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on

Stock Assessment of Commercially Important Fishes in the Bay of Bengal through Multi-model Inferences and Molecular Markers: Management Policy Implications Considering the Emerging Climate Change

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Fisheries Division
Bangladesh Agricultural Research Council
Farmgate, Dhaka-1215

Project Implementation Unit (PIU)
National Agricultural Technology Program-Phase II Project
Bangladesh Agricultural Research Council
Farmgate, Dhaka-1215

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Implementing Organization

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Abbreviation and Acronyms

a	Intercept of Length-Weight Relationship	EPA	Environmental Protection Agency of United States
$a_{3.0}$	Form Factor	$E_{0.1}$	Exploitation rate at 10% of Virgin Stock
A	Adenine	$E_{0.5}$	Exploitation Rate at Half Its Virgin Biomass
A-	Negative Allometric Growth	F	Fishing Mortality
A+	Positive Allometric Growth	FAO	Food and Agriculture Organization
ABR Lab	Aquatic Bioresource Research Lab	F_S	Fu's F_S Statistics Value
AnS	Andaman Sea	FGD	Focus Group Discussion
AnsL	Anus Length	FISAT	Fao-Iclarm Stock Assessment Tool
AP	Andhra Pradesh	FL	Fork Length
ATPase	Adenosine Triphosphatase	F_{ST}	Fixation Index
b	Slope of Length Weight Relationship	FYP	Five Years-plan
BARC	Bangladesh Agricultural Research Council	GoT	Gulf of Thailand
BD	Bangladesh	GSI	Gonadosomatic Index
BFDC	Bangladesh Fisheries Development Corporation	G	Guanine
BFRI	Bangladesh Fisheries Research Institute	GT	Growth Type
BLAST	Basic Local Alignment Search Tool	GUJ	Gujarat
BoB	BoB	GW	Gonad Weight
BW	Body Weight	HL	Head Length
C	Cytosine	*h*	Haplotype Diversity
CL	Confidence limits	I	Isometric Growth
cm	Centimeter	IF	Impact Factor
COI	Cytochrome Oxidase Subunit 1	IFAD	International Fund for Agricultural Research
Cytb	Cytochrome b	IUCN	International Union for Conservation of Nature
D	Tajima's *D* Statistics Value	*K*	Growth Coefficient
DI	Dobriyal Index	K_A	Allometric Condition Factor
DNA	Deoxyribonucleic Acid	K_F	Fulton's Condition Factor
d-loop	Mitochondrial Displacement Loop	K_R	Relative Condition Factor
DO	Dissolved Oxygen	LBB	Length-based Bayesian Biomass
DoF	Department of Fisheries	L_c	Size at First Capture
E	Exploitation Rate	LC	Least Concern
EEZ	Exclusive Economic Zone	LFD	Length Frequency Distribution
E_{max}	Exploitation Rate Producing Maximum Yield	LLR	Length-Length Relationship

L_m	Length at First Sexual Maturity	R^2	Coefficient of Determination
L_{max}	Maximum Length	R_s	Spearman's Rank Value
L_{opt}	Optimum Catchable Length	RU	University of Rajshahi
L_t	Length at Age *T* (Month)	S	Polymorphic Site
LWR	Length Weight Relationship	SAU	Sher-E-Bangla Agricultural University
L_∞	Asymptotic Length	SCS	South China Sea
M	Natural Mortality	SD	Standard Deviation
MAH	Maharashtra	SDG	Sustainable Development Goals
Max	Maximum	SL	Standard Length
MFTS	Marine Fisheries Technology Station	SW	South Western
MGSI	Modified Gonadosomatic Index	T	Age At Year[1]
Min	Minimum	T	Thymine
Mm	Millimeter	TCS	Transitive Consistency Score
MSY	Maximum Sustainable Yield	TDS	Total Dissolved Solid
MT	Metric Ton	Ti	Transition
mtDNA	Mitochondrial DNA	TL	Total Length
NATP	National Agricultural Technology Program	T_m	Age at Sexual Maturity
NCBI	National Center for Biotechnology Information	T_{max}	Life Span
NE	Not Evaluated	T_{opt}	Optimum Catchable Age
NGO	Non-Government Organization	Tv	Transversion
Ns	Not Significant	TU	Tuticorin
NT	Near Threatened	T_0	Hypothetical Age When Length Would be Zero
P	Level of Statistical Significance	USA	United States of America
PBRG	Program Based Research Grant	VBGM	Von Bertalanffy Growth Model
Pcl	Pectoral Length	WB	World Bank
PCR	Project Completion Report	WCS	Wildlife Conservation Society
PCR	Polymerase Chain Reaction	W_R	Relative Weight
pH	Logarithm of The Reciprocal of Hydrogen Ion Concentration	W_S	Standard Weight
PIU	Project Implementation Unit	WW	Worldwide
Poanl	Post-anal Length	W_∞	Asymptotic Weight
Podl	Post-dorsal Length	Y'/	Yield per Recruit
Pranl	Pre-anal Length	Z	Total Mortality
Prdl	Pre-dorsal Length	Ø'	Growth Performance Indices
PSS	Peak Spawning Season	Π	Nucleotide Diversity
Pvl	Pelvic Length	Ml	Microliter

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Executive Summary

In Bangladesh, accurate species/fish or unit stocks identification is very crucial both in the context of monitoring and conservation of the fish species of marine and open water habitats. Moreover, factors affecting fish production in marine ecosystem along many pathways is a vital issue to be considered. Therefore, several studies have been done on stock assessment of marine fishes considering emerging climate change in the BoB with confirmation of unit-stocks through multi-models. Thus the sub-project was implemented accordingly in the BoB aiming to determine and categorize the stock of some commercially important marine fish species for ensuring maximum sustainable yield to assist the livelihood development of the highest number of fishers. Under this sub project, the component of the University of Rajshahi (RU) conducted stock assessment of 15 commercially important marine fish species through Multi-Model inferences. On the other hand, Sher-e-Bangla Agricultural University (SAU) component investigated population genetic structure (i.e. genetic stock assessment) of 10 commercial marine fish species using molecular markers. A joint survey (questionnaire, FGD) by both components was also conducted to identify major threats for marine fisheries of Bangladesh especially caused by human interference beside climate change.

