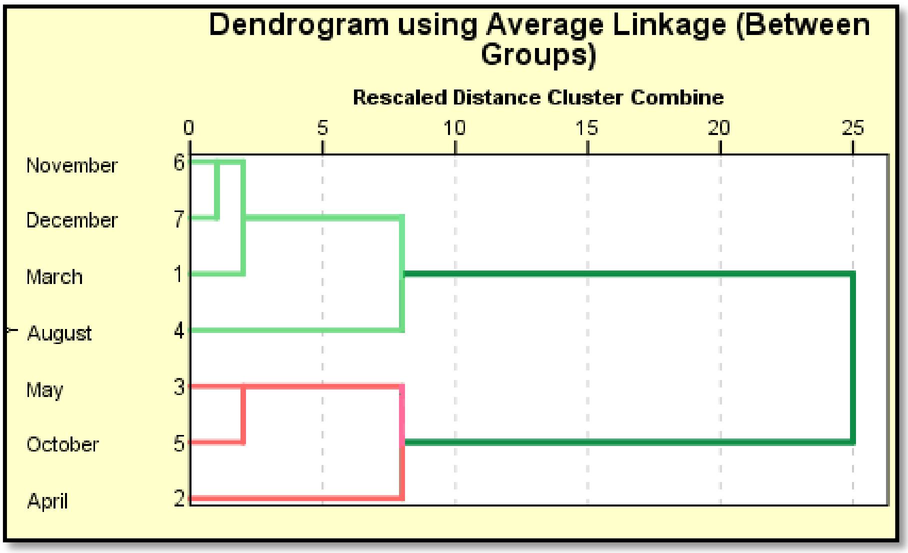


Figure 25: Dendrogram showing the relationships among months based on the morphometric traits of *Escualosa thoracata*

Figure 26 represented the dendrogram for *Sardinella fimbriata*, in which the months November, January and September formed the first cluster, the month of March, October, April and February formed the second cluster and the month August formed a completely separate cluster (third cluster).

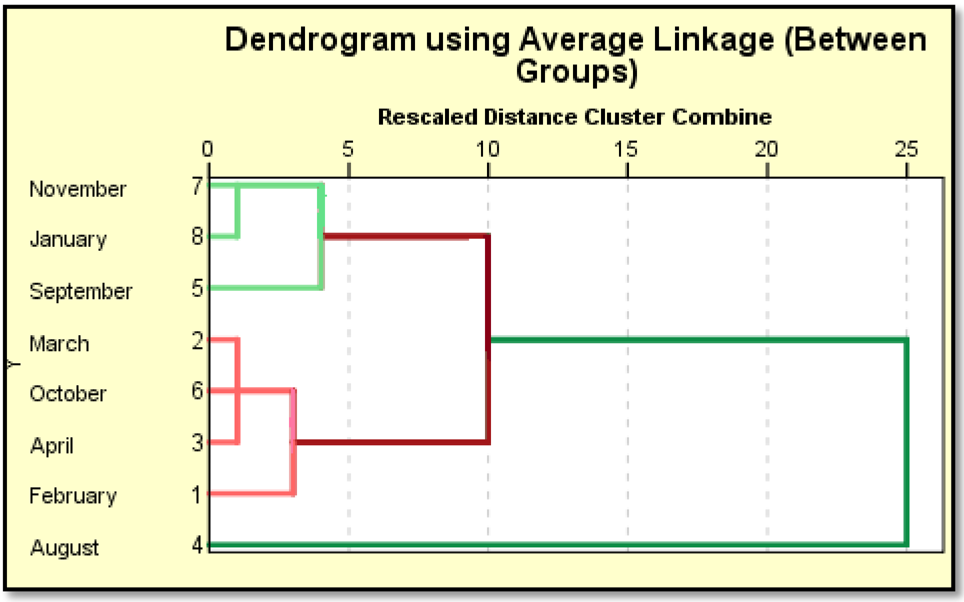


Figure 26: Dendrogram showing the relationships among months based on the morphometric traits of *Sardinella fimbriata*

The cluster analysis of morphometric characters of*Sardinella longiceps* brought out two significant clusters, in which the months of January and February formed one cluster and the month October forming a separate cluster combined with the first cluster at the maximum distance (Figure 27).

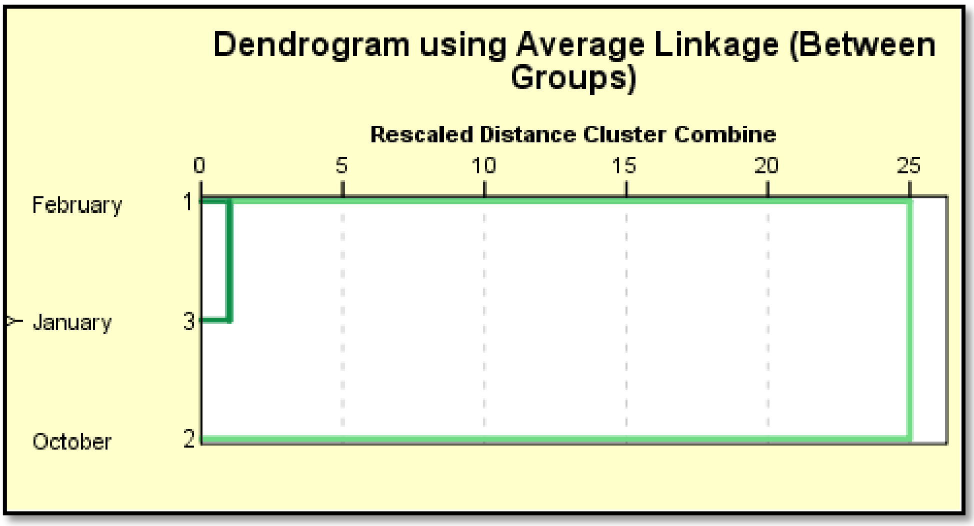


Figure 27: Dendrogram showing the relationships among months based on the morphometric traits of *Sardinella longiceps*

In case of *Hilsa kelee* the result of cluster analysis rendered a dendrogram where the four months classified into two clusters. The first cluster was formed by the months of January and February. The second cluster was formed by the months of March and April. (Figure 28)

