CHAPTER 1

INTRODUCTION

Bangladesh is one of the potential fish producing nations in the world with annual production of 46.21 lakh MT in the FY (Fiscal Year) 2020-21, where aquaculture industry contributes 56.24 percent of the total fish production (DoF, 2017). The average growth execution of this area is 5.26 percent throughout the last 10 years. Marine water covers 71% of our planet, which is 97.95% of our world's total water, and is regarded as the earth's life-supporting environment due to its capacity for supporting marine resources (Cenedese et al., 2020). The research of marine habitats and their nature has a significant impact to explore the marine ecology. Marine ecology comprises versatile areas of research though the ecosystem is quite complicated and complex as well. Therefore, in the massive maritime region of coastal states requires prolific and extensive study on marine ecosystem. In this diverse and unique ecosystem, fish species play a vital role in being an active dwellers group by their number. Being a part of this enormous ecosystem, Bangladesh possesses 432 marine species (DoF, 2019) and 260 freshwater species of fish (DoF, 2017). This diversified fish species have a profound impact to the ecosystem along with its other roles to the aquatic environments. Fish production sector is very important in our country due to the fact that over 17 million of people, among which 1.4 million female workers, remain associated with the fisheries sector for leading their livelihood in Bangladesh (BFTI, 2016). This the sector of fisheries serves 3.50% to the nation's GDP during the year 2018-19. In the present situation, more than 12% of the people works in fishing, both internally and externally. (DoF, 2019). All over the world, maximum people depend on animal protein for the dietary satisfaction especially coastal people. Fish is high in micronutrients like minerals and vitamins as well as micro - nutrients like protein, lipid, and ash. Immunoglobins, which are found in fish proteins, serve as a defensive mechanism against bacterial and viral infections and guard against protein deficiency. Lipids, particularly long-chain (LC) n-3 Polyunsaturated fatty acids (n-3 PUFAs), docosahexaenoic acid (DHA), and eicosapentaenoic acid (EPA), prevent cardiac and myocardial heart illnesses while also maintaining pulse rate and a child's neurological development. Selenium is crucial for the pituitary gland's health. Iron aids in the hemoglobin synthesis and guards against anemia. rickets, osteomalacia, and low bone mineral density are all prevented by the naturally occurring calcium and vitamin D found in fish. (Balami et al., 2019). In Bangladesh, 60% of animal protein consumption is solely dependable on fish protein consumption (DoF, 2016).

An updated checklist is very essential to know about the current status of ariidae family species in Chattogram coast. Survey on ariidae family species was not done for many years in the coastal area of Bangladesh. To evaluate the current status of the fish and shellfish taxa in the coastal and estuarine waters of Bangladesh's South Eastern region, mainly in Chittagong and Cox's Bazar districts, a year-long field inventory was done. Regarding the current perspectives of fishing resources to evaluating the current reality of species compositions, both dependent and independent variables were taken into consideration.

1.1 Morphological systematic

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. For taxonomic status, these morphological measurements, meristic counts, structure, and volume provide several types of information (Ihssen et al., 1981). The first stage in any research project is to identify a species. Morphological characteristics are mainly useful for identifying a species and taxonomic study (Brraich and Akhter, 2015). Furthermore, understanding a morphological feature's purpose is essential for its practical application in classification and ecology. 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. Consequently, morphometric investigations are effective instruments for evaluating discretness within the species (Muhammad and Abdus, 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, 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 is considered obligatory for estimating various physiological and morphological aspects such as width and maturity distribution, rate of growth, and other crucial fish population dynamic factors (Kohler et al., 1995).

1.2 Length-weight relationship

When any fish family or population is studied, the growth of species is considered as an important parameter. The length-weight relationship (LWR) is regarded as a highly significant metric for understanding the growth of a fish population and is used in fisheries studies to determine the rate of growth (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. When managing fishing resources and examining the morphological characteristics and life histories of fish populations living in various locales, the length-weight connection is very important (Martin et al., 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 species' taxonomic characteristics. (Pervin and Mortuza, 2008)

1.3 Significance of the study:

The three primary components of the current study is Ariidae, morphology, and Chattogram coast. So, this analysis will notify us about the current situation of ariidae family along the Chattogram coast. In addition, morphological study will provide us the clear idea about the species abundance of ariidae family.

1.3.1 Importance of Ariidae morphology:

Fish development patterns, habitat circumstances, health in general, infancy, nutrition, fish body fat percentage, development phase, gonad middle - aged, reproductive category, size distribution, physical shape, and common species form and management are all significantly influenced by morphometric analysis (Jisr et al., 2018). Finding the distinctions across geographically diverse population and determining the taxonomic categorization of a genus or species probably need the observation of fish physical characteristics. The majority of scientists currently use DNA sequencing to identify the evolutionary link between various taxonomic groups. Nonetheless, these molecular research are all quite expensive (Masood et al., 2015a, b). As a result, the systematic investigation of fish phenotypic features had been thought to be the earliest method of research (Heinke, 1898). Additionally, the morphological traits of fish are primarily categorized into two: morphometric and meristic attributes (Ambily, 2017). The term "morphometry" refers to the physical investigation of animals, and the term "meristic" refers to the counting of any organism's characteristics. These two terms can be used to observe differences between fish populations of the same species that occur in different areas of the world (Groeger, 2000; Dars et al., 2012). Any fish species' evolutionary characteristics can be explained by all of these variances, which may be brought on by changes in their sex, development rates, environmental conditions, availability of food, predator-prey dynamics, and more (Masood et al., 2015a, b; Ambily, 2017). Furthermore, the similarity or disparity in many qualities between male and female fishes with the same species can be explained by fish morphological features or meristic characteristics. All of these sexual dimorphism differences may result from changes in specific biological fish parameters (Masood et al., 2015b). Numerous environmental conditions, particularly during the juvenile or physical maturity phases of fish during the nesting season, have a major impact on morphometric characteristics (Adeoye et al., 2016; Akter et al., 2019)

In stock assessment, fish morphology accomplishes the initial process. The experiments on morphometric and meristic characteristics include an initial strategy in cohort estimation, asymptotic length, finding the distribution of a specific species, a record of new species in different geological areas according to (Ahmed et al., 2017; Hanif et al.,2017). Another application of morphological and meristic characteristics in aquaculture is measuring hormone treatment (Yanong et al., 2010). Estimating feed nutritional quantity for fish is essential step of aquaculture. As feed nutrition requirement consider the factor which are body weight and age. Therefore, estimating feed is controlled by morphology in some extent because weight is a morphological character and age can be measured through morphological characteristics (Davis, 2015). Nowadays, morphometric characters get emphasized by scientific communities. In all these cases, the result is coming out either in the form of weight or length. In breeding biology, age is an important factor and the circle on the scale, marks, or unique patterns on the body may indicate the fish age, (Carbonara and Follesa, 2019). Fish identification is the most important use of morphometric and meristic characteristics.

Morphometric and meristic traits are typically used to distinguish between closely related species. The suspected fish sample is first to go through a morphometric way, and then it is gone through the genetic experiment for further confirmation. Morphometric characters give the precise feedback and outcome in genetic experiments like hybridization, inbreeding, and comparing between the parents' generation and F1 and F2 generation (Khan et al., 2002). This decision is also taken based on morphometric and meristic characters, especially when selecting the strain. Cryopreservation or live conservation is also dependent on morphological and meristic characters. An individual of a species with remarkable growth or an individual with outstanding quality is usually preserved for the future. So, the decision of cryopreservation or live condition conservation also initially depends on morphometric characters. They may seem to be an indirect process, but the dependency of morphometric characters' processes is unavoidable.

1.3.2 Importance of Ariidae family:

In terms of species diversity, biomass, and frequency, arridae are the most significant group of fishes found in tropical estuaries (Barletta and Blaber, 2007). The ariidae family is ideally suited to living in various estuarine settings throughout the tropical and subtropical world (Barletta et al., 2007).

Marine catfishes especially species of the Ariidae family form important component of demersal fish landings in India with a contribution of 68675 t in 2014 (CMFRI, 2015). Ariidae family was originally described as Arii (Bleeker, 1858) which was hypothesized to be primitive (Regan, 1911). In terms of phylogenetic resolution, the Ariidae family of catfishes is arguably the least well-resolved and hence attempts were made to establish sound species classification based on phylogenetic studies (Marceniuk and Menezes, 2007; Kailola, 2004; Acero et al., 2007 Acero, 2004; Marceniuk et al., 2012). Estimates for the number of genuine ariid species range from 120 to 200 (Kailola, 2004; Acero and Betancur, 2007). The family is reported to have 26 valid genera and 133 valid species including fossil taxa (Ferraris, 2007; Marceniuk and Menezes, 2007). As per the online database, Catalog of Fishes, there are 145 valid species in the family, with 9 species described in the last 10 years (Eschmeyer and Fong, 2015). A detailed description of 27 species of ariid catfishes from the Indian sub-continent was found by (Day, 1889). The study gave field identification characters of

21 of ariid catfishes from Indian waters along with their distribution (Menon and Bande 1987). As of now, ariidae are represented by 9 genera and 25 valid species in Indian waters, with the validity of certain species like *Arius malabaricus* and *Arius gagora* and presence of *Plicofollis nella* and *Plicofollis argyropleuron* being doubtful in Indian waters. Ariid catfishes are mostly distributed in coastal waters with some species preferring deeper waters and a few are reported from freshwater ecosystems. The significant species diversity and declining abundance of the group, due to human interference, warrants immediate management measures that requires sound taxonomic footings to begin with. In this context, taxonomic works related to ariid catfishes, carried out so far, revolved around features like fin rays counts, head shield pattern, vomerine and palatine teeth patch shape and number of barbels and their length.

1.3.3 Importance of Chattogram coast for Ariidae:

Chattogram coast is one the most diversified coast in Bangladesh specially in case of marine and estuarine fish. Fish production was 42.77 lac metric ton, whereas the Chattogram region contributes 11.69 lac metric ton, and Cox's Bazar contributes .90 lac metric ton. (DoF, 2018). Chattogram contributed 27.33% of total production, whereas Cox's Bazar contributed 7.73% of Chattogram's production. (DoF, 2018) Chattogram coast of Bangladesh has unavoidable opportunities and strength to study this ariidae family. All these works followed the morphometric and meristic way of the identification process.

1.4 Objectives of the Study

The prime objective of this research initiative is –

● To identify the morphometric and meristic differences among the available fishes under the Ariidae family along the Chattogram coast.

● To record and investigate new cases arising of any specimen of species under the Ariidae family in Chattogram coast.

CHAPTER 2

REVIEW OF LITERATURE

The fish population, family, and species are theoretically and systematically different due to their morphometric and meristic variation. This variation differs in genetic nature with parasitological ways applying morphometric and meristic differentiations. Genetically or in a parasitological way is another method for the confirmation of the interpretation. In all cases, morphological and meristic characters are taken under consideration to identify initial variation among related species, groups, populations, or families. This chapter reviewed the studies associated with the morphological and meristic characters of fish populations, families, and species in Bangladesh and other countries.