For stock assessment through multi model inference by component 1 (RU), monthly fish samples were collected using traditional fishing gears by the hired fishing boats and fishers from different selected sites in the BoB. Additionally, data on fish composition and its ovarian maturation status were observed in the landing centers on daily basis. Length-weight data, gonadal data and histological data for each individual of 15 commercially important fishes were collected at the laboratory of Department of Fisheries in RU. Sexual maturity, spawning- and peak spawning season, growth patterns and parameters, condition factors etc. of these commercially important fishes were estimated using samples from January 2020 to December 2021. At least 300 marine fish were regularly observed in the landing centers, fish market and fishing boats during sampling. To determine the actual number of marine fishes of Bangladesh, a checklist was prepared by reviewing the authentic publications and literature covering about a 50-year span from 1970 to 2020 along with our observation which revealed that the country has a total of 740 fish species in its marine environment. Among them, 15 commercially important fish were used for analysis. This study illustrated the minimum and maximum length and weight of 15 species found in the BoB. Size at sexual maturity (L_m) and optimum catchable length (L_{opt}) of 15 commercially important marine fish were estimated to select the mesh size of fishing gear. Size at first sexual maturity for different fish obtained from the BoB were 90.0 cm for *Lates calcarifer* , 14.4 for *Panna heterolepis*, 22.0 cm for *Pampus chinensis*, 33.0 cm for *Euthynnus affinis*,15.0 cm for *S. taty*, 17.0 cm for *Setipinna panijus*, 14.5 cm for *Polynemus paradiseus*, 20.0 cm for *Megalaspis cordyla*, 17.5 cm for *Harpadon nehereus*, 13.5 cm for *Coilia dussumieri*, 12.8 cm for *Thryssa setirostris,* 17.8 cm for *Anodontostoma chacunda*, 16.7 cm for *Ilisha megaloptera*, 19.0 cm for *Priacanthus macracanthus*, and 16.5 cm for *Amblygaster leiogaster.* Most of the commercially important marine fishes spawn from April to September. Current ban period in the BoB, Bangladesh is from 20th May to 23th July. The period should be adjusted from mid-April to June based the findings of this sub-project and other relevant data on spawning- and peak spawning season of marine fish from the BoB, Bangladesh. Population structure showed that, minimum and maximum length for different fishes obtained from the BoB were 51.0-105.0 cm for *L. calcarifer* , 10.5-34.5 cm for *P. heterolepis*, 16.5-38.0 cm for *P. chinensis*, 16.0-68.0 cm for *E. affinis*, 8.10-31.8 cm for *S. taty*, 11.5-39.4 cm for *S. panijus*, 10.0-23.1 cm for *P. paradiseus*, 16.0-41.0 cm for *M. cordyla*, 6.5-36.0 cm for *H. nehereus*, 10.0-23.6 cm for *C. dussumieri*, 9.00-22.0 cm for *T. setirostris,* 12.50-27.0 cm for *A. chacunda*, 11.0-37.00 cm for *I. megaloptera*, 14.30-49.0 cm for *P. macracanthus*, and 12.60-30.50 cm for *A. leiogaster*. Growth pattern of marine fish was determined from the calculation of length weight relationship. Based on the value of '*b*', isometric growth found for *S. taty*, (*b*= 3.02), *P. chinensis* (*b*= 3.07), *A. chacunda*, (*b*= 3.03), *I. megaloptera*, (*b*= 2.94); positive allometric growth found for *E. affinis*, (*b*= 3.12), *S. panijus*, (*b*= 3.18), *P. paradiseus*, (*b*= 3.18), *H. nehereus*, (*b*= 3.63) and *C. dussumieri*, (*b*= 3.32); and negative allometric for *L. calcarifer* (*b*= 2.82), *P. heterolepis* (*b*= 2.83), *M. cordyla*, (*b*= 2.63), *T. setirostris*, (*b*= 2.54), *P. macracanthus* (*b*= 2.84) and for *A. leigaster*. (*b*= 2.27). Additionally, growth parameters for 15 commercially important marine fish were estimated as well as the recruitment pattern and mortality (total, natural and fishing) were also estimated. Exploitation rate indicated that, the stock of *L. calcarifer*, *P. paradiseus* and A. *leiogaster* was over exploited. The balance stock exists for *P. heterolepis*, *S. panijus*, *H. nehereus* and *T. setirrostris*, and rest were under exploited. The estimated maximum sustainable yield (MSY) of 15 commercially important marine fishes were estimated as 24298.88 MT for *L. calcarifer*, 10234.47 MT for *P. heterolepis*, 313.65 MT for *P. chinensis*, 13077.43 MT for *E. affinis*, 455.04 MT for *S. taty*, 637.96 MT for *S. panijus*, 99.55 MT for *P. paradiseus*, 769.41 MT for *M. cordyla*, 55708.90 MT for *H. nehereus*, 110.74 MT for *C. dussumieri*, 55.31 MT for *T. setirostris*, 859.92 MT for *A. chacunda*, 525.80 MT, *I. megaloptera*, 6340.75 MT for *P. macracanthus* and 425.44 MT for *A. leigaster*.

For stock assessment by molecular approach for component 2 (SAU), about one hundred samples of each species of ten marine fishes namely, *Pampus chinensis, Pampus argenteus, Euthynnus affinis, Auxis thazard, Megalaspis* *cordyla, Lates calcarifer, Setipinna tenuifilis, Sillaginopsis panijus, Polynemus paradiseus* and *Coilia dussumieri* were collected between October 2020 and April 2022 mainly from coast and rivers of two ecological regions of Bangladesh coast: the South - west (Borguna-Khulna-Patuakhali, KP) coastal zone and the South - east (Chattogram-Cox's Bazar, CC) coastal zone based on different physico-chemical characteristics of habitat (KP: high brackish water area with dense clayed particle in river and estuaries; CC: sandy area with more clear saline water river and estuaries) and biology of species (e.g. migratory, amphidromous, anadromous etc.). For amphidromous or anadromous fish, samples were collected from coastal rivers. Fish/tissue samples or DNA sequence data of other seas in the Indian Ocean region (e.g. Southern BoB, Andaman Sea, Arabian Sea, Persian Gulf etc.) and South-west Pacific (e.g. South China Sea, Gulf of Thailand etc.) were collected from different researchers and scientific studies. For genetic diversity and stock study, sequence variations in different mitochondrial DNA gene regions such as COI, Cytb, and noncoding control region (d-loop) were examined through Polymerase Chain Reaction (PCR) was used to amplify the target mtDNA region and sequenced by sequence analyzer. Lastly, the variation in the obtained DNA sequence data of different geographic locations were analyzed using different bioinformatic softwares such as Geneous, ARLEQUIN, MEGA-6; TCS etc. For all the genes in every sampling locations of Bangladesh, the nucleotide diversities (π) were very low (0.0001 ~ 0.05) but the haplotype or gene diversities (h) were relatively high, 0.5 ~ 1.0 (i.e. h>0.5) indicates that the studied fishes have experienced population expansion after a period of low effective population size, except two species, *M. cordyla* and *L. calcarifer* for which the gene diversities were also low (0.14 ~ 0.263). This result implies that these two fish species of Bangladesh have experienced recent bottleneck. Immediate conservation measures should be immediately taken for these two species, such as limiting catch, banning on fishing season, making long term sanctuary or protected area etc. Neutrality tests such as Tajima's D and Fu's F_S statistics also suggested that most of the studied fish species of Bangladesh populations have undergone the demographic history of population expansion. Interestingly, the population statistic F_{ST}, and exact test of population differentiation revealed two different scenarios for two group of fishes. The first group contains six fish species namely *P. chinensis, P. argenteus, E. affinis, A. thazard, M. cordyla, L. calcarifer*. Fishes of this group have similar characteristics. These fishes are mostly oceandromous, pelagic and highly migratory. They are widely distributed throughout the Indian Ocean and South-West Pacific (or, Indo-west Pacific). These fish showed no significant population genetic structuring indicating that these six species have single genetic stock and these are panmictic (random mating among populations) throughout Bangladeshi marine water. Bangladesh should manage these species as a single conservation unit. Further, these six migratory fish showed its own genetic structure (F_{ST} $P \leq 0.05$) within the BoB when compared with other neighbouring seas such as Arabian Sea, Andaman Sea, Gulf of Thailand, South China Sea etc. So, the BoB countries should manage and conserve these vital and shared marine species through cooperation with each other. On the other hand, the second group consists of four species *viz,S. tenuifilis, S. panijus, P. paradiseus* and *C. dussumieri* is relatively distributed to the narrow or localized geographic area mostly in the BoB and Andaman Sea. These fishes are mostly off-shore or coast dwelling and amphidromous (i.e. migrate between fresh and marine water but not to breeding purpose). For these species, pairwise F_{ST} values of mtDNA markers among fish samples of different sampling rivers showed significant differences ($P \leq 0.05$) in most of the cases. Different rivers showed their own genetic stock for different fish such as Bishkhali, Kirtankhola and Boleshwar river for *P. paradeseus* and *S. panjius*; Naf and Pashur river for *C. dussumieri*; Matamuhuri and Bishkhali river for *S. tenuifilis* etc. Based on this result, it is recommended that different river populations of studied fish having unique genetic structures (i.e. genetic stock) require separate monitoring and management strategies for conservation because the population of each river is genetically distinct and overfishing in any of the rivers may cause extinction of its fish stock. So, it is needed to maintain good water flow and direction such as by regular dredging, and also needed to control water pollution for good ecosystem to safe guard these fish species.