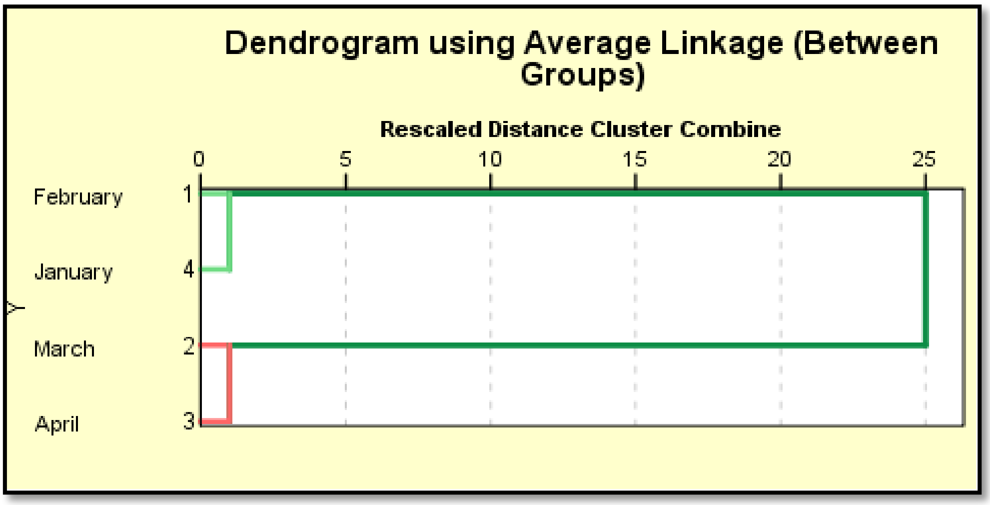


Figure 28: Dendrogram showing the relationships among months based on the morphometric traits of *Hilsa kelee*

In case of Anodontostoma chacunda month wise morphometric parameters formed two clusters. The first cluster was formed by the months of February, December and

January. The second cluster was formed by the months of March and October. Finally the two clusters combined at maximum distance (Figure 29).

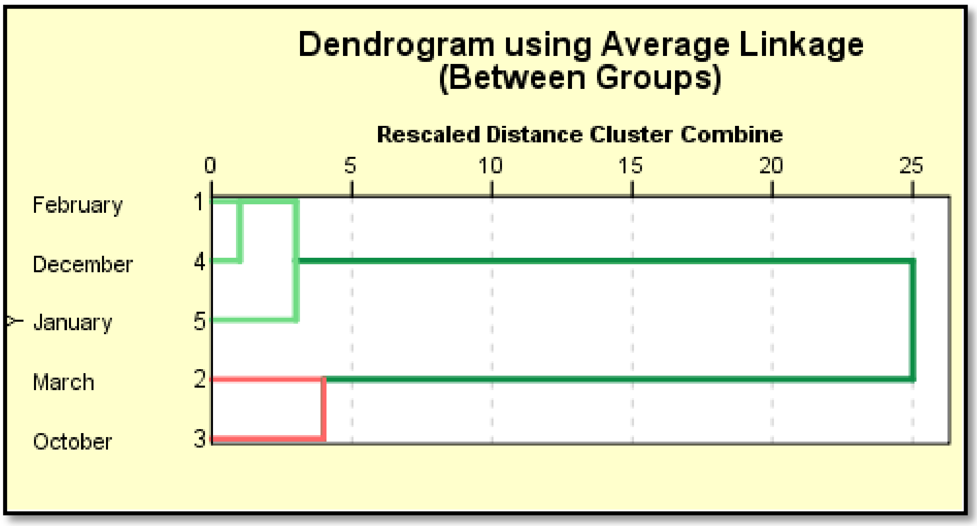


Figure 29: Dendrogram showing the relationships among months based on the morphometric traits of *Anodontostoma chacunda*

The dendrograms of all the species explained that the months in the same cluster were closely related and the distance indicated the dissimilarities between the months on the basis of the morphometric traits.

4.3.7 Principal component analysis:

In the study Principal component Analysis (PCA) was performed using the adjusted morphometric values to establish possible factor that contributed towards the morphometric parameters. Based on the principal component analysis PCA biplot was developed to demonstrate the variation and relationship between three sampling stations. Depending on the suitability and efficacy of analysis, the Principal Component Analysis was applied for *Tenualosa ilisha, Escualosa thoracata* and *Sardinella fimbriata.*

According to the PCA biplot of *Tenualosa ilisha* it was found that four principal components explained 84.3% of the total variance. The first (PC1), second (PC2), third (PC3) and fouth (PC4) principal components accounted for 47.8%, 16.1%, 12.5% and 7.9% of the total variance respectively. The morphometric variables of the three stations formed three distinct clusters. The cluster of station 1 was characterized by high values for pre-ventral length, Pre-orbital length and head length. Station 2 was characterized by large pre-anal length and the station 3 was characterized by large pre-pectoral length and forked length. The PCA biplot showed that pre-anal, pre-dorsal and pre-ventral lengths were correlated. Correlation was found between pre-orbital length, head length and pre-pectoral length and also between pre-dorsal length, head length and body depth. The biplot also indicated that the three sampling stations had similarities between the morphometric characters (Figure 30).

Application of Principal Component Analysis (PCA) for *Escualosa thoracata* showed that the four principal components accounted for 97.5% of the total variance. Among the four principal components the first component (PC1) individually explained 80.8% of the variance. In the PCA biplot two clusters were formed by station 1 and station 3. No cluster was formed by station 2 in this case. Strong correlation was found between body depth and pre-dorsal length, between pre-orbital length, head length and pre-anal length, between pre-anal length and pre-pectoral length and between pre-orbital length, body depth and head length. Similarities in morphometric characters between station 1 and station 3 were found by considering PC1 and PC2 (Figure 31).

Four principal components were extracted for *Sardinella fimbriata* and the four components were explaining 93.11% of the total variance. Among them PC1 were accounted for 37.8% and PC2 were accounted for 34% of the total variance. PC3 and PC4 explained 14.6% and 6.7% of the total variance respectively. High value of pre-anal length characterized the cluster of station 1 in the PCA biplot. Large pre-dorsal and pre-ventral length characterized the cluster of station 2 and the station 3 was characterized for high value of body depth, pre-orbital length and head length. Strong correlation was found between head length and pre-orbital length. By the analysis similarities were found between the morphometric characters of the three sampling stations (Figure 32).