2.1 Studies related with Ariidae family

Researchers looked at the morphological diversity of catfishes from the Ariidae family that live along India's west coast (Kumar et al. 2015). Twelve species of ariid catfish that are found along west coast of India were studied for morphometric and meristic qualities, and the results showed that all these species can be distinguished from one another based on morphological factors. Inter-nostril length, mouth width, and adipose fin length had higher F-ratios, indicating that they may be used alone or in conjunction with other morphometric traits to help distinguish between types. Inter-nostril size, snout length, and adipose fin length were found to be the most significant discriminating features in the stepwise discriminant function analysis (SDFA), which encompassed all variables under consideration and demonstrated their taxonomic relevance. 89.44% of the overall variation could be explained by the first two discriminant functions. With only two incorrect classifications out of 447 specimens, SDFA correctly classifies cases in 99.55 percent of the time. Meristic characteristics are less discriminating than morphometric variables since they are shown to be redundant almost always. A taxonomic study of ariidae family from indian waters was also done (Rajan et al., 2015). A total of 19 species (15 species from fresh collection and 4 from ZSI museum) were examined for taxonomic differences. Descriptive analytics of 19 species' morphometric characteristics include *Netumabilineata*, *N. thalassina*, *Plicofollis dussumieri*, *P. tonggol*, *P. tenuispinis*, *P. platystomus*, *Nemapteryxcaelata, N. macronotacantha, Osteogeneiosus militaris, Arius jella, A. maculatus, A. subrostatus, A. venosus, A. sumatranus, A. gagora, A. arius, Sciadessona, Hexanematichthys sagor* and *Batrachocephalus mino* revealed significant differences between the species. Pre nostril length, snout length, mouth width, pre dorsal lengths, pre anal length, eye diameter, snout length and pre barbel from a taxonomic perspective, lengths were discovered to be more significant. Twelve modified morphometric variables from 12 ariid species were subjected to the Stepwise Discriminant Function Analysis (SDFA). For 12 species, SDFA assigns a proper classification rate of 99.76 percent, with the first two canonical variables accounting for 89.7 percent of the variance. One of the most prominent physical characteristics that helped identify the species in question in the field was its teeth. The osteocranuim showed marked difference between species and in combination with cleithrum and median nuchal plate was found sufficient in delimiting species. The key discriminating features were median mesethmoid notch, lateral horn of lateral ethmoid, posterior cranial fontanel, extrascapular, epioccipital, temporal fossa. The shape of lapillus otolith in dorsal view of 14 ariid species showed marked difference between genera. Differences between species were negligible. To determine the affinities between species, the cluster analysis (Ward's minimal variance approach) depending on 42 features was used. Grouping together species that belong to the same genus confirmed the species' current generic identification.

Another study was done in Malaysia which was titled as "Morphological Variations of *Plicofollis* Species (Siluriformes: Ariidae) in Peninsular Malaysia: An Insight into Truss Network Approach" The study, which focused on the *P. argyropleuron, P. nella,* and *P. tenuispinis* species found in the waters off Peninsular Malaysia, was based on 20 truss measurements and used 22 to 23 specimens per species. Utilizing a multivariate technique of discriminant function analysis, morphological changes were identified (DFA). The findings of this study demonstrated that all of the species in the *Plicofollis* group were clearly separated by discriminant analysis using truss network data. The body depth and caudal regions of the fish have been represented by a number of significant morphological features. Documentary proof of these factors may be viewed as productive function characteristics that help us distinguish between species within the complicated Ariidae group better precisely (Abdurahman et al., 2016)

2.2 Morphometric studies of other fishes

On St. Martin's Island in Bangladesh, there was a new record for the concertina fish, *Drepane longimana* (Perciformes: Drepaneidae) (Ahmed et al., 2017). An analytical technique using morphometry was used to confirm the species. It demonstrated how the body was crushed and shaped like an oval. The mouth was forcefully projecting, and as it did so, it created a tube that pointed down the ward. Anal fins had three spines and 17 to 19 soft rays, whereas a single dorsal fin had 8 to 9 (often 8) spines (the fourth-largest spine). The head and body were silvery in tone. It is simple to distinguish this species from other closely related species of the genus Drepane thanks to the appearance of four to nine subvertical dark bars on the dorsal section from the tip of the head to the base of the caudal fin. Therefore, morphometric and meristic evidence support *Drepane longimana's* existence in Bangladesh. This study updates the geographic range of this species and establishes its presence in Bangladesh's coastal region. Some researchers investigated the morphological traits to calculate the variances in Labeobata populations from Bangladesh's six rivers. The goal of the study was to determine the population status of Labeobata in Bangladesh's north and west.The study was executed based on morphometric traits analysis and landmark analysis. A total of 22 morphometric characters were taken under observation, among which 15 characters showed significant inter-stock variation. The finding was concluded that the populations showed variation among themselves distinctly, which represented separate locations. Still, it was also assumed that this variation might result from environmental influences (plasticity of traits) rather than genetic variation (Mahfuj et al., 2017). Parvez and Nabi executed morphometric and meristic analysis with a view to racial investigation of *Coilla ramcarati* from Chattogram and Cox's Bazar coast. The study's statistical analysis of *Coilia ramcarati* morphometric measures and meristic counts established the surety of any potential racial differences in the species from the Bay of Bengal coasts of Cox's Bazar and Chittagong. The populations of *Coilia ramcarati* from the coasts of Chittagong and Cox's Bazar were not racially distinct, according to some changes that were discovered but were minor with a 5% threshold of importance (Parvez and Nabi, 2014). There was a successful experiment to observe the morphometric relationship of tank goby *G. guiris* by using multiple linear dimensions. The samples of *G. guiris* were taken from the Gorai River in the southwest of Bangladesh and had a total of 13 linear dimensions. Length-Weight Relationships

(LWRs) and Length-Length Relationships (LLRs) were among the morphometric relationships that these dimensions revealed (LLRs). The study also gave focus on meristic characters of samples. As the part of the result fin formula of *G. guiris* was come out in the form of a result. The fin formula for *G. guiris* was D1. VI; D2. 8–11 (II–III/8– 11); pectoral, P1. 17–22 (II-VI/14–19); pelvic, P 2. 10–13 (II–III/8–10); anal, A. 7–12 (II–IV/5–8); and caudal, C. 16–21 (IV–VIII/12–13). The Gorai River and nearby environments can benefit from this study's contribution to species recognition and stock assessment of *G. guiris,* or it can be used in another place (Azad et al., 2018).

The available fish under the Gobiidae family of Nijhum Island, Hatiya adjacent to Meghna River, and Pashur River from Sundarban based on sampling works were investigated by Latifa et al. (2015). This experiment carried out an in-depth observation of morphometric and meristic characteristics. The main objectives of the study were to classify and morphologically distinguish the available Gobiidae fish. There were seven species of Gobiidae fish that had been described by the findings of the study. A comparative study on the conceptual idea of morphometric and meristic characteristics was done in the study could open a further opportunity to identify Gobiidae fish in other available Gobiidae of Bangladesh. A survey type study on the availability of fishes of the greater Noakhali region reviewed the available Gobiidae fishes of the Noakhali region (Hossain, 2013). Based on available Gobiidae fish, the observation of morphometric and meristic traits variation was done. Ten species were found under the Gobiidae family. They were *Taenioides buchanani, Odontamblyopus rubicundus, Pseudapocryptes elongates, Glossogobius guiris, Awaous guamensis, Acentrogobius caninus, Acentrogobius viridipunctatus, Oxyurichthys micorlepis, Parapocryptes batoides*. Identifying them and variating initially by morphological traits among them was the objective of that study. The stage, condition of availability, and other fundamental characteristics related to these species were also studied in the observation. An experiment to examine the morphological variation of G. guiris among three different habitats (Mollah et al., 2012). A variety of landmark-based morphometric data and meristic data were used to conduct the study in several routes including a pond in Mymensingh, a haor in Kishorgonj, and the estuary in Barishal. In this work, the variation between the three groups was determined using measurements of 23 size-adjusted landmarked based data and 13 general morphometric trait data. It showed that haor stock was different in the case of transverse scale on the lateral line. Another significant difference revealed through dendrogram was that, between two main clusters, the pond possessed one group and a hoar and estuary stock that showed a very close relationship between the estuary and haor stock of *Glossogobius guiris*. For determining the differences of the same species among the different populations, the study will be a helpful guide. Researchers have again studied morphological variations and their association to estimate the outcome of induced PG (Pituitary Gland) breeding in *Glossogobius guiris* (Islam and Mollah, 2013). The research was a morphological method or a way of testing the efficacy of another factor (PG effectiveness) rather than a truly morphological examination of the species. In the study, it revealed that the lengths of *Glossogobius guiris* were correlated with total length (LT) except the eye length (LE), the snout length (LSN), and the mouth gap (MG). They were correlated with a head length (LH) at a 1% level of significance. Few differences were also observed in meristic traits. Length-weight (WB= body weight, LT= total length) relationship was revealed as Ln WB = - 4.493 + 2.887 Ln LT with correlation coefficient "r" was 0.976 representing 97.6% of correlation in body weight and total length in male. The weight length equation for females was Ln WB = - 5.327 + 3.291 Ln LT, with a "r" denoting a 99.9% correlation between body weight and total length. B had a value of 2.887 for men and 3.291 for women. They came to PG's permissible dose for a specific month for a particular group of fish in order to encourage the greatest outcome.

Iranian Goby's morphological variation (*Ponticola iranicus*) was studied (Nikmehr et al., 2020). Morphological features of *Ponticola iranicus* populations of Anzali Wetland drainage were investigated during this research. In this analysis, a total of 22 morphometric traits were measured. Under the statistical test with a 5% level of significance, the results revealed a significant difference between the tested populations in the interorbital gap, the minimum width of the caudal peduncle, and the diameter of the eye. The study also showed that the morphological traits of the Anzali wetland population set them apart from other populations. *Potamoschistus bathi*, an alien species from the Black sea, was the subject of experiments by Boltachev et al. (2016). The distribution, ecology, and biological characteristics of the species were primarily the focus of the study. All components of the experiment, particularly the physical component of the investigation, underwent morphological analysis. The result revealed the fin formula of the species that D1- (VI-VII), D2- (I/12-13), A-I(II)/10-12, P-(14-

16) and possessed 32-38 scales on the transverse row. Meristic and morphometric characteristics of white Gobys (*Glossogobius guiris* Hamilton, 1822) from three lakes in Southern Luzon, the Philippines, including Laguna de Bay, Taal Lake, and Naujan Lake, were compared by Campang and Ocampo to reflect the pattern of morphological differences. It was discovered that some morphometric characters had notable differences. This study discovered variation in three dimensions for morphometric traits. They were head dimensions, comprising head length, lower jaw length, and head width; trunk dimensions, including body depth and width at the ventral fin and anal-fin origin; and fin dimensions, including anal fin base length, caudal fin length, and pelvic fin length among the three sites. The study's findings were the character variations for which the population varied from one another. The primary contributors to population variation were variations in measurements such as snout to anus (SA), pre-dorsal length (Pre1), pre-pelvic length (PPL), pelvic fin length (VFL), and length from pelvic fin to anus (VFA). Some meristic features, including scale on lateral line (LLS), caudal fin ray (CR), pectoral fin ray (PR), and anal fin ray, showed significant differences with a 5% level of significance (AR). The scientists hypothesized that the morphological variations of *Glossogobius guiris* between the chosen sites were not the result of genetic variation, but rather might be explained by the plasticity of features brought on by geographic isolation and ecological variations.

Another study conducted a thorough comparison of the closely related species *Glossogobius guiris* and *Glossogobius celebius* (Mahilum et al., 2013). The study concentrated on the many morphometric traits that differed across species and between the male and female sex groupings. From samples taken from Lake Lanao Mindanao in the Philippines, the authors employed 24 morphometric data points. According to the study's findings, *G. guiris and G. celebius* both exhibited more morphometric measurement uncorrelation in females than in males. Otherwise, there were no real differences between the two species.

Researchers were focused on the jaw morphology of a fish, which was the resulting appearance of the new species *Gobiodon brochus* from the west of the South Pacific (Harold and Winterbottom, 2012). Another researchers have experimented with morphometric studies on *Boleophthalmus boddarti* (Malaysian Goby) (Daud et al., 2005). This study included samples of *Boleophthalmus boddarti* from five populations that were counted in the areas of Pulau Pinang, Kuala Selangor, Banting, Port Dickson, and Melaka. The samples were morphologically analyzed using classic morphometric data, truss morphometric data, and meristic data. 15 morphometric data, 28 morphometric trusses, and 9 meristic data were used in the study to examine the degree of heterogeneity among the five populations. The analysis of all morphometric character data within and between populations revealed a significant difference of less than 5% of significance. Populations from Kuala Selangor and Banting make up the first set of morphometric truss data, followed by populations from Melaka and Port Dickson and Pulau Pinang in the third group. The third group differed somewhat from the other two groups. The results provided information on the shape of mudskippers on the Malaysian peninsula. Mudskippers from the central and southern areas of Malaysia were distinct from one other in the northern half of the country's border. In the instance of the meristic results, there was no identification for grouping. The link between length and weight found in the *Boleophthalmus boddarti* study was determined by the authors as logW = log 0.754 + 1.029 log TL.