Findings of questionnaire survey and FGD reflects that fishing with mosquito net in estuaries and mangrove areas and fishing through Behundi net are the major man-made causes or threats for declining of commercially important marine fishes in the BoB followed by catches of fry, fingerlings and *jatka*, poison fishing in mangroves, illegal fishing by Indian and Myanmar's fishers, catches of brood fish and use of destructive fishing gears. It was also observed that indiscriminate fishing has been increasing alarmingly due to illegal introduction of destructive fishing gear like China net in Bangladesh territory of the Bay. The findings of this research project will contribute towards as a scientific basis for stock assessment and sustainable management policy of marine fish species in the BoB.

Keywords: BoB, Stock status, Fishing ban period, Molecular marker, Fisheries management

PBRG Sub-project Completion Report (PCR)

A. Sub-project description

1. **Sub-Project title:** Stock Assessment of Commercially Important Fishes in the BoB Through Multi-model Inferences and Molecular Markers: Management Policy Implications Considering the Emerging Climate Change

2. **Implementing organization (s)**

   Coordination Component: Fisheries Division, Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka-1215

   Component-1: Department of Fisheries, University of Rajshahi, Rajshahi-6205

   Component-2: Department of Fisheries Biology and Genetics, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207

3. **Name and full address with phone, cell and E-mail of Coordinator, Associate Coordinator, PI/Co-PI (s):**

   Coordinators

15 Oct'19 to 09 Feb'22	*12 Apr'22 to 29 Jun'22*	*30 Jun'22 to 29 Dec'22*
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4. Sub-project budget (Tk.)

4.1	**Total:(in Tk as approved)**	**: Tk. 33000000.00**
i.	Coordination component	: TK. 1480000.00
ii.	Component 1 (RU)	: TK. 18780000.00
iii.	Component 2 (SAU)	: TK. 12740000.00
4.2	**Latest Revised (if any)**	**: Tk. 34300000.00**
i.	Coordination component	: Tk. 1780000.00
ii.	Component 1 (RU)	: Tk. 18780000.00
iii.	Conponent 2 (SAU)	: Tk. 13740000.00

5. Duration of the sub-project

5.1 Start date : 15 October 2019

5.2 End date : 29 December 2022

6. Background of the sub-project

The BoB, the marine area of Bangladesh, is characterized by a semi-enclosed tropical basin. The BoB is one of the world's 64 Large Marine Ecosystems. The entire shelf area of Bangladesh (up to 200 m depth contour) covers about 70,000 km^2. Marine fisheries production contributes 15.05% of the national fish production (DoF, 2020). The BoB is very rich in fish and shrimp species biodiversity. Around 511 marine species, together with shrimps, exist within Bangladeshi waters. Marine fisheries can be classified into pelagic and demersal. Pelagic fisheries including Hilsa, Mackerel, Pomfret, Ribbon Fish, Bombay Duck, Indian Salmon, Mullets, Oil Sardine, Pelagic sharks, Sword Fish, Butter Fish, Pike, Bonito, Skipjack, Threadfin, Smelts, Indian Anchovy, Dorab Herring, Indian Scad, Sharks, etc are found in the upper zone of water of the BoB. Most of the demersal fishes live on or near sea floor, and are either carnivores or detritus feeders. Some of these fishes are: Jaw Fish, Croakers, Catfishes, Flatfishes, Pike, Sea breams, Snappers, Scavengers, Eel, Goat Fish, Crabeater, Rabbit Fish, Rock Fish, Seabass, Grouper, Silver Bream, Ribbon Fish, and demersal sharks. There are about 100 important species of which 20 fish families are highly commercial, contributing about 82-87% of the total demersal exploitation in Bangladesh. Furthermore, abundance of pelagic fishes, e.g., 7 species of Tuna and Skipjack, 4 species of Mackerel, 14 species of Sharks and rays are also found. About 36 Species of Shrimps have been recorded from the marine water of Bangladesh. However, accurate species/ stocks or unit-stocks identification is very crucial both in the context of monitoring and conserving the fish species in any habitat.

Catch or production from open-water capture fisheries have been declined abruptly in Bangladesh due to the environmental degradation, climate change and numerous anthropogenic activities such as indiscriminate catching of juveniles, killing of spawners during peak spawning season, pollution from various sources, constructions of barrage and dams, siltation etc. Nevertheless, the total fish productions, especially from culture and marine catch of Hilsa have been increased in recent years (DoF, 2020). In addition, for the last few years, the catch of marine fishes has been increased progressively, indicating a viable alternative for more and more fish production to meet the demand of the expanding population of the country and increasing export earning.

The potential of the coastal fisheries sector has not been rationally harvested. Rather the resources have been over-exploited, and as a result, the stocks of several important fish declined. The sustainable exploitation of marine fishery resources is constrained by (a) lack of knowledge of the species-wise current stock, location of the breeding ground and the grow out areas for each genetic stock (i.e., unit stock), and the potential maximum sustainable yields by species, season and location; (b) over-fishing. Strategies to overcome these will include: a rapid assessment of fisheries stocks by species including detection of their unit stocks in recently resolved South-West waters of EEZ, formulation of national marine fisheries policy, registration of all mechanized fishing boats and fishing licensing, strict surveillance should be continued for fishing to ensure compliance to all relevant acts, rules and regulations. Though a number of surveys conducted to examine the status of marine fisheries resources, it was long time ago between 1970s and 1980s (FAO, 2014). No recent or comprehensive knowledge is available on the fisheries stocks, systematics, biological and ecological aspects of the coastal and marine fisheries of Bangladesh (Shamsuzzaman et al., 2017a)

Climate change unswervingly affected fishery production in marine ecosystems along many pathways. Fish growth, reproduction, distribution, migration, stocks are mostly affected by temperature, rainfall and hydrology. Climate change is likely to badly affect marine fishes and shrimps in Bangladesh. Information on the fish stock assessment is crucial for studies and inference on stock status including structure, natural-, fishing- and total mortality and exploitation, as well as the possible outcomes of different management alternatives. It helps to determine whether the abundance of a stock is below or above a given target point and whether the stock is overexploited or not. Besides, it also tells us if a catch level will maintain or change the abundance of the stock (Frank and Brickman, 2001) which ultimately help for sustainable fisheries management of marine fishes and shrimps. Only few studies have been conducted on sustainable management on marine fishes by Shamsuzzaman et al. (2017b) and Dutta et al. (2016), but to the best of knowledge, no sound studies have been done on stock assessment of marine fishes considering emerging climate change in the BoB with confirmation of unit-stocks through multi-models.