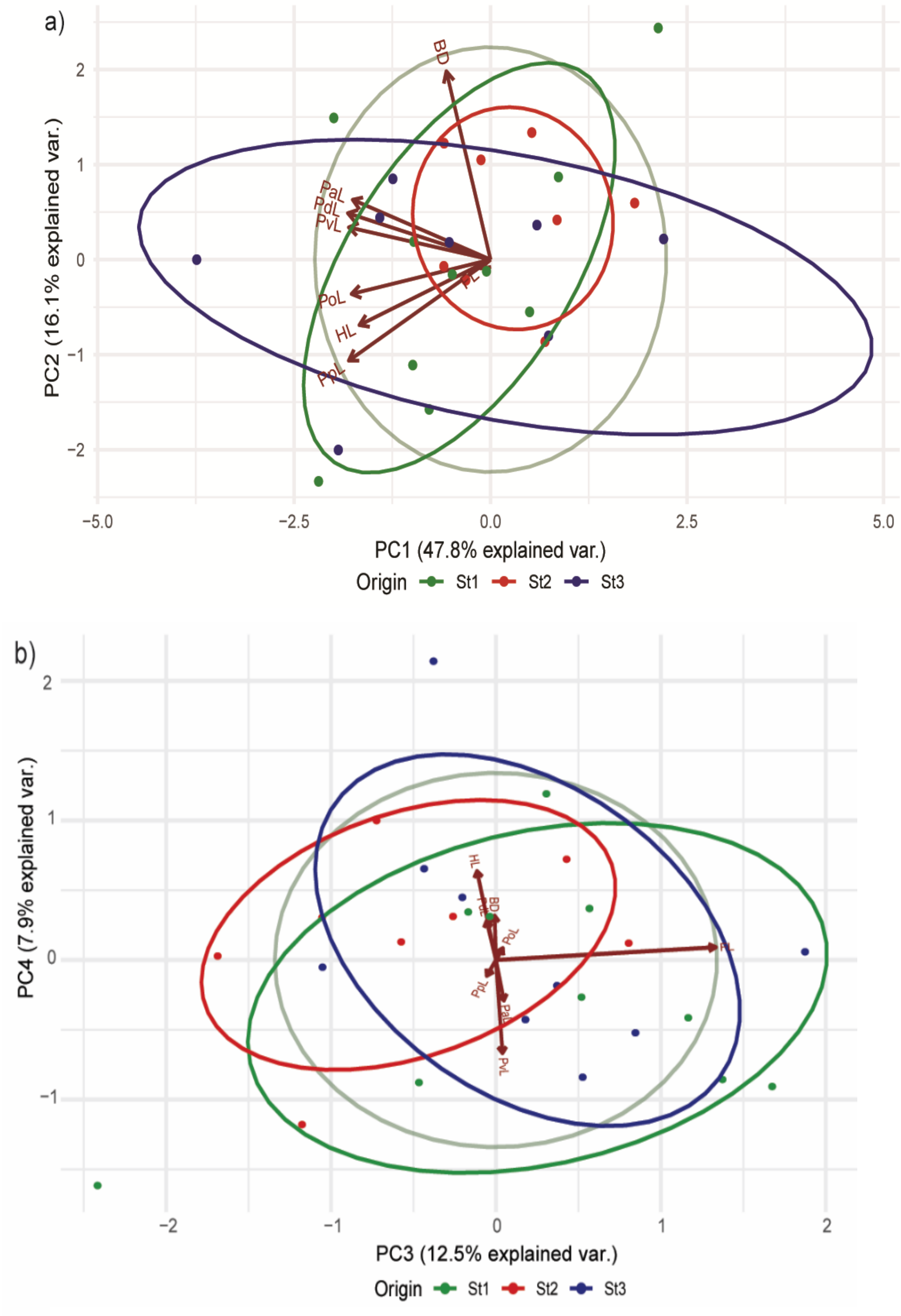


Figure 30: PCA biplot for adjusted morphometric measurements of *Tenualsa ilisha* collected from three sampling stations.

a) PC1 and PC2, b) PC3 and PC4

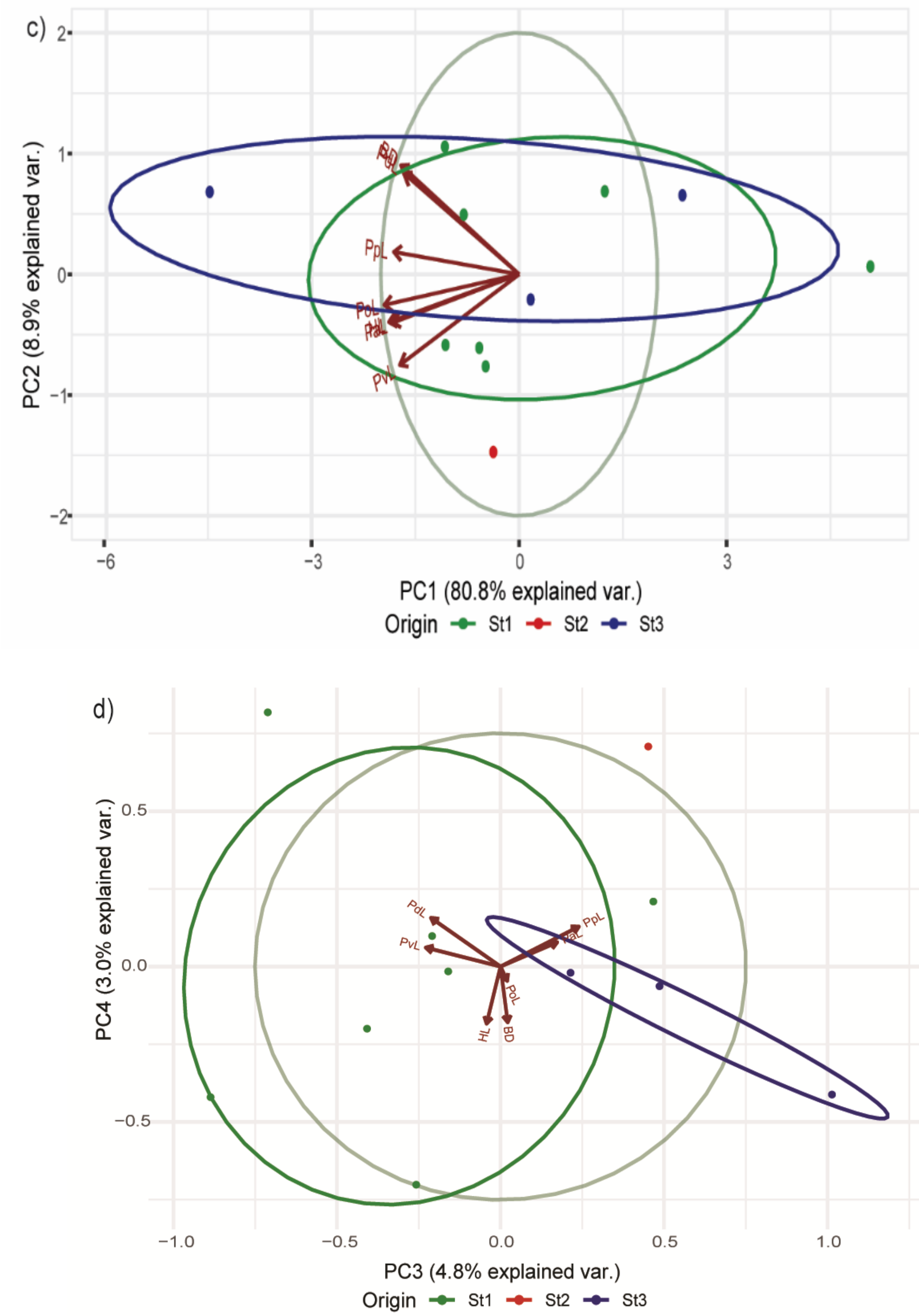


Figure 31: PCA biplot for adjusted morphometric measurements of *Escualosa thoracata* collected from three sampling stations.