The study region yielded a total of 64 taxa, including 10 shellfish species and 54 finfish species divided among 27 families. Based on family-wise contribution, Sciaenidae scored highest (7%) with 6 species, followed by Gobiidae (9%) and Scombridae (9%) with each having 5 species. Engnaulidae and Cynoglossidae ranked lowest (7%) with 4 species each. For shellfish (shrimp) species, the Pennidae family contributed (80%), represented by 8 species, while the Hippolytidae family contributed (20%), represented by 2 species (Akter Taslima et al. 2017)

The morphometric and meristic examination of *Tenualosa sp.* had received a lot of attention internationally. In order to better understand the morphological differentiation that exists between two congeneric Hilsha populations, *Tenualosa ilisha* and *Tenualosa toli* from Bangladesh water bodies, they also conducted a land mark based morphometric with truss measurements combined and meristic variations (Das et al., 2020). In West Bengal, where the populations of *Tenualosa ilisha* were geographically isolated, Vaisakh et al. (2020) discovered considerable morphological variations among three unique tropical habitats, namely rivers, estuaries, and resevoirs. On the other hand (Tint et al., 2019) conducted morphometric measurements between the two species of *Tenualosa sp.* to determine the likelihood of morphological diversification in Malaysia.

Ara et al. (2019) investigated the morphometric, meristic, and proximate composition of marine and freshwater Hilsa fish to compare the two. Young Hilsha Shad, *Tenualosa ilisha*, were gathered from three distinct places by (Jassim et al., 2012), who then conducted some statistical analysis. With the exception of some morphometric ratios, the results demonstrated negligible changes in some statistical analysis ratios. A comparison study of the morphometric and meristic differences between two varieties of *Tenualosa ilisha* from the river Indus in Pakistan was conducted (Narejo et al., 2008). The study discovered significant intertype differences in six morphometric parameters and seven meristic features.

Dizaj investigated the association between length and weight in Iranian clupeid fish (Dizaj et al., 2020). According to the study's findings, *Tenualosa ilisha* has a maximum slope b value of 3.48, indicating a highly significant and associated length-weight association. Bhakta investigated the length-weight connection of the *Tenualosa ilisha* seasonally (Bhakta et al., 2019). According to the findings, the species experienced positive allometric growth during the moonson and negative allometric growth throughout the winter. The relationship's values were very important. A research conducted on the length-weight relationship of the Hilsha Shad, *Tenualosa ilisha*, in the Bilah River, Indonesia (Machrizal et al., 2019). The outcome demonstrated a negatively allometric length-weight connection, with a b value smaller than 3 and a growth pattern strongly correlated with light penetration. In the Meghna river in Bangladesh, a research conducted on the length-weight relationships of hilsa, *Tenualosa ilisha* fishes (Flura et al., 2015). Every association between length and weight was found to be substantially connected. A study also found changes in the length-weight relationship, condition factor values, and GSI values between the summer and winter forms of *T. ilisha* (Narejo et al., 2008).

Tenualosa ilisha length-weight relationships in Bangladeshi water were examined (Amin et al., 2005). The study's findings showed that there was a highly significant association between length and weight and that the species in Bangladesh's water had a favorable allometric growth pattern.

Although *Amblygaster clupeoides* is an oceanic species connected with reefs and has long-standing socioeconomic as well as ecological value, there was little research about the morphometric variability. Bangladesh's coast along the Bay of Bengal served as their study region. *Sardinella pacifica*, a new species of sardine reported by (Hata and Motomura, 2019) was based on 21 specimens that were taken from the Philippines. five populations of *Sardinella lemuru* from the waters of the Bali Strait, northern, and southern-east Java, were examined for differences in morphometric and meristic traits, as well as their relationships to the environment. A researcher used the morphometrics of the Indian Oil Saredine, *Sardinella longiceps*, to determine the implications of adaptive variation (Sukumaran et al., 2016). Researchers conducted a biometric investigation of *Sardinella longiceps* throughout the Ratnagiri coast of Maharashtra using 14 morphometric features from 917 specimens (Shah et al., 2014). *Anodontostoma sp.* morphometric and meristic characteristics change between Kelabat Bay and Tukak Strait, according to research by (Aisyah and Syarif, 2018). Results from 23 morphometric multivariance analyses of Selangat fish revealed 52.17 percent similarity. Between two stocks, there was no discernible variation in meristic properties.

There was a research on the *Sardinella longiceps* from Pakistan's Baluchistan Coast (Baset et al., 2020). The estimated slope b value of 2.25 revealed the experimental species' negative allometric growth. *Sardinella fimbriata* from Indonesia underwent population dynamics analysis in a study by Binotro et al. (2019). The length-weight connection showed a negative allometric increase, according to the study. The new species may be distinguished thanks to reduced counts of lateral scales, pseudo branchial filaments, post pelvic scutes, and a shortened lower jaw. *Escualosa thoracata* systematics were studied (Abdussamad et al., 2018). The predicted "b" value for an unsexed population's length-weight relationship indicated that the growth pattern was allometric. *Sardinella longiceps* from the Mumbai shore were subjected to a biometric analysis study (Ahirwal et al., 2017). Positive allometric growth was found as a result of the length-weight relationship for both males and females as well as the combined data. The morphometric study of *Eleutheronema tetradactylum* in the Persian Gulf analyzed (Jaferian *et al*., 2010) based on the truss network and showed significant differences among the samples in the *E. tetradactylum* populace in the two zones of examining.

In Bangladesh, a wide range of rohu (*Labeo rohita*) and Mrigal (*Cirrhinus cirrhosus*) populations rely on the morphometric and meristic data of the populations examined (Hasan et al., 2007). This study suggested that Rui and Mrigal incubation center populations may have diverged from their source and that morphological traits of these species may be used to guarantee the virtue of the species.

There was a study on the morphological characteristics of *Notopterus notopterus* and their relationships, discovering that the standard length, pectoral blade length, body tallness, and head length (dependent factors) are remarkably connected to the complete length (free factors) while the eye distance across and interorbital width (subordinate factors) are strongly connected to the head length (autonomous factors) (Prakash and Verma, 1982).

There was a milestone-based morphometric characters, support network estimations, and meristic checks to evaluate the population status of the endangered carp, kalibaus (*Labeo calbasu*), from two disconnected streams (the Jamuna and the Halda), as well as an incubation facility, and found significant differences in four (most extreme body tallness, pre-orbital length, peduncle length, and maxillary free weight length (Hossain et al., 2010).

Some researchers used *Liza abu* stocks from the Orontes, Euphrates, and Tigris waterways to determine the hereditary and morphometric structure. While this was going on, researchers used allozyme electrophoresis for hereditary analysis and the bracket network framework for morphometric correlation on the same example set. They found pronounced morphological differences between the three *Liza abu* stocks and then isolated the Tigris stock from the other two stocks (Turan et al., 2004a).

A significant morphometric diversity was found when they used the support framework for the recognized proof of incubator and wild populations of Coho salmon (*Oncorhynchus kisutch*) (Swain et al., 1991).

In order to assess the level of population segregation, Ferrite studied the morphological characteristics of four Italian populations of *Lebias fasciata*. In comparison with the skull, vertebral segment, and the beams of the dorsal and butt-centric blades, fourteen meristic and 23 morphometric features were examined. However, their morphological separation cannot be explained biogeographically. The morphological results showed an essential isolation among the four populations, reflecting their substantial level of disengagement (Ferrite et al., 2003).

Morphometric data with the bracket network architecture to determine the anchovy population status (*Engraulis encrasicolus*) in Turkish earthly waters. They found a significant degree of variation among the anchovy tests and subsequently identified them as separate stocks (Turan et al., 2004b).

Morphometric characteristics and their relationship in the fish *Gudusia chapra* were examined who discovered that the fish's fork length, dorsal balance length, pectoral balance length, pelvic balance length, body profundity, and head length had exceptionally matched the fish's total length. Although there is a strong correlation between the looked-at breadth, nose length, and post-orbital head length and the fish's head length (Hoque and Rahman, 1985).

A study was conducted on the morphometric traits of the catfish *Rita rita* (Hamilton) from the Yamuna stream in North India (Devi et al., 1991). Absolute length, fork length, standard length, head length, and the body's profundity at the base of the pectoral balance and at the caudal peduncle were taken into consideration when forming perceptions. They discovered that both men and women represented character variability. At the base of the pectoral balance, the standard length and profundity of the body varied by 1%, whereas the forked length and head length varied by 5% of the centrality. The relationship between body characteristics and maximum length was established as being straight.

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 analysis of the morphometric characteristics of red tilapia (freak *O. mossambicu* and *O. niloticus*) (Kohinoor et al., 1995).

The morphology of *Labeo bata* from the Kaptai repository was noted, and it was noted that the relationship between the dependent factors, such as standard length, fork length, head length, predorsal distance, length of the dorsal balance, profundity of the dorsal balance, preanal distance, length of the pectoral balance, length of the pelvic blade, least body width, most extreme body width, distance between pectoral and pelvic balance, distance between pelvic. According to this study, the autonomous variable (the fish's absolute length) corresponds to 0.1 percent of the whole population (Azadi and Naser, 1996)

Morphometric and meristic characteristics of *Gudusia chapra*, which was collected from Keenjhar Lake (Pakistan), and found that there was little morphological difference between the sexes. Regressions of length-weight did not substantially depart from the isometric development shown by the 3D square law (Narejo et al., 2000).

Due to their distinct ecological characteristics and geological regions, three distinct Rhinomugil stocks (the Meghna, Padma, and Ichamoti) showed a high degree of morphological diversity (Hossain et al., 2015).

Toxotes chatareus and *Toxotes jaculatrix,* two congeneric archerfish species found in Malaysian beachside waters, were distinguished using morphometric and meristic characteristics (Simon et al., 2010).

Large intertype differences were found in six morphometric measurements (all-out length, standard length, fork length, head length, eye width, and circumference) and seven meristic characteristics (absolute number of scutes, pre pelvic scutes, post pelvic scutes, dorsal balance beams, pectoral balance beams, pelvic balance beams, and butt-centric blade beams) of two types of *Tenualosa ilisha* (Narejo et al., 2008).