In order to deal with fisheries stock assessment, it is instructive to consider a fish population or stock as a simple biological system. Fish population has four parameters such as growth, reproduction, recruitment and mortality. Growth parameters are required for the estimation of the stock status through estimation of exploitation rate and maximum sustainable yield. Most of the studies on stock assessment using growth parameters which is based on single model. However, the proposed project is going to deal with the stock status through multi model inferences. In fact, each model depends on the life history and environmental status for each species. In such cases, best growth model can be selected from the multi models using some biological index, which is the main target of this proposed study. Therefore, multi model are always better than single model to predict the actual growth parameters, which can give sound stock assessment.

In order to manage the commercially important fishes effectively, it is also necessary to identify the exact reason for declining in relation to its life history straits, i.e., populations parameters and stock status. For sustainable exploitation, conservation and management of the renewable marine resources, investigations on the spawning seasons of commercially important marine fishes in the BoB (Bangladesh) is the important opton for the country. Besides, this project was also recognized the limitations of fisheries management at the unit stocks level and establish sustainable conservation and management policy for commercially important fishes effectively in the BoB.

Unit stock identification and population genetic structure analysis establish a basis for management of fisheries resources. It is a great concern whether the most commercial marine fish species have experienced "bottlenecks" (recent dramatic changes in population size). Populations experiencing bottlenecks should be identified from a conservation or management point of view because they are likely to suffer from inbreeding depression, loss of genetic variation and fixation of deleterious alleles, thus reduce the adaptive potential and the probability of population persistence. Signals of past population bottlenecks can be detected using genetic analysis. Since the abundance of fish in natural waters in Bangladesh is declining day by day several commercial fish species may face the vulnerability of population decrease. So, it requires a proper management strategy, which includes investigation on current levels of genetic diversity and differentiation within and between populations as a basis for sustainable management recommendations. However, our knowledge on the population genetic structure (i.e. genetic stock assessment) of highly commercial marine fishes of Bangladesh is still limited.

Several important commercial fish species of Bangladesh are reported to face the vulnerability of population decrease. When managing a species as a resource, assessment of genetic diversity and population structure can be a vital tool for maintaining a productive fishery (Seeb et al. 1990). Generally, a single panmictic population could be recovered through increased recruitment by propagation or momentary conservation initiative (Munro and Bell, 1997). On the other hand, different populations with unique genetic structures should be managed as distinct units, and such units require separate monitoring and management policy (Salgueiro et al., 2003). Because each stock might be genetically largely isolated from the others through behavioural or distributional differences. The different stocks also reflect genetic diversity and if a particular stock is fished to extinction or to very low levels, this genetic diversity may be lost. The stock will not readily be replenished from other stocks because of the genetic isolation, and therefore the production it was generating will also be lost, leading to a permanent or at least long-term loss of benefits. Fisheries management should therefore attempt to address each stock separately and to ensure sustainable use of each stock and not just of the population as a whole. Besides, it is also important to know the genetic diversity of each of the existing population of a fish. Genetic variability influences both the health and long-term survival of populations because decreased genetic diversity has been associated with reduced fitness, such as high juvenile mortality, diminished population growth, reduced immunity, and ultimately, higher extinction risk.

The genetic structure of a population is measured by analyzing variations that occur in the DNA. The value of molecular genetics to stock identification depends on the method used (e.g., allozyme, mitochondrial and nuclear DNA analysis), objectives of the study (biological, genetic or fisheries-related) and the time scale of interest (short- versus long-term management) (Cavalho and Hauser 1995). The basic principle of all molecular genetic methods is to use inherited stable markers to identify genotypes that characterize populations.

Based on above background, component 1 (RU) conducted stock assessment of 15 commercially important marine fish species through Multi-Model inferences. On the other hand, component 2 (SAU) investigated population genetic structure (i.e. genetic stock assessment) of 10 commercial marine fish species using mitochondrial DNA as an effective molecular marker. A joint survey by both components was also conducted to identify major threats for marine fisheries of Bangladesh especially caused by human interference beside climate change.

The studies of this sub project dealt with the 'rapid assessment of fisheries stocks by species in recently resolved waters of EEZ of Bangladesh' which was the 'first priority' of Fisheries Sub-Sector of 7th FYP in Bangladesh with aiming to achieve the SDGs. The results of the study will contribute to the management and policy strategies of Marine Fisheries to exploring Blue Economy.

7. Sub-project general objective (s)

To determine and categorize the stock of commercial fish species of the BoB to ensure maximum sustainable yield for assisting the livelihood of highest number of fishers.

i. To categorize the fish stocks and to assess its status through multiple models in the BoB (BoB);
ii. To upgrade the livelihoods of fishers through sustainable management of marine fisheries;
iii. To identify the major man-made and climatic threats/ factors to fisheries resources in the BoB, Bangladesh.

8. Sub-project specific objective (s)

Coordination component BARC

i. To ensure smooth and efficient implementation of sub-project activities to achieve desired project outputs within the stipulated timeframe under strengthened capable research management system;
ii. To coordinate project implementation efforts and integration of activities to generate desired information /technology as per methodology of the sub-projects;
iii. Identify operational deviations and addressing constraints/problems (if any) under a process of strong and regular monitoring of the project activities;
iv. To upgrading the level of output of the sub-project through reviewing of yearly technical progress;
v. Collect and collate project data, finding and observation and production of compiled project completion report (PCR).

Compone4nt-1 (RU)

i. To find out the fish stocks through morphometric and meristic characteristics then to estimate the size at sexual maturity, age at sexual maturity, spawning- and peak-spawning season of fishes through multiple functions for the justification of fishing-ban period in the BoB;
ii. To calculate the growth parameters through multi-models using length-frequency analysis and then to assess the stock's status of commercially important fishes in the BoB; and
iii. To identify the major man-made and climatic threats/ factors to fisheries resources in the BoB, Bangladesh.

Component-2 (SAU)

i. To determine whether there are single or discrete genetic stocks of commercial marine fish with variation of habitat in Bangladesh using mitochondrial DNA markers;
ii. To assess the intra and inter population genetic diversity and divergence of commercial fish in the BoB, Bangladesh and other neighbouring seas.
iii. To identify the major anthropogenic that are the threats for the marine fish stock in the BoB (BoB), Bangladesh beside climatic factors and detect the priority areas where management actions are needed;

9. Implementing location (s)

Field location: Coastal and Marine EEZ waters of Bangladesh i.e., BoB along with different coastal rivers. (Field statios: Chattogram, Cox's Bazar, Kuakata, Patharghata).
Laboratories: Department of Fisheries, University of Rajshahi, Rajshahi-6205 and Aquatic Bioresource Research Laboratory (ABR Lab), Department of Fisheries Biology and Genetics, Faculty of Fisheries Aquaculture and Marine Science, Sher-e-Bangla Agricultural University, Dhaka-1207