c) PC1 and PC2, d) PC3 and PC4

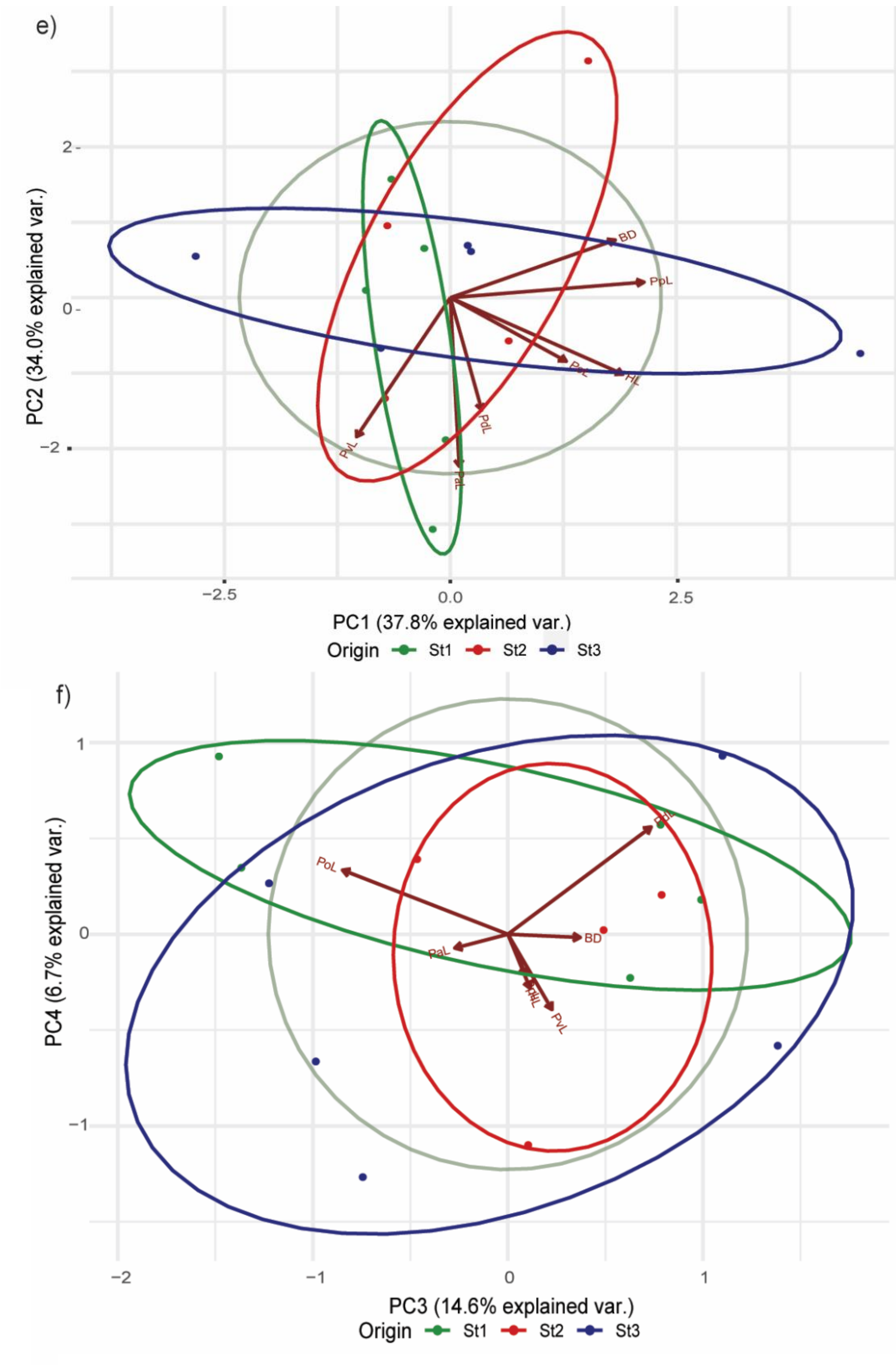


Figure 32: PCA biplot for adjusted morphometric measurements of *Sardinella fimbriata* collected from three sampling stations.

e) PC1 and PC2, f) PC3 and PC4

4.4 Length- Weight relationship: During the study, weight of every specimen was measured as a morphometric character. By using the total length and body weight data of species, the length-weight relationship was established for every species. The length-weight relationship graph of each species was shown in the figure 33. From the graph a power curve equation between total length and body weight was originated, by which the value of parameter ‘a’ and ‘b’ was estimated. The value of ‘b’ for all the collected fish species ranged from 2.45 to 3.72. For *Hilsa kelee* and *Anodontostoma chacunda* the ‘b’ value was greater than 3, value in *Hilsa kelee* = 3.44, value in *Anodontostoma chacunda* = 3.72. The ‘b’ value of these two species indicated that their growth was positive allometric. The value of ‘b’ was very close to 3 in *Sardinella fimbriata* which specified that this species had isometric growth. In *Tenualosa ilisha*, *Escualosa thoracata* and *Sardinella longiceps* the ‘b’ value was 2.65, 2.73 and 2.45 respectively. As the b value is less than 3, so the growth of these three species was negatively allometric.