CHAPTER 3

MATERIALS AND METHODS

3.1 Sampling Area

The research was conducted in Chattogram coast along the north-eastern Bay of Bengal to reveal the availability of fishes from Ariidae family. As the research executed on the Chattogram coast, so the main focus was to find out available marine and coastal Ariidae fishes. The sampling areas were decided by following the study goal. This study was conducted in three sampling areas which satisfied the conditions of being in the coastal zone and the fish landing stations of estuarine and marine fish. The sampling areas were as following:

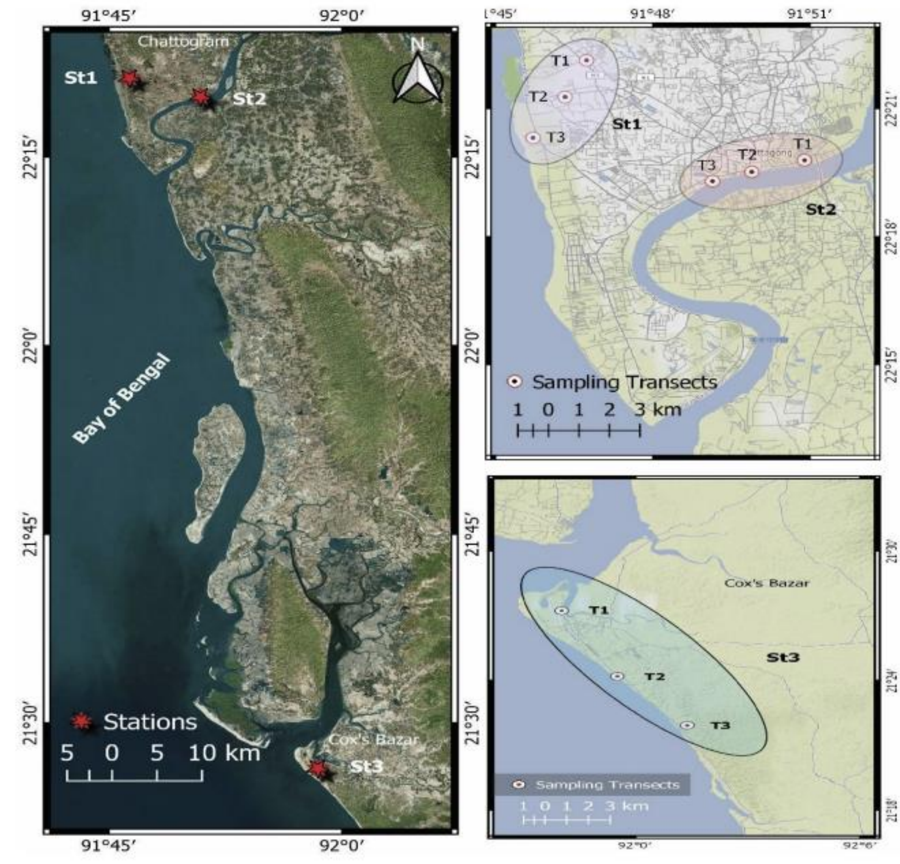


Figure 1: Map of sampling stations with transects

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 220 32’ 97.36’’N and longitude 910 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 site of Chattogram.

2) Sampling station 2 (Kattoli coast, Chattogram)

Adjacent to Sagorika beach, Halishohor, Chattogram including Foillatoli Bazar, Betech Bazar and Colonel Hat Bazar were investigated under this sampling station 2. The positioning of this station is latitude 220 34’46.15’’N and longitude as 910 77’ 87.25” E.

3) Sampling station 3 (Cox’s Bazar)

Sampling station 3 includes the BFDC Landing Center region, coastal sites of CVASU field station, and adjacent coasts of Cox's Bazar. The geographical location of St3 is 210 44’ 53.36’’N latitude and 910 97’35.1”E longitude.

3.2 Working schedule – During the research process, a schedule was maintained. Sample was collected from March (2019) to February (2020). The considerable data were collected.

Table 1: Working schedule of whole thesis work

Activities	Feb 2019	M	A	M	J	J	A	S	O	N	Dec 2019	Jan 2020	F
Laboratory Setup													
Sampling													
Laboratory Analysis					BAN-PERIOD								

3.3 Sampling frequency and sampling period

Sampling was started followed by the monthly pattern during March 2019 to complete the target of one year sampling period, which ended in January 2020. Sampling was done from three stations, maintaining a full moon period within 1-2 days intervals from one station to another once in month. Samples were done even on the same day of a month.

3.4 Sampling strategy

Sampling was done by following the "Stratified Random Sampling" method. As the work focused on the morphological aspect, big sized fish were considered for sampling. Three related measures categorized in small, medium, and big size of the available samples were taken as a specimen to represent the population and avoid biases. My sampling process was stratified random sampling. From 3 stations, a total of 88 samples were collected throughout the sampling period. After completing the sample collection, they were transported with ice in an insulated icebox to maintain the freshness of sample to secure all body parts uninfected from physical injury and chemical disruption.

Figure 2. Collected sample

3.5 Laboratory activities and measurement

Laboratory activities was conducted immediately after completing the sampling. The laboratory measurements were done in the Oceanography Laboratory under the Faculty of Fisheries of Chattogram Veterinary and Animal Sciences University.

This step had some segments.

- Identified the species of the specimen by following the previous record.
- Measured the total weight of the sample and also measured the individual specimen weight.
- Morphometric characteristics were recorded.
- Counted meristic characteristics and recorded.

Figure 3: Colleting Morphometric Data

The measured morphometric and meristic characteristics are enlisted in Table-2.

Table- 2: Morphometric and meristic characteristics

Morphometric data		Meristic Data
Pattern	Length	Fin Rays
Mouth Caudal fin	Total Length (TL) Standard Length (SL) Head Length (HL) Pre-orbital Length (PrOL) Pre-dorsal Length (PrDL) Pre-pectoral Length (PrPL) Pre-pelvic Length (PrVL) Pre-anal Length (PrAL)	Dorsal Fin (DF) Pectoral Fin (PF) Pelvic Fin (VF) Anal Fin (AF) Caudal Fin (CF)

3.5.1 Morphometric characters

Regular scale and digital slide calipers were used for measuring morphometric characters. The characters were as follows:

1. Total length (TL)= Length of fish in centimeter from starting point of mouth to ending point of the tail

2. Standard length (SL)= fish's total length, measured in centimeters, from the top of the head to the caudal peduncle

3. Head length (HLlength of fish in centimeters measured from the tip of the head to the operculum4. Pre-orbital Length (PrOL)= Length of fish in centimeter from the very first point of head to the starting of eye border

5. Pre-pectoral Length (PrPL)= Length of fish in centimeter from the very first point of head to starting of the pectoral fin base

6. Pre-pelvic Length (PrVL)= Length of fish in centimeter from the very first point of head to starting of the pelvic fin base

7. Pre-dorsal Length (PrDL) = Length of fish in centimeter from the very first point of head to starting of dorsal fin base.

8. Pre-anal Length (PrAL) = Length of fish in centimeter from the first point of head to anal-fin base.

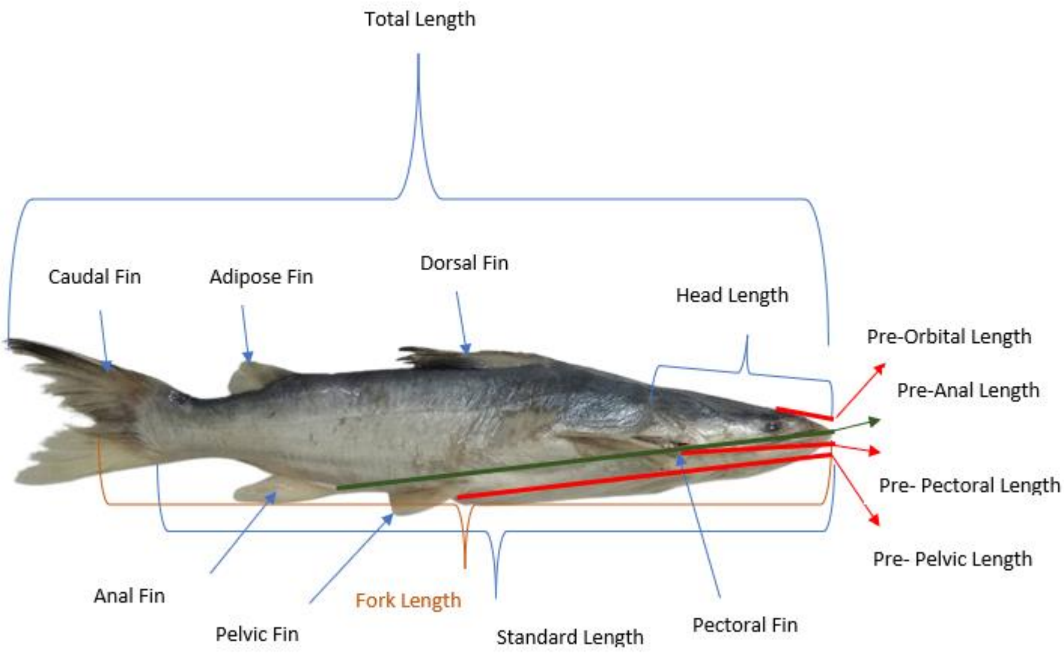


Figure 4: Measurement of Morphometric and meristic characters

Figure 5: Normal Scale

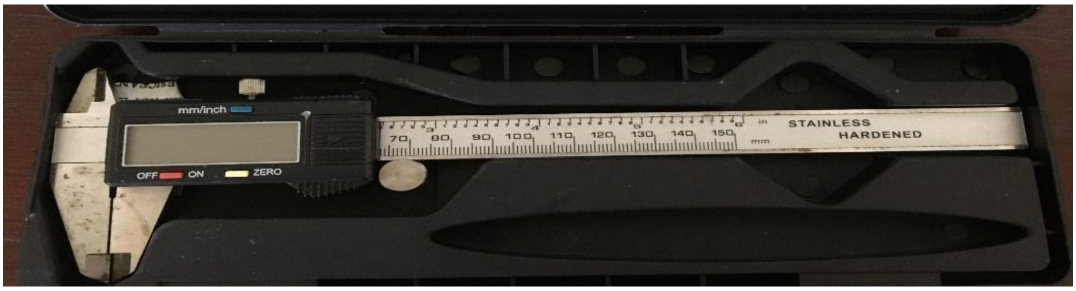


Figure 6: Digital Slide Calipers used to measure length

3.6 Species Identification

Before data collection, species were confirmed by morphological characteristics from previous studies. Some distinct features of species played a very influential role in the identification of species. All these characters were observed from samples and they showed similarities. (Latifa et al., 2015 and Hossain, 2013).

Table 3: The distinctive characteristics

Species	Distinct Characters
Osteogeneiosus mlitaris	The dorsal profile of the head rises gently to the base of the first dorsal fin; there is only one pair of stiff, semiosseous maxillary barhels; the mental barbells are absent; the head shield is smooth without granulations or rugose striations; the supraoccipatal process is narrow, more than twice as long as it is wide, and its hind end is narrowly curved; the median longitudinal groove is broad but does not reach the First dorsal and pectoral fins have robust spines, and there are 19 to 22 anal fin rays overall (Figure 7).
Plicofollis nella	When young, the supraoccipital process is triangular; as it grows older, it takes on a rounded shield shape; the process's apex is convex; the long axes of the posterior tooth patches on the palate typically diverge posteriorly; the posterior caudal-fin margin is clearly sublunate; the

	dorsal-fin spine has internal transverse partitions; the lower limb of the first gill arch has nine gill rak (Figure 8).
Hemiarius sona	Outer patch of palatal teeth triangular with emarginate hind margin and very much larger than inner (vomerine) patch; palatal teeth conical and sharp; eye 6 to 9 times in head length; fin spines strong (Figure 9).

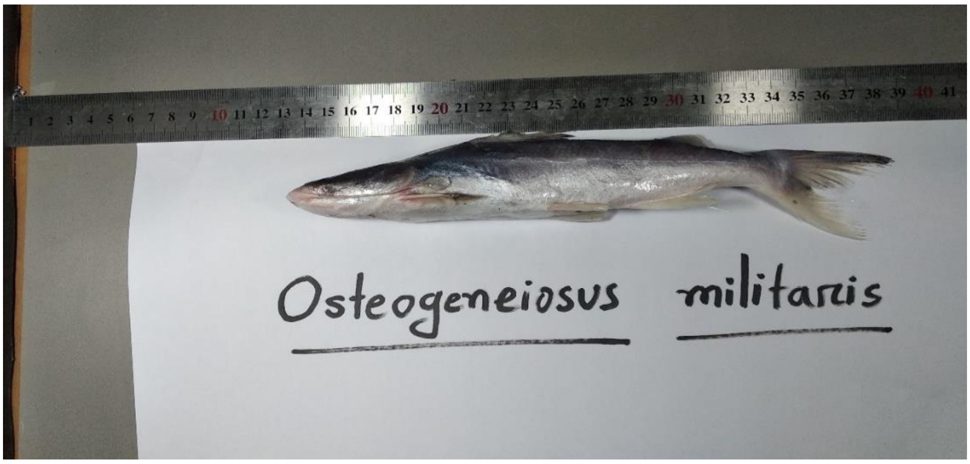


Figure 7: *Osteogeneiosus mlitaris*

Figure 8: *Plicofollis nella*

Figure 9: *Hemiarius sona*

3.7 Data collection and recording

The pictorial record was documented by a portable photo lab (Figure 10). After measuring the data of every specimen, the raw data were collected in a record sheet, and all data were documented in MS Excel-13 for further analysis (Figure 11).