10. Methodology in brief (component wise)

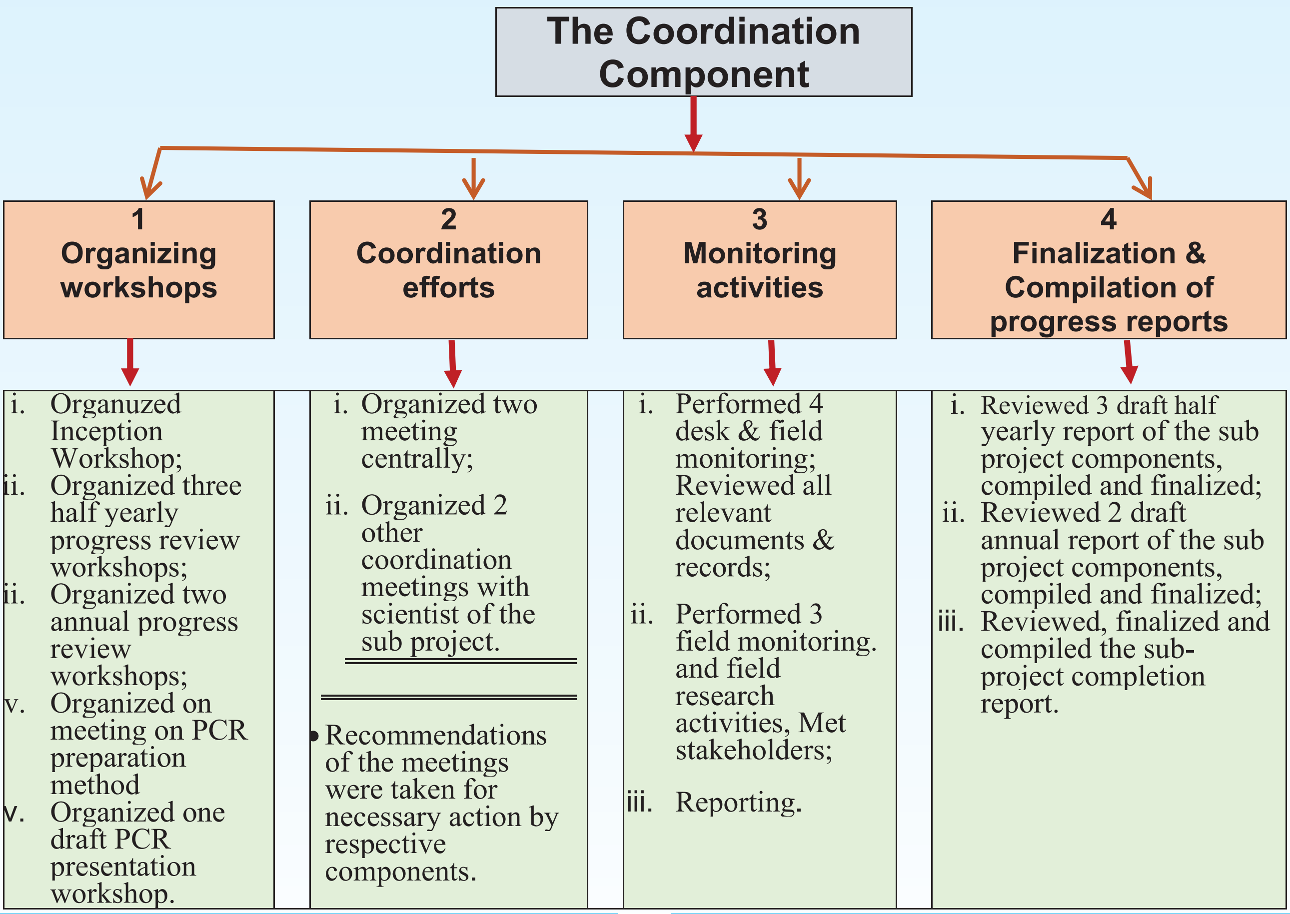
10.1. Activity implementation approach of the Coordination component

The Coordination component as the responsible unit of the sub project to initiate all potential efforts in the process of implementation of each component under the sub project so that the general objectives and goal of the sub project can be achieved through smooth and successful completion of each of the specific objectives as per activity time plan of the sub-project document. To ensure that, the Coordination component, taken into consideration its own activity and objectives and duration of the sub-project, thus accordingly designed its own plan of activity (approach) for the proposed period.

Following are the major activities carried out by the Coordination component under the plan:

a. Organizing seminars/workshops.
b. Monitoring of the sub-project activities (specifically financial and research activities);
c. Coordination of activities within the components of the sub-projects.
d. Review and compilation of half yearly and annual research progress reports.

The implementation approach and activities there under for the Coordination component of the sub-project shown in the following diagram:



Recommendations of the inception workshop, half yearly and annual research progress review workshops and different Coordination meetings are furnished here under in **Annexures: BARC (A – E).**

Following table presenting the summary statement of achievements performed by the Coordination component of the sub project

Summary statement of achievements		
Name of activities	**Performance against each component of the sub-project**	**Remark**
Inception workshop	Organized centrally at BARC in November' 2018	Attended all PI, Co-PI & expert members.
Revision of PP	Done as per recommendations of inception workshop	
Half yearly progress review Workshop	Organized centrally at BARC in March 2020, January 2021 & June 2022.	Attended all PI, Co-PI & expert members
Workshop on Draft PCR	01 (24/10/22 to 25/10/22)	Review of the respective draft PCR done
Ann. Progress review Workshop	Organized centrally at BARC in December 2020 & in April 2022	Attended all PI, Co-PI & expert members.
Coordination meetings - 03	03 *(one meeting held virtually)*	All coordination meeting held centrally.
Monitoring of field and Lab activities	04 *(RU & SAU)*	Covered all components under the sub-project.
Training/orientation	01 (11.05.22)	Orientation workshop of 09 sub-project PIs on PCR development
Financial achievement	Approx. 84% of total approved budget & 100% of released money	Delay in procurement plan approval and Covid-19 pandemic hampered desired progress
Reporting performance	Provided sub-project inception report, SoE, Half yearly and Annual compiled progress reports of all sub project components as per planned time frame.	Major reports/proceedings: • Inception report (1 no); • Compiled half yearly progress report (3 no); • Compiled annual progress report (2 no); • Monitoring reports (4 no); • Workshop proceeding (6); • Project Completion Report-1;