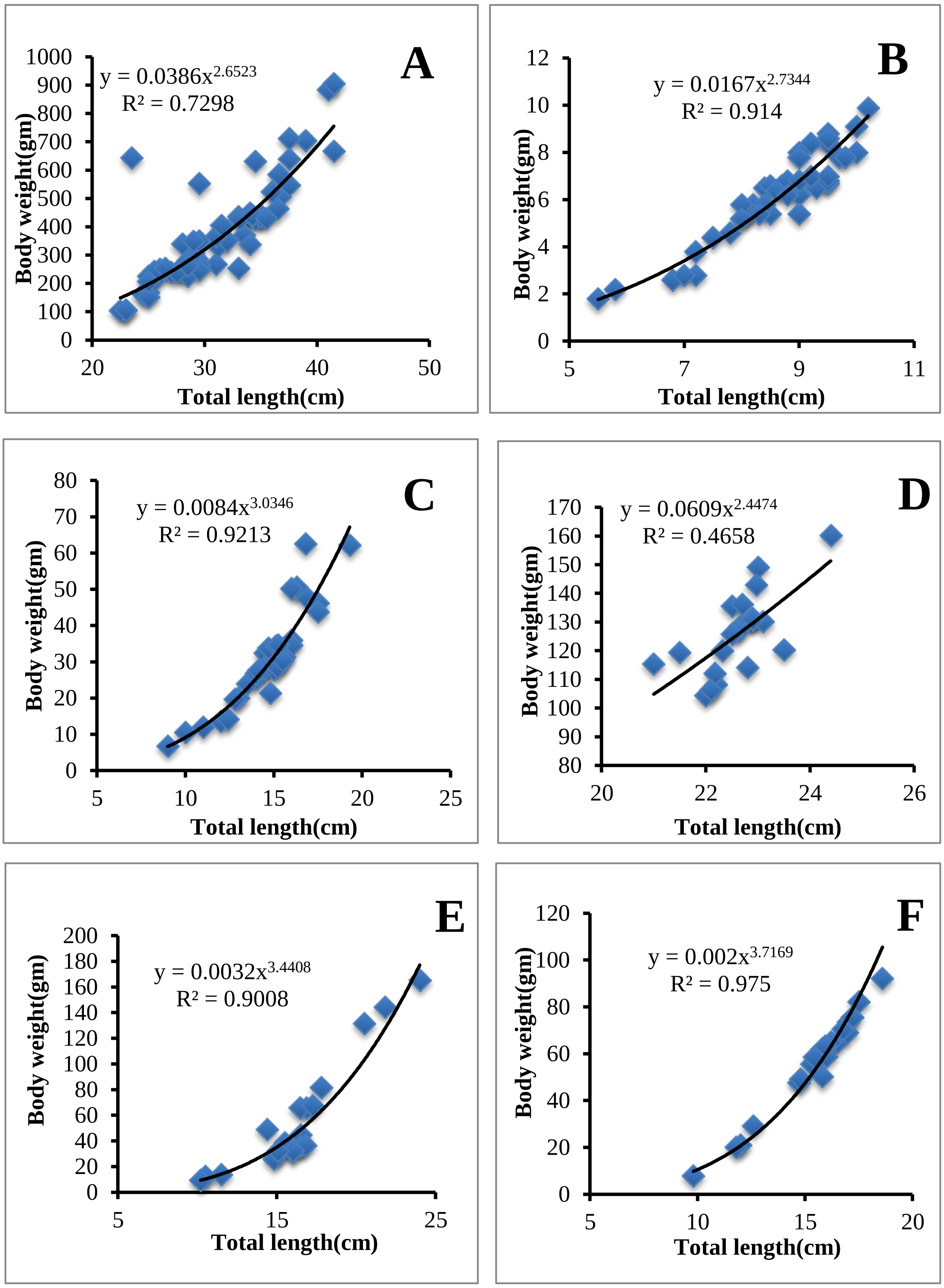
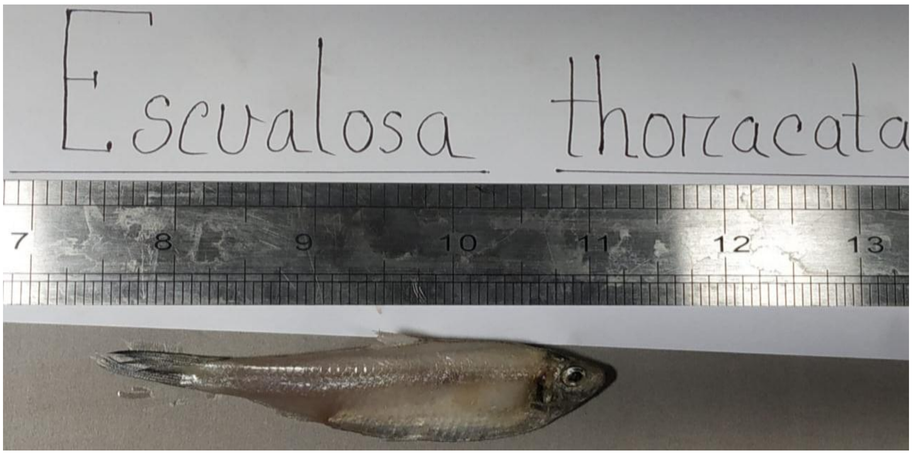


Figure 33: A) Length-weight relationship of *Tenualosa ilisha*, **B)** Length-weight relationship of *Escualosa thoracata*, **C)** Length-weight relationship of *Sardinella fimbriata*, **D)** Length-weight relationship of *Sardinella longiceps*, **E)** Length-weight relationship of *Hilsa kelee*, **F)** Length-weight relationship of *Anodontostoma chacunda*

Identified species:




Sardinella longiceps
6 7 8 9 10 11 12 13 14


Hilsa kelee
5 6 7 8 9 10 11 12


Anodontostoma chacunda
7 8 9 10 11 12 13

CHAPTER FIVE

DISCUSSION

In many marine pelagic fish species, especially in the fishes of Clupeidae family differences among the morphological characters have been reported (Thomas *et al*., 2014). For taxonomic work and systematic studies, information about the morphometric characters of fishes and the statistical relationship among the characters are very essential (McConnel, 1978). The analysis of morphometric and meristic characters is considered as an important tool for differentiating closely related species having huge similarities of various parameters (Ahammad *et al*., 2018).

5.1 Species availability:

The main purpose of the study was to figure out the available fish species under the Clupeidae family from the Chattogram coastal region. In one year of sampling period, ten months sampling was done considering ban periods. In that process 6 species were identified and they were *Tenualosa ilisha*, *Escualosa thoracata, Sardinella fimbriata, Sardinella longiceps, Hilsa kelee* and *Anodontostoma chacunda.* Ahmed (2008) documented that total 9 marine fish species of Clupeidae family were available in Bangladesh. Besides in accordance with Hossain (2013), 7 species of this fish family were available in the greater Noakhali region. The present study found a species which was not mentioned by Ahmed (2008) and Hossain (2013). The species was *Sardinella longiceps.* The existence of the species in Bangladesh was confirmed by Fishbase and Shamsunnahar *et al.* (2017). The present study suggested that *Sardinella longiceps* was also available in Chattogram coastal region.

5.2 Analysis of meristic traits:

The meristic counts of *Tenualosa ilisha* from three sampling stations revealed that the species had 16-18 dorsal fin rays, 14 pectoral fin rays, 8 ventral fin rays, 18-20 anal fin rays, 20 caudal fin rays and 45-48 scales on the lateral line. Das *et al.* (2020) analyzed the meristic characters of *Tenualosa ilisha* from three different habitats (coastal, riverine and marine) of Bangladesh and found similar meristic characters for the species like the present study. Meristic counts of all specimen of *Sardinella longiceps* collected from three sampling stations ranged from 14-15 for pectoral fin rays, 16 for dorsal fin rays, 8-9 for ventral fin rays, 14-16 for anal fin rays, 20-22 for caudal fin rays and 45-50 for lateral line scales. Shamsunnahar *et al.* (2017) conducted a study on *Sardinella longiceps* from coastal waters of Bangladesh and through the study same meristic characters were found for the species. For being coastal region of the same Bay (Bay of Bengal) the result of this studies shared similarities. The biometric analysis of *Sardinella longiceps* from Ratnagiri coast of Maharastra by Shah *et al.* (2014) developed the taxonomic formula of the species as- $B_{5-7}P_{14-16}V_{8-9}D_{14-18}C_{18-24}A_{11-17}$ (B=Branchiostegal ray, P=Pectoral fin ray, V=Ventral fin ray, D=Dorsal fin ray, C=Caudal fin ray, A=Anal fin ray). The number of fin rays obtained through this analysis was similar to the present study. Based on the analysis of meristic traits, the present study identified *Escualosa thoracata, Sardinella fimbriata, Hilsa kelee* and *Anodontostoma chacunda*. Taxonomic formulas of identified species (Table- 1) agreed with the findings of Hossain (2013) and Ahmed (2008). Through the analysis of the meristic counts it was observed that every meristic character of a species remained within a certain range and the range didn't vary with the size and growth of fish and also with the different months and stations. Das *et al.* (2020) made similar observation as no significant difference was found in the meristic characters among different habitats by the Kruskal-Wallis test. Gonzalez et al. (2016) also documented that the meristic traits of fish didn't vary with increasing and decreasing length and weight of fish. The result of the study conducted by Aisyah and Syarif (2018) disagreed with the observation of the present study. According to Aisyah and Syarif (2018) the meristic characters of *Anodontostoma sp.* were dependent on body size and length and different areas and environment had impacts on the meristic traits.