Figure 10: Portable Photo-lab

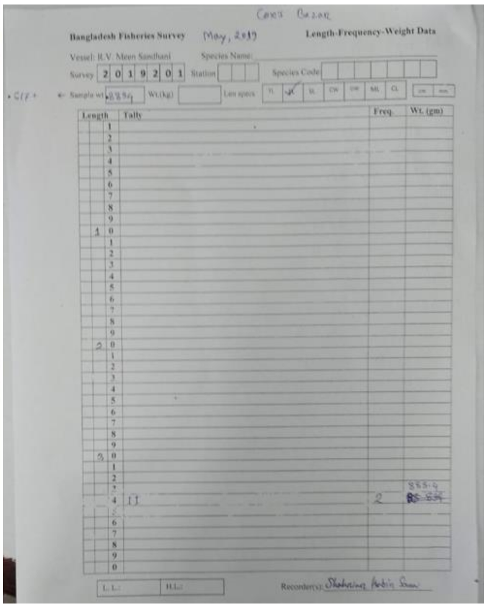


Figure 11: Data Collection Sheet

3.8 Statistical analysis

This study was mainly focused on the morphological and meristic characters of available Ariidae family fish along the Chattogram coast. As it was a morphological study, the conducted statistical analysis was parametric analysis. Here, the simple linear regression with the correlation coefficient, independent sample T-test, and dendrogram representation were included. The analysis was conducted for eight different morphological lengths. The eight different length data were collected from different sample of 3 available Ariidae family species. The equation followed for the simple regression and coefficient was

$$Y= aX+b$$

Here,

Y= Total Length of the fish sample; a= Constant

X= Different measured Length; b= Correlation coefficient

Statistical Package for Social Sciences (SPSS) version-25 with Microsoft office excel, 2019 were used for data analysis.

CHAPTER 4

RESULT

The result section of the analysis summarizes the output of the performance of the study. The analysis was based almost entirely on the morphological and meristic characteristics of the available Ariidae fish in Chattogram coast.

4.1 Month wise availability of fishes from Ariidae family:

The data and statistical analysis of the morphometric and meristic characteristics of the fish species recorded through monthly samples are displayed in this part. A total of 3 species and 3 genus of Ariidae from Chattogram coast were reported from the study and the entire research process.

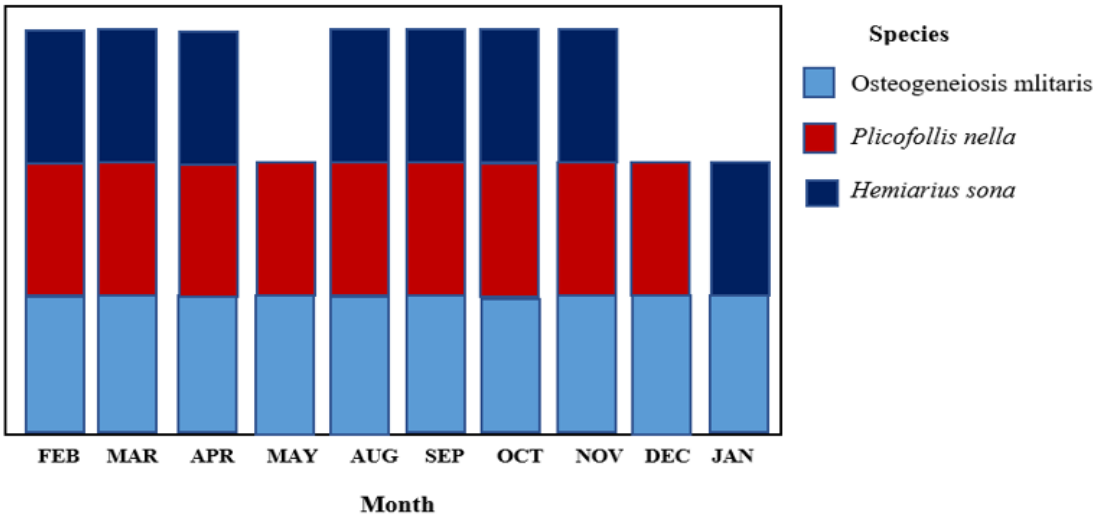


Figure 12: Monthly available species

A total of 88 specimens from three stations for the investigation throughout the sampling period and after examining and analyzing them 3 species were identified as the member of Ariidae fish family. Among the 88 specimens 29 were identified as *Plicofollis nella*, 43 as *Osteogeneiosis mlitaris* and 16 as *Hemiarius sona*. The available species frequency is presented in the pictorial presentation (Figure 12). *Plicofollis nella* species was found in every month except January. During those months *Osteogeneiosis mlitaris* species were collected in every month. Among the identified species *Hemiarius sona* was the most dominant fish species in the Chattogram coastal region. Hence, *Hemiarius sona* species was found in every month except May and December. Almost in every month this investigation on different species of this group was conducted and specimen collected for further analysis.

4.2 Intra-species relation and variation

The relation and variation within single species were analyzed by the a) Fin formula b) Correlation and c) Linear regression. Fin formula revealed the unique criteria for every species. Correlation represented the associations between the measured parameters. Test result showed the higher correlation with insignificant value that could symbolize that the ratio of change would not be constant.

4.2.1 *Plicofollis nella*

Fin Formula – D(I /7), P_1(I /11), $P_2$6; A 14-17

Table 4: Correlation table for *Plicofollis nella*

Correlations									
Parameters	TL	SL	FL	HL	PrOL	PrDL	PrPL	PrVL	PAL
TL	1								
SL	.988**	1							
FL	.990**	.998**	1						
HL	.982**	.977**	.981**	1					
PrOL	.991**	.991**	.994**	.991**	1				
PrDL	.965**	.988**	.984**	.971**	.979**	1			
PrPL	.941**	.973**	.968**	.946**	.960**	.971**	1		
PrVL	.969**	.984**	.981**	.956**	.972**	.975**	.960**	1	
PAL	.976**	.985**	.986**	.962**	.977**	.973**	.947**	.996**	1

* Correlation is significant at the 0.01 level

Description- TL= Total length, SL = Standard length,FL= Fork Length, HL= Head lemgth, PrOL = Preorbital length, PrPL = Pre-pectoral length, PrVL = Pre- pelvic length, PrDL = Predorsal length, PrAL = Pre- anal length.

Comment- All the values of this table is closed to 1. That means all parameters were correlated.

4.2.2 *Osteogeneiosus mlitaris*

Fin Formula – D(I /7), P_1 (I /9), P_2 6; A 19-21

Table 5: Correlation table for *Osteogeneiosis mlitaris*

Correlations									
Parameters	**TL**	**SL**	**FL**	**HL**	**PrOL**	**PrDL**	**PrPL**	**PrVL**	**PAL**
TL	1								
SL	.982**	1							
FL	.989**	.997**	1						
HL	.185	.174	.177	1					
PrOL	.989**	.979**	.988**	.158	1				
PrDL	.970**	.991**	.988**	.140	.972**	1			
PrPL	.960**	.983**	.981**	.127	.966**	.976**	1		
PrVL	.987**	.988**	.994**	.204	.990**	.983**	.976**	1	
PAL	.985**	.992**	.995**	.187	.986**	.989**	.976**	.995**	1

Description- TL= Total length, SL = Standard length,FL= Fork Length, HL= Head lemgth, PrOL = Preorbital length, PrPL = Pre-pectoral length, PrVL = Pre- pelvic length, PrDL = Predorsal length, PrAL = Pre- anal length.

Comment- Here, all the values are closed to 1 except the HL. That means HL were less significant correlation with other parameters.

4.2.3 *Hemiarius sona*

Fin Formula – D(I /7), P_1 (I /12), P_2 6; A 17

Table 6: Correlation table for *Hemiarius sona*

Correlations									
Parameters	**TL**	**SL**	**FL**	**HL**	**PrOL**	**PrDL**	**PrPL**	**PrVL**	**PAL**
TL	1								
SL	.991**	1							
FL	.992**	.999**	1						
HL	.987**	.985**	.987**	1					
PrOL	.988**	.985**	.988**	.996**	1				
PrDL	.982**	.994**	.994**	.979**	.985**	1			
PrPL	.971**	.988**	.986**	.969**	.976**	.988**	1		
PrVL	.965**	.969**	.970**	.931**	.951**	.974**	.964**	1	
PAL	.962**	.962**	.964**	.924**	.944**	.968**	.951**	.997**	1

Description- TL= Total length, SL = Standard length,FL= Fork Length, HL= Head lemgth, PrOL = Preorbital length, PrPL = Pre-pectoral length, PrVL = Pre- pelvic length, PrDL = Predorsal length, PrAL = Pre- anal length.

Comment – All the values from this table is close to 1 and 1 that means SL significantly correlated with other parameters.

4.2.4 Morphometric measurements

The ratio of other's length was measured with the total length. So, an output was come out on this species in the form of Table 7.

Table 7: Length percentage table of *Plicofollis nella.*

Constant Parameters	**Variable Parameters**	**Ratio**	**Value**	**Percentage**
Total length(TL)	Standard length (SL)	SL/TL	0.853409	85.3408686
Total length(TL)	Fork Length (FL)	FL/TL	0.912522	91.2521894
Total length(TL)	Head length (HL)	HL/TL	0.258695	25.8695287
Total length(TL)	Pre-orbital length (PrOL)	PrOL/TL	0.106494	10.6494291
Total length(TL)	Pre-doesal length (PrDL)	PrDL/TL	0.367389	36.7389475
Total length(TL)	Pre-pectoral length (PrPL)	PrPL/TL	0.228937	22.8937023
Total length (TL)	Pre-pelvic length (PrVL)	PrVL/TL	0.479835	47.9835454
Total length (TL)	Pre-Bnal length (PrAL)	PAL/TL	0.559969	55.9968755

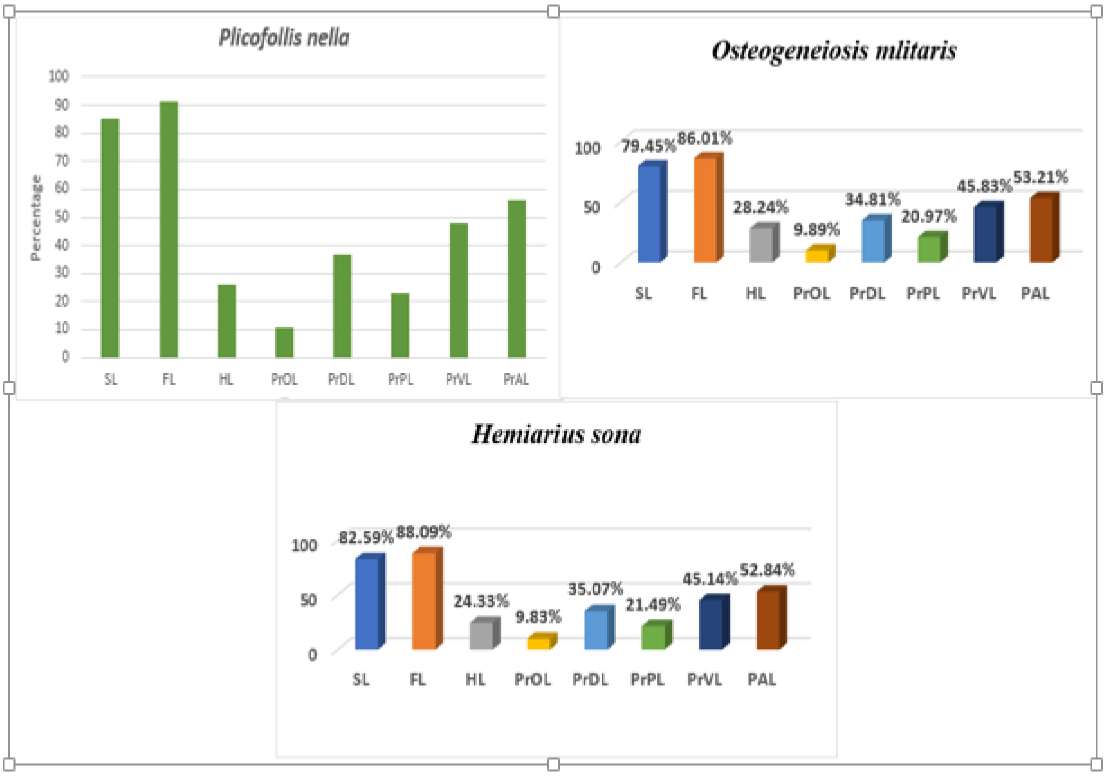


Figure 13: Ratio of length with total length

The graph is representing the ratio in percentage with total length. Here, fork length is in highest percentage and pre orbital length is in lowest percentage.