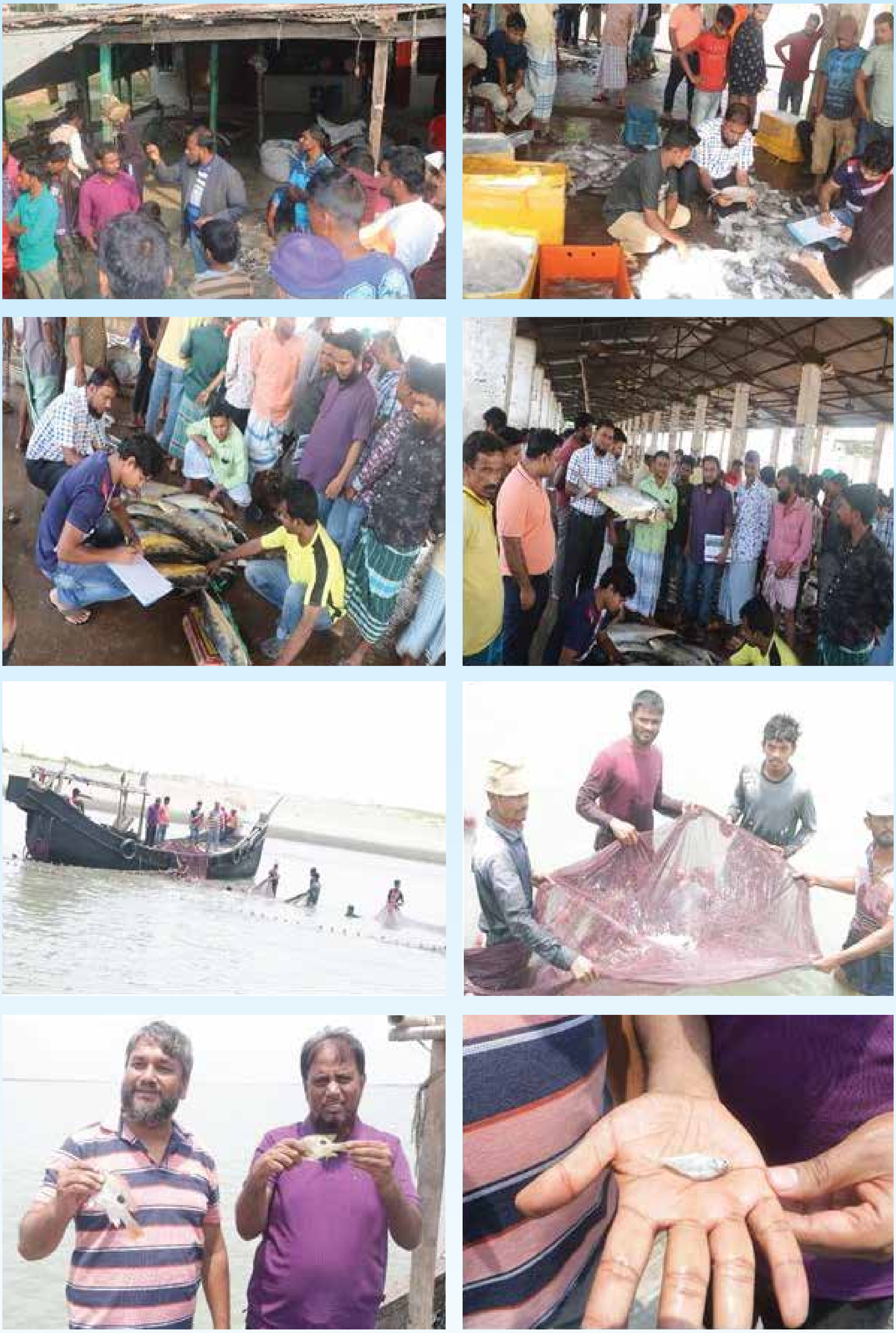
Plate 1 (a). Pictorial views of different workshops, coordination meetings and field monitoring activities.

10.2. Component 1(RU)

The proposed study was conducted in the BoB, Bangladesh side covering Khulna Region (Khulna, Bagerhat, Barguna & Patuakhali), Barishal Region (Barishal & Bhola), Chattogram and Cox's Bazar (Cox's Bazar, Taknaf, St. Martin) regions (Fig 1). Monthly samples of 15 commercially important fishes were collected using hired commercial fishing boat/ fishers from October 2019 to March 2022. The fresh samples were immediately placed in ice, and then fix in 10% formalin and 10% formalin/alcohol on arrival in the laboratory. Additionally, catches data of marine commercial fishes were collected from BFDC landing center, Patharghata, Barguna, (Plate 1). Interview was conducted with the local fishers, boatmen and owners, aged group, businessmen and exporters over the major fish landing centers of Bangladesh through pre-tested structured questionnaire for gathering local knowledge of commercially important marine fish, their fishing, nursery, spawning grounds and spawning season, lunar periodicity, catch trends etc. The landing sites were visited daily in all seasons considering lunar cycle and species availability. Additionally, water quality parameters were monitored using Multi-Meter Digital Meter from October 2019 to March 2022. Furthermore, a long-term data set of climates were collected from the meteorological department to relate its changes with the reproductive cycle/ spawning season and also with stock' status.

10.2.1 Fish category (commercially important, edible & exploitable species)

Fish species in BoB was enlisted based on commercial small- and large-scale fishers' catch at different landing sites and from different sampling stations, areas and sites of the proposed study using hired fishing boats. Collected fishes were categorized based on economic point of view into (i) Commercial edible stock, (ii) Commercially exploitable stock and (iii) Non-commercial stock through survey with structured questionnaire and Focus group discussion (FGD). Additionally, fish species was categorized based on fishing pressure into (i) Over-exploited stock, (ii) Under-exploited stock, (iii) Balanced stock, and (iv) Virgin stock.



Plates 1(b). Fish catch data collection from BFDC landing center, Patharghata, Barguna and Cox's Bazar landing center thorough direct observation and hired fishing boat

10.2.2. Fish measurement

The preserved specimens were then taken out one by one later to be weighed, measured and sexed (Plate 2). All specimens of fishes were sexed by morphometric characteristics and gonad observation under a binocular microscope. For each individual, various lengths including total length (TL), Standard length (SL), and fork length (FL), body depth (BD), pre-dorsal, post-dorsal, anal-length were measured to the nearest 0.01 cm and body weight (BW) was taken with 0.01 g accuracy.

The population structure for the marine commercially important fishes were constructed using 1 cm intervals of TL. Based on Hasselblad's maximum-likelihood method (Hasselblad, 1966), the normal distribution was fitted to TL frequency distributions through Microsoft® Excel-add-in-Solver.