5.3 Descriptive statistics of the morphometric traits:

A brief summary of the morphological data of every species including maximum and minimum values, mean, standard distribution and median was calculated through descriptive statistics and Box and Whisker plot. The main purpose of using descriptive statistics for any statistical analysis is that it provides baseline information about variables in a data set. In different morphological studies of fish the range (maximum and minimum value), average and standard deviation was determined in the initial step. Sartimbul *et al.* (2018) calculated the mean value with standard deviation for both morphometric and meristic characters of *Sardinella lemura* from different locations. Narejo, Lashari and Jafri (2008) determined range, mean and standard deviation of the morphometric measurements and meristic counts to differentiate to types of *Tenualosa ilisha* from Indus River, Pakistan. Same values were calculated by Ara *et al.* (2019) and Abeed, Ismaeel and Khatan (2012) for the morphometric and meristic analysis of *Tenualosa ilisha.* The descriptive statistics was also followed by Shah *et al.* (2014) for biometric analysis of *Sardinella longiceps.*

In the study Box and Whisker plot was used because of large number of observation and to compare the basic statistical values of the ten morphometric measurementsfor every species in single graph. Same graphical representation was used by Hanif *et al*. (2019) to demonstrate the size frequency distribution of *Ambygaster clupoides* in four different stocks (Sundarban, Kuakata, Bhola, Cox's Bazar) of Bangladesh.

5.4 In percentage of total body length:

The graphical presentation expressing percentage of all morphometric measurements against total length showed that all the fish species followed same trend. Only an exception was found in the graph of *Sardinella longiceps.* The percentage of the head length was greater than the percentage of body depth for this species and it was because the head of this species was comparatively more elongated than the other species. In case of all species the highest and the lowest percentage was for forked length and pre-orbital length respectively. During the study on morphometric and meristic traits of *Dayella Malabarica* and *Hyporhamphus limbatus,* Johny, Inasu and Dominic (2016) developed graphs using different lengths in the form of percentage of total length and the graphs showed similar trend like the present investigation. The similarities between the findings of two studies confirmed that different morphometric lengths of fish followed a specific range of percentage of the total length and it could be considered as an inherent character of fish.

5.5 Correlation between the morphometric traits:

In the morphological studies Pearson correlation was conducted to measure the association between various morphometric and meristic parameters. The correlation coefficients between ten morphometric measurements were calculated in the current study. The values of correlation coefficients between the morphometric characters of *Tenualosa ilisha, Sardinella fimbriata* and *Hilsa kelee* indicated that all the characters had high positive correlation with each other and in case of *Tenualosa ilisha* and *Sardinella fimbriata,* all the correlations were significant at the 0.01 level. For *Hilsa* *kelee,* correlations of the morphometric characters were found to be significant at the 0.01 and 0.05 levels. Out of ten morphometric characters of *Escualosa thoracata*, nine characters showed high positive correlation with each other. Only the pre-orbital length was weakly correlated with the other measurements. For this species except eight correlations all the correlations among the morphometric measurements were significant at the 0.01 and 0.05 level. The pre-orbital length of this species had only significant correlation with the head length. Only five correlations such as total length with standard length, total length with forked length, standard length with forked length, head length with pre-ventral length and pre-dorsal length with pre-anal length came out as significant correlations in case of *Sardinella longiceps.* According to the value of correlation coefficient there was no correlation between pre-orbital length and pre-dorsal length. The pre-orbital length and body depth were negatively correlated in this species. In*Anodontostoma chacunda* all the morphometric measurements showed moderate to high positive correlation with each other. Except the pre-orbital length all the measurements were significantly correlated in this species at 0.01 and 0.05 level of significance. Vasave and Saxena (2013) carried out Pearson correlation between total length and all the other morphometric parameters in case of *Onchorynchus mykiss* and the result revealed that the morphometric measurements were highly correlated with total length at 0.01 level of significance. Correlation among the morphometric parameters was executed by Mahilum *et al.* (2013) in order to differentiate body proportionality between male and female group of two Goby species (*Glossogobius celebius* and *Glossogobius giuris*). Correlation between morphometric measurements of *Euthynnus alletteratus* revealed that except length of second dorsal fin base and length of pectoral fin all the measurements had very high level of correlation (Hajjej *et al.*, 2013). The similarities between the findings of present study and previous studies established that almost all the morphometric characters of fish had correlation with each other.

5.6 Month and station wise variation in morphometric traits:

Fishes are very much sensitive to the changes in it's surrounding environment and adapt themselves by adjusting the required morphometric characters (Brraich and Akhter, 2015). Fish typically exhibit greater differences in morphological traits both within and between populations and more susceptible to environmentally influenced morphological variation (Allendrof *et al*., 1987; Wimberger, 1992). Considering this special traits of fish, variations among different sampling stations and sampling months were determined in the current research. By comparing the average values of the morphometric measurements between the sampling stations an exception was found in case of *Hilsa kelee*. This exception might happen for the effect of any specific environmental factor or combined effect of many environmental factors which could alter their growth pattern. Same graphical presentation was done by Olopade *et al.* (2018) to compare between the morphometric measurements of *Coptodon guineensis* in two different locations.

5.6.1 Cluster analysis:

Cluster analysis involves looking via multivariate data for observations which are sufficiently close or similar to each other to be usefully categorized as part of a common cluster. The cluster analysis was carried out in case of all species to observe the monthly variation among the morphometric traits. The dendrogram which was drawn on the basis of morphometric measurements demonstrated that all the six identified species had variation in their morphometric traits according to different months; some moths showed similar morphometric traits, some had different traits than the other months and in case of some species single month formed separate cluster indicating more deviated traits from the other months. Every year fish goes through different developmental stages of its life and at each stage some changes happen in the morphology of the fish (Andujar *et al.,* 2016). As well as seasonal variation also influences the morphological characters of fish (Ogut and Altuntas, 2011). The present study suggested that due to all these reasons, the morphometric characters of the fish species varied according to the months.

On the basis of morphological measurements dendrogram was developed for the population of *Tenualosa ilisha* (Das *et al*., 2020), *Ompok bimaculatus* (Mahfuj *et al*., 2020), *Sardinella lemuru* (Sartimbul *et al*., 2018), *Labeo ariza* (Ahammad *et al*., 2018) and *Euthynnus alletteratus* (Hajjej *et al.*, 2013) from different habitats in order to understand the relationship and variation between the habitats.