4.2.5 Regression:

Regression illustrated the effect of one definite parameter upon other parameters and how changes in one defined factor affecting other dependent factor or factors. This study considered the total length (TL) as the influencer characters upon other morphometric characters. Eight linear regressions were done for each species. In case of *Osteogeneiosis mlitaris*, the Standard length (SL) was explained as R^2 = 0.965 by the linear relationship with total length in the graph (Figure 15). According to that, 92.8%, 3.4%, 98.7%, 92.1%, 97.5%, 94% and 97% of the variation was observed in Fork Length (FL), Head length (HL), Pre-orbital length (PrOL), Pre-pectoral length (PrPL), Pre- pelvic length (PrVL), Pre-dorsal length (PrDL), Pre- anal length (PrAL) respectively predicted by the linear relationship with total length (Fig: 14).

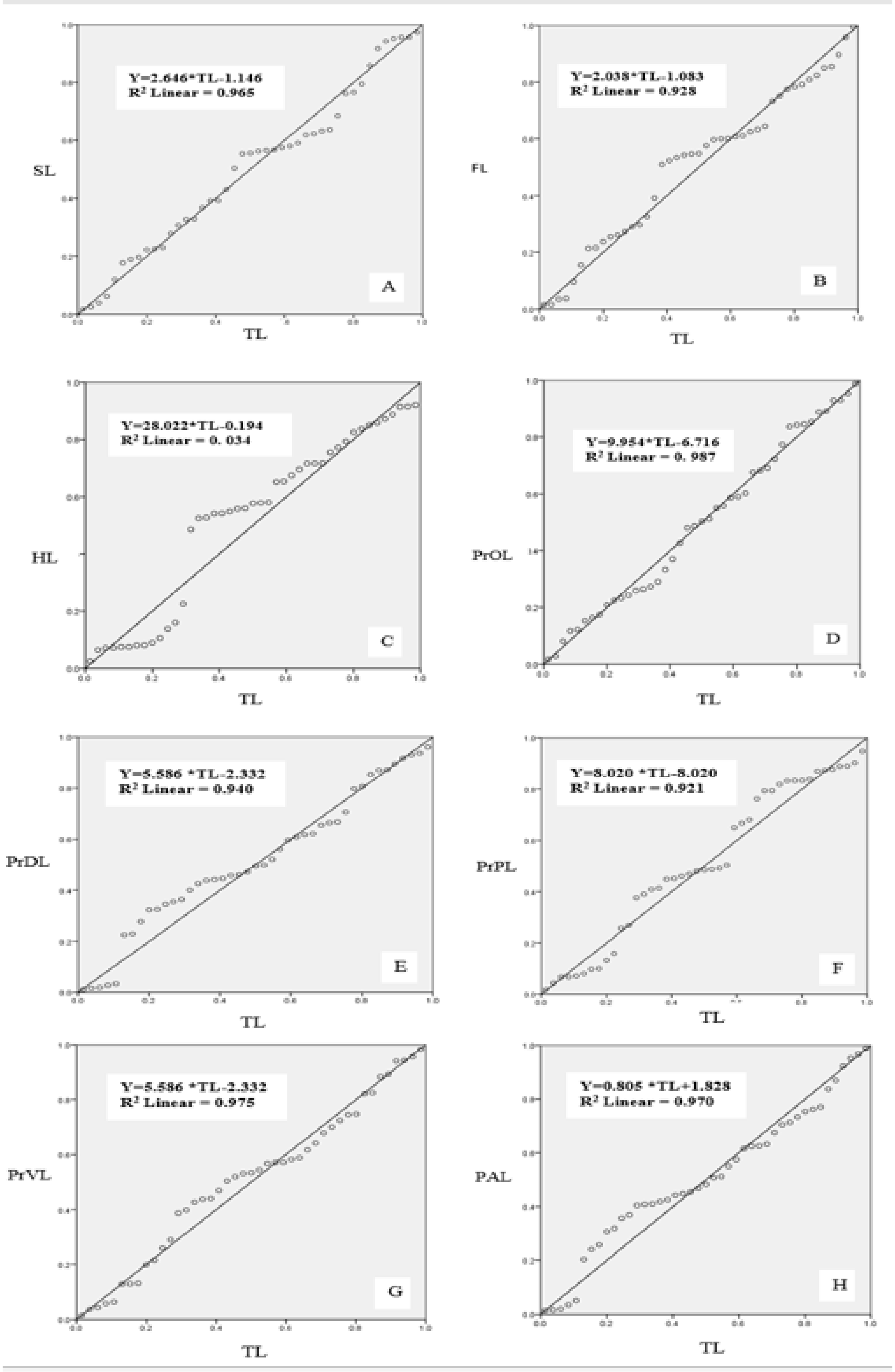


Figure 14: Regression line of (A-H) length on total length (A= Standard, B= Fork, C= Head, D= Pre-orbital, E=Pre-dorsal, F =Pre-pectoral, G =Pre-pelvic, H =Pre-anal)

4.3 Inter-species relation and variation

Inter-species relation and variation were determined by the analysis of the independent sample T-test and dendrogram. An Independent T-test was performed to check the difference between the mean of different parameters of two different species groups. Here *Plicofollis nella* was common in every comparison group as it was the most available species.

Independent T-test -analysis illustrated that all parameters showed a significant difference between mean in the case of *Plicofollis nella* and *Hemiarius sona*. But the mean difference of *Plicofollis nella* and *Osteogeneiosus mlitaris* less significant. Here,HL, PrPL, PrVL, PAL, PrDL revealed a significant difference in the case of *Hemiarius sona.* But *Plicofollis nella* and *Osteogeneiosus mlitaris* also showed the difference in HL, SL, PrDL, PrOL(Table 8).

Table 8: Table for T-test among species group

Species	Parameters	T-test	Sig (p<0.05)	Mean difference
Plicofollis nella	**TL**	16.098	.000	28.2159
	SL	15.412	.000	24.0797
	FL	15.359	.000	25.7476
	HL	13.746	.000	7.2991
	PrOL	11.789	.000	3.0048
	PrPL	13.745	.000	6.4597
	PrVL	15.357	.000	13.5390
	PrDL	14.584	.000	10.3662
	PAL	16.800	.000	15.8000
	TL	22.643	.000	29.64837
	SL	20.992	.000	23.55628
	FL	21.326	.000	25.50105
	HL	6.711	.000	8.37209
	PrOL	15.213	.000	2.93233

Osteogeneiosus mlitaris	**PrPL**	17.212	.000	6.21814
	PrVL	19.821	.000	13.58884
	PrDL	18.954	.000	10.31814
	PAL	22.370	.000	15.77488
Hemiarius sona	**TL**	11.618	.000	25.93937
	SL	11.050	.000	21.4237
	FL	11.550	.000	22.84875
	HL	9.725	.000	6.31062
	PrOL	8.349	.000	2.55062
	PrPL	9.372	.000	5.57437
	PrVL	11.504	.000	11.7100
	PrDL	9.983	.000	9.096875
	PAL	12.784	.000	13.70687

4.3.1 Cluster Analysis

To further understand the relationship between different months, cluster analysis (similarity) was done on the average morphometric measurement results for each month. Morphometric data organized into four main clusters by month. This is a sign that the fluctuation over a year looks like four periodic clusters. Four months, such as February, March, April, and May, made up the first cluster. The morphometric characteristics of February and March were the most similar to those of other months in the first cluster. August, September, and October were the months that made up the second cluster. The third cluster was made up of the months of November, which stood out as being very distinct from the other months. Last cluster was formed by December and January which were also substantially different from all of the other months at a higher level. The morphometric measurements had changed throughout the year (Figure 16).

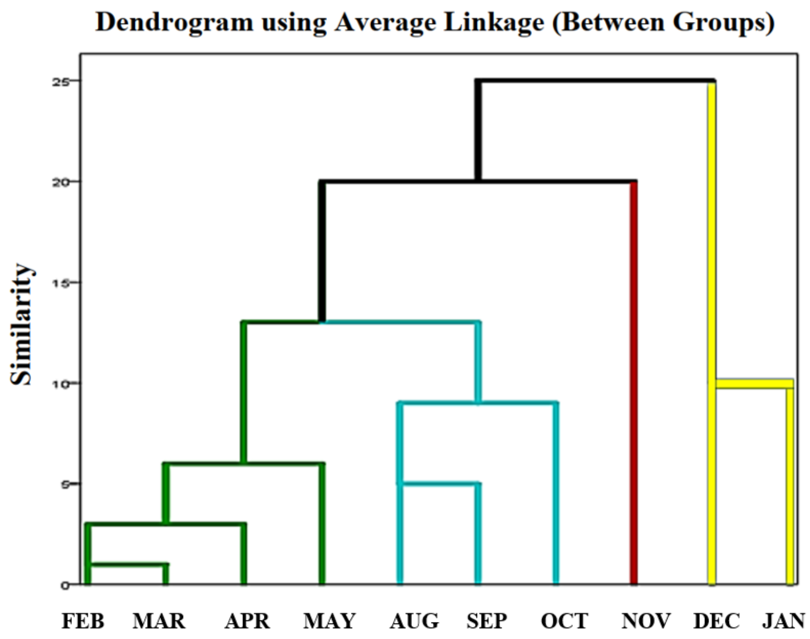


Figure 15: Dendrogram showing the Month wise similarity of various morphometric measurements

4.4 Meristic counts

Meristic counts of this study did not show much variation in their value. They were kind of fixed type. All data's of meristic counts were collected below in Table 9. Here, meristic counts of species were gathered in a charted form to interpret the characters of fish quickly.

Table 9: Table for the meristic count for all available species

Meristic counts and Abbreviation	***Plicofollis nella***	***Osteogeneiosus mlitaris***	***Hemiarius sona***
Spine on dorsal fin	I	I	I
Dorsal Fin Ray	7	7	7
Spine on Pectoral fin	I	I	I
Pectoral fin ray	11	9	12
Pelvic fin ray	6	6	6
Anal Fin Ray (AFR)	14-17	19-21	17
Caudal fin ray	27-29	27-28	27-28

4.5 Principal component analysis:

Using changed morphometric values, principal component analysis (PCA) was utilized in the study to find likely contributors to the morphometric parameters. A PCA biplot was created using principal component analysis to show the variance and connection between three sampling locations. The Principal Component Analysis was used for *Plicofollis nella*, *Osteogeneiosus mlitaris*, *and Hemiarius sona*, depending on the applicability and usefulness of the analysis. Only one component was extracted that is shown in Table 10.