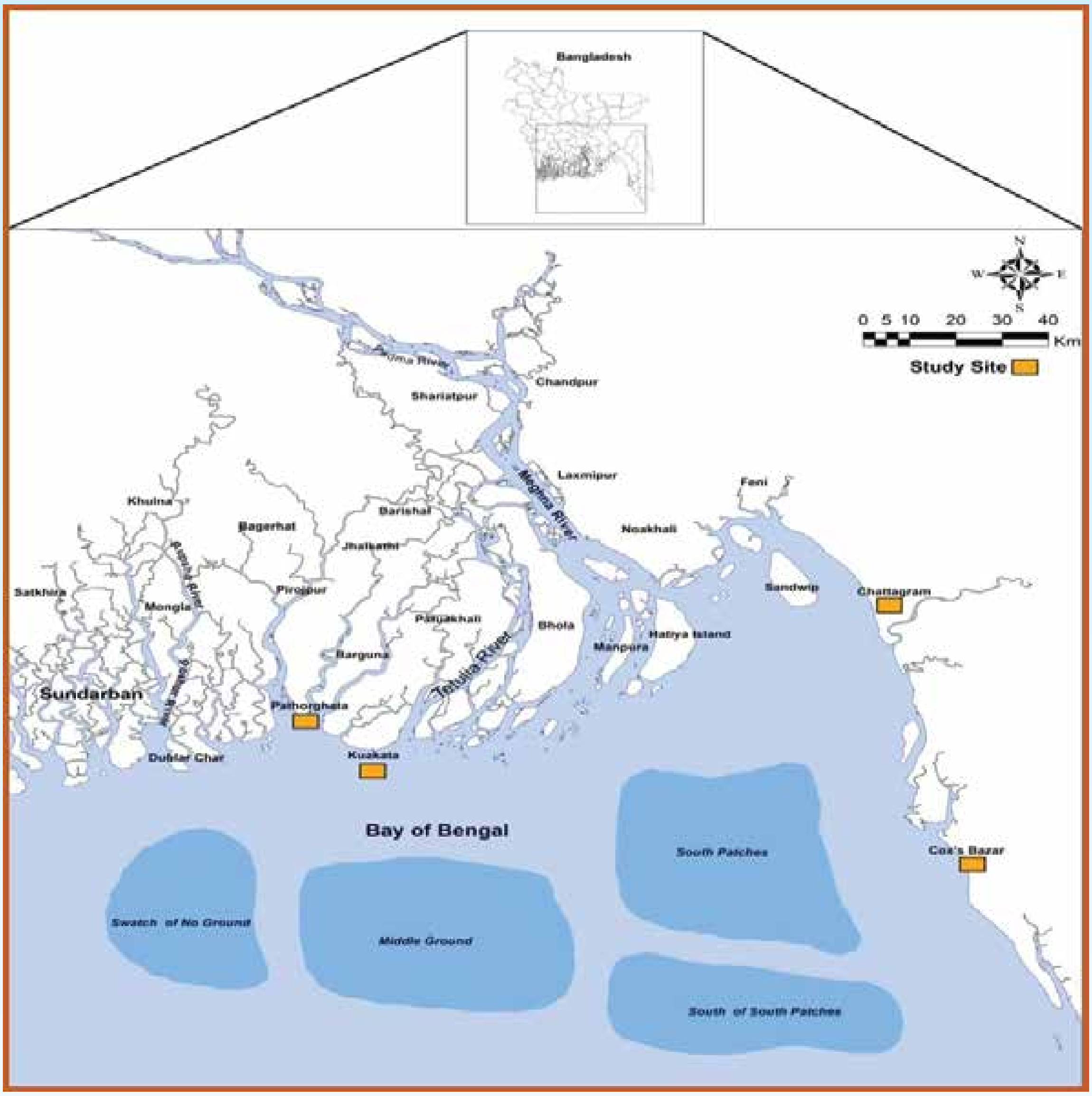


Fig 1. Different sampling sites (Patharghata, Barguna; Alipur, Patuakhali; Chattogram and Cox's Bazar) in the BoB, Bangladesh.

10.2.3 Relative growth and condition of fishes in the BoB

The growth pattern was calculated through the relationships between length and weight (LWR) as: $W = a L^b$, where W is the total body weight (BW, g), L the total length (TL, cm), a and b are the parameters of regression analysis. Parameters a and b of the LWR was estimated by linear regression analysis based on natural logarithms: $ln(W) = ln(a) + b\ ln(L)$. Additionally, 95% confidence limits of the parameters a and b and the statistical significance level of r^2 (coefficient of determination) was estimated. The r^2 value of the coefficient lies between 0 and 1 and it describes the proportion of the variation of one of the correlated variables which can be explained by the variation of the other variable (King, 2007). Even though the r^2 may indicate a relationship between the variables, the correlation may not be significant because of small sample sizes or correlation in comparison to the other value. In this situation, a one-tailed t-test, $t = r \sqrt{(n-2)}/ \sqrt{(1-r^2)}$ for independent means might be applied to express correlation between two variables. In addition, to confirm whether b values are significantly different ($p \leq 0.05$) from the isometric value ($b \approx 3$), the equation of Sokal & Rohlf (1981): $t_s = (b-3) / s_b$ was applied, where t_s is the sample t-test value, b is the slope, and s_b is the standard error of the slope (b). The comparison between t_s and tabulated critical values for b allowed determination statistical significance, and their classification as isometric growth ($b \approx 3$) or allometric growth (negative allometry for $b<3$ or positive allometry for b>3). In this study, prior to the regression analysis of ln BW on ln TL, ln-ln plots of length and weight values was performed for visual inspection of outliers, with extremes being excluded from the regression analyses.

Plates 2(a). Sorting of commercially important marine fishes collected from hired fishing vessels and different landing centers

Plates 2(b). Measurement, weighing, dissecting, and collection of gonads of marine fishes collected from hired fishing vessels and different landing centers.

Plates 2(c). Dissecting, weighing, collection and histology of gonad of collected marine fishes

10.2.4 Growth pattern and form factor ($a_{3.0}$) of commercially important marine fishes

The condition factors of fishes in the BoB, Bangladesh were calculated using large number of specimens with small to bigger body sizes. Fulton's condition factor (K_F) (Fulton 1904) was calculated following the equation: $K_F = 100\times (W/L^3)$, where W is the total body weight (BW, g) and L is the total length (TL, cm). The scaling factor of 100 is used to bring the K_F close to unit. In addition, the relative condition factor (K_R) for each individual was calculated using the equation of Le Cren (1951): $K_R = W/(a\times L^b)$, where W is the BW, L is the TL, and a and b are the LWR parameters. Furthermore, the allometric condition factor (K_A) was calculated using the equation of Tesch (1968): W/L^b, where W is the BW, where L is the TL, and b is the LWR parameter. To focus the prey-predator' status, the relative weight (W_R) was calculated by the equation given by Froese (2006) as $W_R = (W / W_S) \times 100$, where W is the weight of a particular individual and W_S is the predicted standard weight for the same individual as calculated by $W_S = a\,L^b$ where the a and b values are obtained from the relationships between TL and BW.

The form factor $a_{3.0}$ of fishes was calculated using the equation given by Froese (2006) as: $a_{3.0} = 10^{\log a - s\,(b-3)}$, where a and b are regression parameters of LWRs, and S is the regression slope of $\ln a$ *vs* b. In this study, a mean slope $S = -1.358$ (Froese, 2006) was used for estimating the form factor because information on LWRs is not available for each species to estimate the regression (S) of $\ln a$ *vs* b.

10.2.5 Sexual maturity, spawning- and peak-spawning season

For each individual, body weight (BW) was taken with 0.01 g accuracy. Whole gonads were removed from each individual and weighed (GW) with an electronic balance to an accuracy of 0.01 g and then was preserved with 10% formalin solutions. Ovary color, size and oocyte diameter was noted for each individual. Histological studies were followed for the confirmation of ovarian maturation stages/ status. The gonadosomatic index (GSI%) as GSI(%)= (GW/BW)*100; Modified GSI as MGSI(%) = [GW/(BW-GW)]*100 and Dobriyal index (DI) as [DI= $\sqrt[3]{GW}$ (Dobriyal et al., 1999) were calculated. Size ($L_{m50\%}$) at first sexual maturity for fish was estimated by (i) relationship between TL *vs.* GSI (Hossain et al., 2012), TL *vs.* MGSI (Hossain et al., 2017) and TL *vs.* DI (Hossain et al., 2017); (ii) maximum length-based equation (Binohlan and Froese, 2009), (iii) ovarian maturation stages against its length using ovary color and histological studies (Hossain and Ohtomi, 2008), and (iii) logistic model (King, 2007). Age at sexual maturity was also be calculated as $T_{m(50\%)} = (-1/1)*\ln(1-L_m/L_\infty)$. Spawning- and peak-spawning season were estimated using the monthly changes of GSI, MGSI, DI. Additionally, monthly variations of ovarian maturation stages through colors and histological studies were used for the confirmation of spawning- and peak-spawning season for commercially important fish in the BoB. Based on peak spawning season from the studies of GSI, MGSI, DI, maturation stages, histological studies, data regarding catch composition obtained from interview and different secondary sources (Marine Fisheries Survey Unit-DoF, Chattogram and some of artisanal catch data from BFDC landing centers, publishes books and papers), the existing fishing ban period (20 May to 23 July) was justified.