Aisya and Syarif (2018) and Kashefi, Bani and Ebrahimi (2012) drew dendrogram for *Anodontostoma sp.* and *Rutilus frisii* respectively to determine the relations among their morphometric variables.

5.6.2 Principal Component Analysis (PCA):

In morphological studies principal component analysis is used for reducing morphometric data (Mir *et al*., 2013) and for minimizing the repetition between the variables (Samaee *et al*., 2006). According to Principal Component Analysis (PCA) and PCA biplot, variation among the adjusted morphometric measurements and sampling stations was analyzed for *Tenualosa ilisha, Escualosa thoracata* and *Sardinella fimbriata.* The PCA biplot of this three revealed some correlations among the adjusted morphometric variables. PCA biplot of *Tenualosa ilisha* and *Sardinella fimbriata* indicated that with a few minor exceptions, the adjusted morphometric characters had similarities among the three sampling stations. For *Escualosa thoracata*, the variables of station 2 couldn't form a cluster in the PCA biplot due to lack of data. It was occurred as the availability of this species in station 2 was very low. The connection of station 1 and station 3 in the biplot suggested that similarities were present in the morphometric measurements of these two stations. As the sampling stations were the parts of the same coastal region, so similarities were found in the morphometric characters of fish species collected from the stations. The reason of some exceptions might be due to the influence of environmental factors. Caneco, Silva and Morais (2004) conducted similar type of Principal Component Analysis and PCA biplot using morphometric variables to identify the morphometric variations among *Engraulis escrasicholus* from two different waterbodies. Principal Component Analysis was done by Das *et al*. (2020) using the morphometric characters and truss measurements of *Tenualosa toil* and *Tenualosa ilisha* collected from three habitats of Bangladesh to differentiate between this two Clupeidae species.

5.7 Length-weight relationship:

From the length-weight relationship the value of parameter "b" of every fish species was determined which indicated the growth pattern of the species. In the study "b" value of *Tenualosa ilisha* was 2.65 which revealed the species had negative allometric growth. According to the growth pattern the Hilsa fishes of the Chattogram coastal region grew faster in length than in weight. According to Ahmed *et al*. (2018) the growth pattern of *Tenualosa ilisha* was positive allometric in the Bay of Bengal. Both the male and female *Tenualosa ilisha* had isometric growth pattern in Meghna River, Bangladesh (Flura *et al*., 2015). By sampling from Chandpur, Barishal, Bhola and Kuakata, Amin *et al*. (2005) stated that *Tenualosa ilisha* had positive allometric growth with “b” value of 3.381 in the Bangladesh water. Habitat difference and influence of environmental or seasonal factors might cause dissimilarities between the results of current and previous studies. In the present study *Escualosa thoracata* had a “b” value of 2.73 indicating the negative allometric growth of the species in the study area. Similar growth pattern of this species was found by Gurjar *et al.* (2017) in Maharastra, India. Growth pattern of both male and female *Escualosa thoracata* was determined as positive allometric in Kerala, India (Abdussamad *et al*., 2018). According to the length-weight relationship, *Sardinella fimbriata* of Chattogram coastal region had isometric growth as the “b” value of the species was 3. It indicated that the length and weight of the species increased at the same rate. Bintoro *et al*. (2019) and Rilani, Mulyanto and Setyohadi (2017) mentioned that the growth pattern of *Sardinella fimbriata* was negative allometric in Bali strait and in West Nusa, Tenggara of Indonesia respectively. *Sardinella fimbriata* had negative allometric growth pattern with “b” value of 2.85 and 2.91 for male and female respectively in Karwar coast (Kudale, Rathod and R, 2016). According to the length-weight relationship graph parameter b=2.45 for *Sardinella longiceps* which indicated negative allometric growth of the species in the coastal region. Similar growth pattern of the species was found in Ratnagiri coast of Maharastra, India and in Baluchistan coast, Pakistan by Shah *et al*. (2014) and Baset *et al*. (2020) respectively. The growth pattern of *Sardinella longiceps* was positive allometric in Mumbai coast of Maharastra (Ahirwal, Jaiswar and Chakraborty, 2017). During the present investigation values of “b” were calculated as 3.44 and 3.72 for *Hilsa kelee* and *Anodontostoma chacunda* respectively. The values of “b” indicated that both species had positive allometric growth in the Chattogram coast and they grew faster in weight than in length. Siddik *et al.* (2016) conducted a research on length-weight relationship from a coastal artisanal fishery, southern Bangladeshand stated that $W = 0.011L^{3.04}$ was the length-weight relationship for *Anodontostoma chacunda.* The differences in habitat and also in environment might cause the dissimilarities in the growth pattern of the same species. Different factors which influences the growth of fish could also cause these type of dissimilarities.

CHAPTER SIX

CONCLUSION

Study on the morphological characters in fish is considered as an important tool as they can be used to differentiate the taxonomic units and are able to determine variations among the populations. Morphological systematics is the easiest and fastest method of fish identification which includes the morphometric and meristic characters. The present morphological study confirmed the identification of six species of Clupeidae family in the Chattogram coastal region. From the data obtained by the study it might be concluded that *Tenualosa ilisha* was the most dominant fish species of the coastal area; the meristic characters of the fish species didn't vary with growth, different months and sampling stations; except pre-orbital length and body depth all the morphometric characters were correlated to each other; monthly variation was found in the morphometric characters of every species but station wise variation was very low in the characters. In case of growth pattern *Tenualosa ilisha*, *Escualosa thoracata, Sardinella longiceps* had negative allometric growth, *Sardinella fimbriata* had isometric growth and *Hilsa kelee, Anodontostoma chacunda* had positive allometric growth in the Chattogram coastal region. Analysis of their morphometric and meristic characters provided useful information about the species which are able to fulfill the research gap in the field. Due to the demand and economic value large amount of research works were done on *Tenualosa ilisha*. But sufficient information is not available about the other available species of the family. As morphological study is the initial step for the advance studies on a fish species, so the information obtained from the present research will make the path of future research easier.

CHAPTER SEVEN

RECOMMENDATION AND FURTHER PERSPECTIVE

According to this research work, the following recommendations may be done:

- Nutritional studies can confirm nutritional profile of the identified species of Clupeidae family and if any species is found as equivalent as *Tenualosa ilisha* in nutrition and flavor, then this species may reduce the pressure of high market demand on *Tenualosa ilisha.*
- Landmark based truss network can be applied as a part of morphological study to identify different stocks of *Escualosa thoracata, Sardinella fimbriata, Sardinella longiceps, Hilsa kelee* and *Anodontostoma chacunda*.
- Except *Tenualosa ilisha* sufficient information about other identified Clupeidae fish species is not available.So further researches such as biometric analysis and studies on the reproductive and population biology of the species will reveal detailed information of them.
- Information about the growth pattern of the available species of Clupeidae family will help in determining condition factor of the species.
- As it is a pilot study, further studies may be conducted on similar field to make a concrete remark.