Table 10: Principal component analysis (PCA1)

Parameters	**PCA 1**	**PCA 1**	**PCA 1**
	Plicofollis nella	***Osteogeneiosus mlitaris***	***Hemiarius sona***
Total length (cm)	.989	.990	.998
Standard length (cm)	.998	.996	.997
Forked length (cm)	.998	.998	.996
Head length (cm)	.985	None	.993
Pre-orbital length (cm)	.995	.990	.990
Pre-dorsal length (cm)	.989	.990	.988
Pre-pectoral length (cm)	.973	.983	.984
Pre-pelvic length (cm)	.988	.997	.980
Pre-anal length (cm)	.989	.997	.974

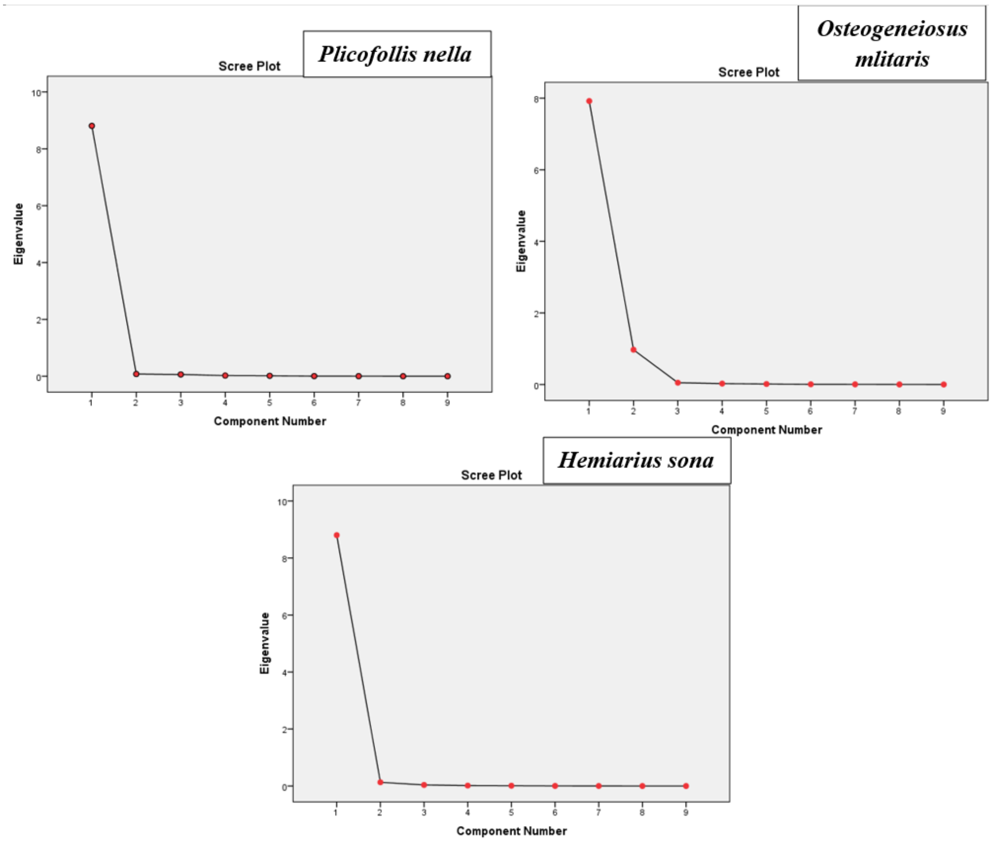
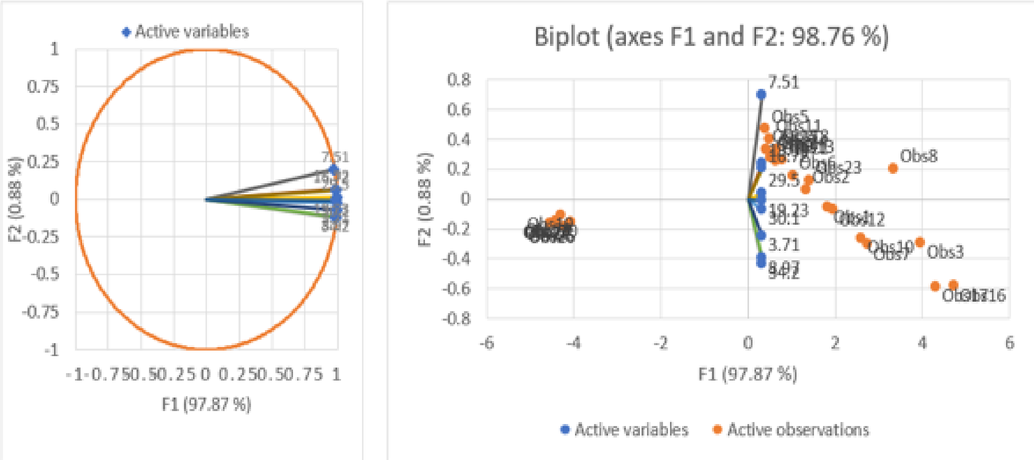
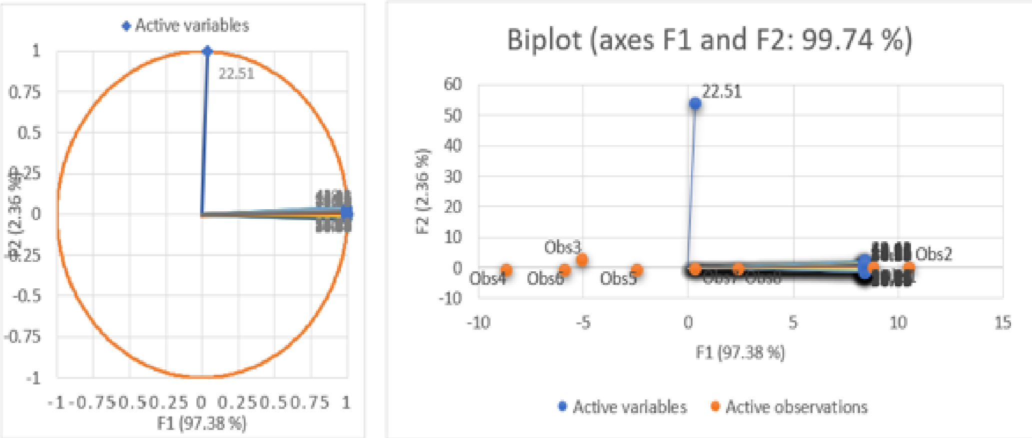


Figure 16: Scree plot of *Plicofollis nella, Osteogeneiosus mlitaris, and Hemiarius sona*

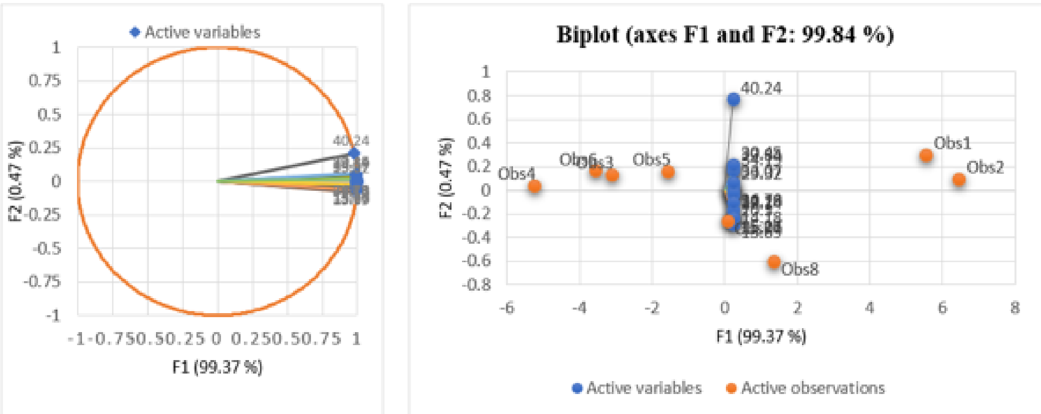
According to the PCA biplot of *Plicofollis nella, Osteogeneiosus mlitaris, and Hemiarius sona* it was found that one principal component explained 97.87%, 97.38% and 99.37% respectively of the total variance as scree plot shown in Figure 17. The morphometric variables of the three stations formed three distinct clusters. In case of *Plicofollis nella*, 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. Another Principal Component Analysis (PCA) for *Osteogeneiosus mlitaris* showed that 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 and head length. On the other species, principal components were extracted for *Hemiarius sona* showed that strong correlation was found between head length and pre-orbital length. Finally, the biplot also indicated that the sampling stations had similarities between the morphometric characters which is illustrated in Figure 17.



Plicofollis nella



Osteogeneiosus mlitaris



Osteogeneiosus mlitaris

Figure 17: PCA biplot for adjusted morphometric measurements

CHAPTER 5

DISCUSSION

The morphological and meristic analysis measure and observe external appearances and interpretation of obtained data that revealing the outcome. The present study reveals the information about the available species of the Ariidae family along Chattogram coast. In this process of identification, three species were recorded under this Ariidae family. The whole study revealed data about those available species.

In our study, the recorded species were *Plicofollis nella, Osteogeneiosus mlitaris, Hemiarius sona*. The fin formula that were revealed as D(I /7), P1 (I /11), P2 6; A 14-17 for *Plicofollis nella,* D(I /7), P1 (I /9), P2 6; A 19-21 for *Osteogeneiosus mlitaris* and D(I /7), P1 (I /12), P2 6; A 17 for *Hemiarius sona.*

5.1 Key findings:

The key objective of our study was to figure out the available fish species under the Ariidae family from the Chattogram coastal region. At first, I observed month wise availability of the species. Over the one-year sampling time frame, I did sampling for 10 months as we did not able to perform the sampling in restricted ban periods (June-July). In that process 3 species were identified. But we know that approximately 21 species are available in Bay of Bengal according to an updated checklist of marine fishes of Bangladesh (Habib et al., 2021). This is because fishermen catch fishes from certain area of the coastline which are known as fishing ground and all the 21 species are not target species for marketing. On the other hand for making checklist researchers surveyed all area randomly. Unlikely, I found a new species across eight-month study period namely *Hemiarius sona* that was not identified by the check list provided by (Habib et al., 2021)

5.2 Variation of meristic counts

Despite the fact that there were no significant differences in meristic counts across Ariidae populations from three different locales, substantial morphometric differences were identified. Meristic traits of the population, such as dorsal, pectoral, pelvic, and anal fins, showed no significant variations in the current research. Certain findings demonstrate that these meristic features are not significantly influenced by environmental influences. The systematics and taxonomy of the Ariidae are primarily impacted by the findings of this study. It might be a subject of debate for a longer period of time and lead to misunderstandings among ichthyologists all over the world. Within the systematics of the Siluriformes, the characterization of the genera, delineation of their limits, and species composition have been particularly difficult tasks. About 130 species are currently accepted as legitimate, although many more require improved taxonomic characterization. The widespread geographic distribution of this family is mostly to blame for the challenges associated with identifying species identity and monophyletic taxa. The lack of sufficient series of specimens in museum collections along with the general uniformity in the outward morphology of their representatives. Due to the limitations, studies aiming for more thorough approaches to the systematics and phylogeny of the Ariidae have not always been effective.

5.3 Variation of morphometric counts

A study used 22 to 23 individuals of each species namely *P. argyropleuron, P. nella,* and *P. tenuispinisfound* in Peninsular Malaysian waters and was based on 20 truss measurements. Utilizing a multivariate technique of discriminant function analysis, morphological changes were identified (DFA). The findings of this study demonstrated that all of the species in the Ariidae group were clearly separated by discriminant analysis employing truss network data (Abdur Rahman , 2016).