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APPENDICES

Appendix A (I): Result of One-Sample Kolmogorov-Smirnov Test for different morphometric measurements of *Tenualosa ilishsa*

	TL	SL	FL	HL	BD	PoL	PdL	PpL	PvL	PaL
Kolmogorov-Smirnov Z	.589	.423	.457	.621	.513	.810	.464	.392	.573	.583
Asymp. Sig. (2-tailed)	.878	.994	.985	.835	.955	.527	.983	.998	.898	.886

a. Test distribution is Normal.

b. Calculated from data.

Appendix A (II): Result of One-Sample Kolmogorov-Smirnov Test for different morphometric measurements of *Escualosa thoracata*

	TL	SL	FL	HL	BD	PoL	PdL	PpL	PvL	PaL
Kolmogorov-Smirnov Z	.585	.457	.552	.671	.511	1.204	.466	.620	.500	.560
Asymp. Sig. (2-tailed)	.884	.985	.921	.759	.957	.110	.982	.836	.964	.912

a. Test distribution is Normal.

b. Calculated from data.

Appendix A (III): Result of One-Sample Kolmogorov-Smirnov Test for different morphometric measurements of *Sardinella fimbriata*

	TL	SL	FL	HL	BD	PoL	PdL	PpL	PvL	PaL
Kolmogorov-Smirnov Z	.744	.684	.853	.826	.423	1.303	.616	.643	.672	.874
Asymp. Sig. (2-tailed)	.638	.737	.461	.503	.994	.067	.842	.802	.758	.429

a. Test distribution is Normal.

b. Calculated from data.

Appendix A (IV): Result of One-Sample Kolmogorov-Smirnov Test for different morphometric measurements of *Sardinella longiceps*

	TL	SL	FL	HL	BD	PoL	PdL	PpL	PvL	PaL
Kolmogorov-Smirnov Z	.450	.544	.381	.883	.475	.614	.351	.436	.769	.417
Asymp. Sig. (2-tailed)	.988	.928	.999	.417	.978	.846	1.000	.991	.595	.995

a. Test distribution is Normal.

a. Calculated from data.

Appendix A (V): Result of One-Sample Kolmogorov-Smirnov Test for different morphometric measurements of *Hilsa kelee*

	TL	SL	FL	HL	BD	PoL	PdL	PpL	PvL	PaL
Kolmogorov-Smirnov Z	.462	.473	.438	.410	.618	.701	.405	.509	.485	.554
Asymp. Sig. (2-tailed)	.983	.979	.991	.996	.839	.710	.997	.958	.973	.919

a. Test distribution is Normal.

b. Calculated from data.

Appendix A (VI): Result of One-Sample Kolmogorov-Smirnov Test for different morphometric measurements of *Anodontostoma chacunda*

	TL	SL	FL	HL	BD	PoL	PdL	PpL	PvL	PaL
Kolmogorov-Smirnov Z	.568	.717	.636	.390	.409	.508	.555	.651	.608	.705
Asymp. Sig. (2-tailed)	.904	.683	.813	.998	.996	.959	.918	.790	.854	.703

a. Test distribution is Normal.

b. Calculated from data.

Appendix B (I): Descriptive statistics for *Tenuaosa ilisha*

	Mean	Std. Deviation	Minimum	Maximum
TL	34.0407	4.56064	23.00	41.50
SL	28.3926	3.79351	19.00	35.50
FL	29.5407	3.87499	20.00	36.60
HL	7.9370	1.09233	5.30	9.70
BD	8.4726	1.34938	5.00	11.20
PoL	1.8474	.29719	1.30	2.40
PdL	13.2559	1.94186	8.50	16.70
PpL	7.7900	1.14858	5.50	9.80
PvL	13.6196	1.97584	9.30	17.20
PaL	20.6848	3.00132	13.50	26.00

Appendix B (II): Descriptive statistics for *Escualosa thoracata*

	Mean	Std. Deviation	Minimum	Maximum
TL	8.9727	.89676	7.20	10.20
SL	7.2727	.65892	6.00	8.20
FL	7.8273	.73769	6.50	9.20
HL	1.4909	.14460	1.20	1.70
BD	2.2273	.30030	1.70	2.70
PoL	.3727	.07862	.20	.50
PdL	3.2727	.33194	2.60	3.70
PpL	1.6091	.17581	1.30	1.90
PvL	3.3455	.33575	2.60	3.90
PaL	5.0273	.50812	3.90	5.70

Appendix B (III): Descriptive statistics for *Sardinella fimbriata*

	Mean	Std. Deviation	Minimum	Maximum
TL	14.8714	3.04869	9.00	19.30
SL	12.2357	2.62930	7.10	16.20
FL	12.9071	2.70653	7.60	17.00
HL	3.0429	.43978	2.30	3.70
BD	3.4929	.63907	2.10	4.40
PoL	.8850	.21292	.50	1.10
PdL	5.3429	1.04713	3.50	6.90
PpL	3.0500	.47027	2.20	3.80
PvL	5.8264	1.21190	3.70	7.60
PaL	8.8000	2.06249	5.10	11.60

Appendix B (IV): Descriptive statistics for *Sardinella longiceps*

	Mean	Std. Deviation	Minimum	Maximum
TL	22.9250	1.18708	21.50	24.40
SL	19.4500	.90000	18.30	20.50
FL	20.6750	1.16440	19.20	22.00
HL	5.7000	.20000	5.40	5.80
BD	4.7250	.27538	4.40	5.00
PoL	1.6500	.05774	1.60	1.70
PdL	9.1000	.43970	8.60	9.60
PpL	5.5250	.30957	5.10	5.80
PvL	10.4500	.43589	9.80	10.70
PaL	15.3750	1.32004	13.70	16.70

Appendix B (V): Descriptive statistics for *Hilsa kelee*

	Mean	Std. Deviation	Minimum	Maximum
TL	17.8600	5.02723	11.50	24.00
SL	14.8200	3.95563	9.50	19.70
FL	15.4600	3.96207	10.00	20.00
HL	4.2600	1.23612	2.60	5.80
BD	4.9800	1.70353	3.20	7.30
PoL	1.0600	.46152	.70	1.70
PdL	6.6600	1.85284	4.00	8.90
PpL	4.1000	1.22678	2.60	5.60
PvL	7.2600	2.21991	4.50	10.00
PaL	11.0600	3.58511	7.00	16.10

Appendix B (VI): Descriptive statistics for *Anodontostoma chacunda*

	Mean	Std. Deviation	Minimum	Maximum
TL	14.5800	3.58357	9.80	18.60
SL	11.8600	2.80589	8.00	14.50
FL	12.5000	3.12250	8.50	16.00
HL	2.8800	.63797	2.00	3.60
BD	4.7000	1.43527	2.50	6.20
PoL	.7000	.21213	.50	1.00
PdL	5.5800	1.36638	3.80	7.00
PpL	3.0600	.68044	2.10	3.70
PvL	5.8800	1.39356	3.90	7.30
PaL	8.6600	2.18014	5.70	10.70

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