A (Pearson) correlation was a value between -1 and +1 that indicated how linearly connected two quantitative variables were. The key diagonal correlations (TL versus Wt, TL vs FL, TL vs HL, PrOL vs TL, PrDL vs TL, PrPL vs TL, PrVL vs TL, PAL vs PrPL) were all equal to 1. The correlations on the major diagonal were between each variable and itself, which explains why they were all 1 and meaningless. There was a statistically significant linear association between morphometric measures and the Pearson correlation coefficient. For example (*Osteogeneiosis mlitaris)* had a statistically significant linear relationship with other morphometric characters (standard length, fork length, head length, pre-orbital length pre-dorsal length, pre-pectoral length, pre-pelvic length and pre-anal length moderately related and pre-orbital length) ($r=0.98$, 0.96, 0.185, 0.98, 0.97, 0.96, 0.98, 0.98 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 TL vs SL, TL vs HL and TL vs PrPL where r = 0.98 and its 2-tailed significance, p = 0.000.

Regression is a straight forward methodology for displaying the connection between two factors. The dependent variable were different morphometric measurements (standard length, 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 for *Plicofollis nella*. The standard length, fork length, head length, pre-orbital length, pre-dorsal length, pre-pectoral length, pre-pelvic length and pre-anal length were explained as 97.7%, 98%, 96.4%, 98.1%, 93.2%, 86.6%, 94% and 95.2% respectively predicted by the linear relationship with total length. All the morphometric characters were highly explained by the regression line of total length.

5.4 Identification of principle components

Principal component analysis was performed on the important characteristics (morphometric and meristic measures) (PCA). Characters that were statistically significant at a high level (p 0.05) were evaluated for principal component analysis in this study (PCA).

A study discussed the Ariidae, which consists of the following twenty-six genera that are legitimate: *Amissidens, Arius, Aspistor, Bagre, Batrachocephalus, Brustiarius, Cathorops, Cephalocassis, Cinetodus, Cochlefelis, Cryptarius, Doiichthys, Galeichthys, Genidens, Hemiarius* (Alexandre et al., 2007). The family Ariidae can be divided into two monophyletic lineages. A fan-shaped lamina is formed when the postcleithral process of the new subfamily Galeichthyinae which consists of one genus and four species is fused to the posterior dorsal process of the cleithrum. The remaining ariids belong to the subfamily Ariinae, which is distinguished by four anatomical synapomorphies. First, the sustentaculum of the Weberian apparatus was generated by the posterior process of the epi occipital and joined to it. Second, the anaortic tunnel is formed by the ventral basioccipital process and the ventral ossification of complicated vertebra. Thirdly, the orbitosphenoids' anterodorsal bony block is present. Fourth, the anterior nuchal plate is absent. The monophyly of the Ariidae (three aminoacid synapomorphies) and its subfamilies (Galeichthyinae, six aminoacid autapomorphies of Galeichthysperuvianus; Ariinae, four aminoacid synapomorphies) is also well supported by mitochondrial and nuclear data (Acero and Betancur, 2007).

Significant variables in our current investigation were defined as those with loadings larger than 0.5. The eigenvalues of the first principal components (PC1) were larger than one. The components of *Plicofollis nella* explained 89.2 percent of the variance in the data. In the principal component, the eigenvalues began to form a straight line, as seen by the scree plot. Because 89.2 percent of the variation in the data could be explained, the first three main components were chosen. Similarly, *Osteogeneiosis mlitaris and Hemiarius sona* provide 79.6% and 87.8% of the main components (PCA1), respectively. The loadings on PC1 were considerable for several of the thirteen morphometric and meristic metrics. These results demonstrated that there were substantial variations between these components where PC1 included morphometric values. As a consequence of the current study, it was demonstrated that all of these scale traits might be employed as alternative methods for detecting the systematic link between the various genera or species of mullet fishes.

5.5 Different statistical test

The threadfin sea catfish *Arius arius* (Hamilton, 1822) from the Hooghly-Matlah estuary system, West Bengal, India, is the subject of the study which examines its length-weight connection, relative condition factor and morphometric and meristic characteristics (Chirwatkar et al., 2021) . Over the course of a year, 391 samples, including 243 females and 148 males ranging in size from 52 to 254 mm total length (TL) and weight from 1.62 to 176.75 g were examined (April 2017 to March 2018). The male, female and pooled samples' respective 'b' values were estimated to be 3.065, 3.127 and 3.104, showing positive allometric growth. The monthly mean relative condition factor (Kn) values for males and females, respectively varied from 0.923 to 1.309 and showed the species to be in good condition. The analysis of 14 morphometric features showed that the correlation between the overall length and the majority of the morphometric parameters was highly significant (p 0.05). The first dorsal fin of *A. arius* has one spine and seven soft rays, the pelvic fin has six soft rays, the pectoral fin has one spine and eight to eleven soft rays, the anal fin has fourteen to seventeen soft rays and the caudal fin has sixteen to twenty-three soft rays.

Using morphometric analysis the native catfish Arius jella (Ariidae) was examined in five estuarine locations in Sri Lanka (Koggala lagoon, Walawe estuary, Garanduwa lagoon, Nilwala estuary, and Chilaw lagoon) for intra-specific morphological variation. The shapes of the fish as described by five morphometric traits varied significantly across several of the locations. Pre-orbital length is a population-specific characteristic that is noticeably shorter in specimens from the Walawe estuary (8.3 percent SL vs. 9.2-10.7 percent SL in the other populations). There were significant variances in other traits, which suggests that morphology is heterogeneous. Despite the fact that the first two canonical variates (CV) described 82.7 percent of the data's overall variation, the CV plot did not show any discernible distinction of the sample populations. An average of less than 50% of people could be appropriately classified into their a priori groups by derived classification functions.In our study we didn't analyze any statistical test on the basis of sex. But some statistical analyses of linear regression relationships were shown mostly strong correlations ($r \geq 0.70$; $p < 0.05$) between total length (TL) and most morphometric characters in males, females, and combined sexes, except the height of pectoral-fin (PFH), and pelvic-fin base length (PelFL); whereas, meristic characters were found to be constant and indicate weak or negative type correlations ($r \leq 0.50$; $p > 0.05$) with total length (TL) of *Alepes vari* (Masood et al, 2022)

There was research titled as 'Landmark-based Morphometric and Meristic Analysis of Serranidae.' Here, for visualizing the vertebrae, skeleton and swim bladder of whole fish by radiographic x-ray photographs images were taken of the lateral view of overall body shape of samples of each species, respectively, and images were made on an x-ray machine (Lim et al., 2016).

CHAPTER 6

CONCLUSION

Fish and fisheries are the indispensable pieces of Bangladeshi culture, occupations and in dietary patterns as well. Yet, this area is confronting an expanding danger due to overfishing, habitat degradation, contamination in the waterways and the unpredictable utilization of agrochemicals, invasion of non-native species, absence of appropriate territory and decreased fecundity. Stock collapses are often more challenging to recover from when a marine fish population is continuously overexploited and effective conservation and management of the resource are not implemented in time. Overexploitation has been shown to have short- and long-term consequences on population dynamics and demography, which can compound lower abundance and lead to a regime shift to a new population production stage. This is in addition to reducing spawning stock biomass and fisheries yield. The present investigation has given significant morphological data that can be utilized to separate this *Ariidae* family from all the more decisively among groups and species. This examination was not intended to explore the real reason of morphological variations and to decide whether the variations are earth prompted or hereditary components or both. Examination in such a manner might be started based on the current discoveries. Findings of the study would serve as the foundational knowledge for stock management and enable effective management techniques for the specific populations of Ariidae to make their fishery sustainable and develop appropriate protection plans in the not-too-distant future. The information obtained from the current inquiry, in the opinion of the authors, will be helpful for taxonomists, academics, and fisheries interested in these intriguing fish species. For further research, this study might work as basic data source for the further study on the fish of Ariidae family.

CHAPTER 7

RECOMMANDATION

The use of morphological features as benchmark data seems promising in this sector because the identification of populaces and their availability with each other is a vital step for sustainable protection and management of species. The current study handles the cost of basic information regarding the variety of Ariidae populations in different water areas in Bangladesh and this suggests the utilization of morphometric characters and support estimations create dependable data for stock separation of Ariidae.

Notwithstanding, the current examination had a few impediments regarding a predetermined number of individuals and populations. The after effect of the current examination may be utilized as a rule for additional investigation with more examples and for more explanation and adaptation. Over all, the following issues could be addressed for sustaining Ariidae species in Bangladesh.

- Future researchers can explore the other species of Ariidae family.
- *Osteogeneiosismlitaris* is the mostly founded species Therefore, a comprehensive future study on this population might have a commanding impact to conserve this species.
- Data has to be collected from different coastal region of Bangladesh to study in provide conclusive evidence in a big scale.
- A further nutritious study and the conservational research, may be conducted with each of the found species.
- Finally, legitimate preservation plans ought to be formed.

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APPENDICES

Appendix- I: Regression table for *Plicofollis nella*

Parameters	a	b	R	R^2	Y=aX+b
Standard length	1.156	1.109	0.988	0.977	Y=1.156*TL-1.109
Fork Length	1.562	1.035	0.990	0.980	Y=1.562*TL-1.562
Head length	4.562	3.241	0.982	0.964	Y=4.562 *TL-3.241
Pre-orbital length	7.745	6.813	0.991	0.981	Y=7.745*TL-6.813
Pre-pectoral length	5.544	3.510	0.941	0.886	Y=5.544*TL-3.510
Pre-pelvic length	2.123	1.927	0.969	0.940	Y=2.123*TL-1.927
Pre-dorsal length	3.539	2.380	0.965	0.932	Y=3.539*TL-2.380
Pre-anal length	-.538	1.820	0.976	0.952	Y=-.538*TL+1.820

Appendix- II: Regression table for *Osteogeneiosis mlitaris*

Parameters	a	b	R	R^2	Y=aX+b
Standard length	2.646	1.146	0.982	0.965	Y=2.646*TL-1.146
Fork Length	2.038	1.083	0.963	0.928	Y=2.038*TL-1.083
Head length	28.022	.194	0.185	0.034	Y=28.022*TL-.194
Pre-orbital length	9.954	6.716	0.989	0.978	Y=9.954*TL-6.716
Pre-pectoral length	8.020	3.478	0.960	0.921	Y=8.020 *TL-8.020
Pre-pelvic length	4.024	1.886	0.987	0.975	Y=4.024*TL-1.886
Pre-dorsal length	5.586	2.332	0.970	0.940	Y=5.586*TL-2.332
Pre-anal length	0.805	1.828	0.985	0.970	Y=0.805*TL+1.828

Appendix- III: Regression table for *Hemiarius sona*

Parameters	a	b	R	R^2	Y=aX+b
Standard length	1.520	1.141	0.991	0.981	Y=1.520*TL-1.141
Fork Length	2.367	1.119	0.992	0.983	Y=2.367*TL-1.119
Head length	4.512	3.395	0.987	0.974	Y=4.512*TL-3.395
Pre-orbital length	7.528	7.218	0.988	0.976	Y=7.528*TL-7.218
Pre-pectoral length	5.613	3.646	0.971	0.944	Y=5.613*TL-3.646
Pre-pelvic length	1.165	2.116	0.965	0.930	Y=1.165*TL-2.116
Pre-dorsal length	4.061	2.405	0.982	0.964	Y=4.061*TL-2.405
Pre-anal length	-1.512	2.003	0.962	0.925	Y=-1.512*TL+2.003

BRIEF BIOGRAPHY OF THE AUTHOR

Shahriar Kabir Sourov; son of Md. Golam Mostafa and Gannatul Ferdoushi from Panchbibi Upazila under Joypurhat district of Bangladesh. He passed his Secondary School Certificate Examination in 2012 from Panchbibi L.B.P. Govt. High School, Panchbibi followed by Higher Secondary Certificate Examination in 2014 from Joypurhat Govt. College, Joypurhat. He completed his graduation degree on B.Sc. in Fisheries (Hons.) in 2018 from Faculty of Fisheries, Chittagong Veterinary and Animal Sciences University (CVASU), Bangladesh. Now, He is an MS degree candidate under the Department of Marine Bio-resource Science, Faculty of Fisheries, CVASU.