10.2.6 Growth parameters, performance and life span

For each individual, total length (TL) was measured to the nearest 0.01 cm. Monthly length-frequency distributions (LFDs) was constructed using 1 cm intervals of TL. A series of component normal distributions was fitted to the LFD of each sample by sex, using a computer analysis (Microsoft Excel-add-in-Solver) based on Hasselblad's maximum-likelihood method (Hasselblad, 1966). The actual ages of individuals belong to each age group was estimated by arbitrarily assigning from the peak spawning season. The growth paremeters were modeled by fitting von Bertalanffy equation to the mean TLs at ages estimated for each component normal distribution at the various sampling dates. The equations are-

von Bertalanffy equation (von Bertalanffy, 1938): $L_t = L_\infty [1\text{-}exp\{-K(t\text{-}t_0)\}]$;

where, L_t is the TL (mm) at age t (month), L_∞ is the asymptotic TL (cm), K is the growth coefficient (year^{-1}), and t_0 is the hypothetical age when the TL would be zero.

The growth performance indices (Ø') was calculated by Pauly and Munro (1984):

$$Ø' = log_{10} K + 2log_{10}L_\infty$$

The longevity was estimated from the time series of the LFD. The life span was estimated by $T_{max} = 3/K$ (Pauly and Munro, 1984). Also, weight-based growth parameters (W_∞) were estimated by conversion of length to weight using length-weight relationship, $W = a^*L^b$, where a and b are regression parameters.

For the limited data stocks, the growth parameters were described through the von Bertalanffy (VBG) model (von Bertalanffy, 1938) as $L_t = L_\infty [1\text{-}exp\{-k(t\text{-}t_0)\}]$ for length basis and $W_t = W_\infty [1\text{-}exp\{-k(t\text{-}t_0)\}]^b$ for weight basis, where L_t = mean length at age t; L_∞= asymptotic length; W_∞= asymptotic weight; k = growth co-efficient; t = the age year^1 and t_0 = the hypothetical age at which the length is zero. The asymptotic length (L_∞) was calculated by the Wetherall plot according to King (2007) as a seed value. In this study, L_∞ was calculated based on the maximum observed length using the empirical model as $\log(L_\infty) = 0.044 + 0.9841^* \log(L_{max})$ (Froese & Binohlan, 2000). Additionally, the L_m was estimated based on the maximum observed length by $\log(L_m) = -0.1189 + 0.9157^* \log(L_{max})$ (Binohlan & Froese, 2009). Furthermore, the t_m was calculated by using the equation of $t_{m(50\%)} = (-1/1)^*\ln(1-L_m/L_\infty)$ (King, 2007). Another growth parameter, K was calculated by the equation of $K = \ln(1+L_m/L_\infty)\ t_m$ (Beverton, 1992). The t_0 of marine data limited fish stock was determined by $\log(-t_0) = (-0.3922 - 0.2752 \log L_\infty - 1.038 \log K)$ (Pauly, 1980).

10.2.7 Recruitment pattern and length, and age-at first recruitment

The recruitment pattern of Marine fishes was determined from the analysis of the entire time series of LFDs and growth parameters using the best fitted equation. Input parameters L_∞, K, (C, amplitude of seasonal growth oscillation = 0; WP, winter point = 0), and t_0 was used in the analysis (Moreau and Cuende, 1991). The recruitment pattern was presented in terms of the percentage of recruitment against time in months. A normal distribution of the recruitment pattern was determined by NORMSEP (Pauly and Caddy, 1985) in FiSAT II.

10.2.8 Stock assessment (exploitation rate and maximum sustainable yield, MSY)

Once growth parameters are obtained, the instantaneous rate of total mortality (Z) was estimated by the length converted catch curve method (Pauly, 1983) which is given as $ln(N_t/\Delta_t) = a + b.t$; where, N is the number of individuals of relative age (t), and Δ_t is time needed for the shrimp through a length class. The slope b of the curve with its sign changed gives an estimate of Z (King, 2007).

Natural mortality (M) was estimated by Pauly (1980) given as-

$$log_{10}M = -0.0152 - 0.279\ log_{10}L_\infty + 0.6543\ log_{10}K + 0.4634\ log_{10}T$$

where, M is the natural mortality, L_∞ the asymptotic length, K refers to the growth coefficient and T is the average annual environmental temperature (°C) in which the stocks live. Fishing mortality (F) was estimated by subtracting the natural mortality (M) from the total mortality

(Z): F = Z – F. Exploitation rate (E) was calculated as the proportion of the fishing mortality relative to total mortality (Gulland, 1965): $E = F/Z = F/(F+M)$.

The model of Beverton and Holt (1966), as modified by Pauly and Soriano (1986), was used to predict the relative yield per recruit (Y'/R) of the species to the fisheries. $Y'/R = EU^{M/K} \{1 - (3U)/(1+m)\} + (3U^2)/(1+2m)\} + (U^3)/(1+3m)\}$; Where, E = F/Z, the current exploitation rate, i.e. the fraction of death caused by fishing activity, F = the instantaneous rate of fishing mortality, $U = 1 - (L_c / L_\infty)$ is the fraction of growth to be completed by fish after entry into the exploitation phase (where, L_c= size at first capture), and m = (1-E)/ (M/K) = K/Z. The relative biomass per recruit (B'/R) was estimated as: B'/R = (Y'/R) / F. Then, E_{max} (exploitation rate producing maximum yield), $E_{0.1}$ (exploitation rate at which the marginal increase of Y'/R is 10% of its virgin stock) and $E_{0.5}$ (the exploitation rate under which the stock is reduced to half its virgin biomass) were computed through the first derivative of the Beverton and Holt (1966) function using FiSAT II.

Beverton and Holt (1966) described yield per recruit model, is the best widely used method for the estimation of yield per recruit can be expressed as a function of L_c/L_∞, F/K, M/K and relative fishing mortality F/M. Recently Maximum sustainable yield was estimated by the equation of Froese and Pauly 2020:

$$\frac{Y}{R} = \frac{\frac{\mathrm{F}}{\mathrm{M}}}{1+\frac{F}{M}}\left(1-\frac{Lc}{L\infty}\right)^{M/K}$$

$$\left(1-\frac{3\left(1-L_{opt}-L_\infty\right)}{1+\frac{1}{\mathrm{M/K}+F/K}}+\frac{3(1-L_c-L_\infty)^2}{1+\frac{2}{\mathrm{M/K+F/K}}}+\frac{3(1-L_c-L_\infty)^3}{1+\frac{3}{\mathrm{M/K+F/K}}}\right)$$

Length at maximum yield per recruit was calculated as Log (L_{opt}) = 1.0421*Log (L_∞)-0.2742. The Optimum age (T_{opt}), the age where fish reaches its highest biomass, was calculated by $T_{opt} = t_0 + (\ln(3k+M)-\ln M)/k$.

10.2.9 Biomass model

According to Ricker (1975), the relative biomass, i.e., the total relative weight of the cohort was estimated by multiplying the individual weight by the numbers surviving. Additionally, the numbers surviving in the cohort was calculated from the exponential decay equation as $N_{t+1}=N_t*\exp[-M]$, where N_t is the number present at the beginning of one year and N_{t+1} is the number at the beginning of following year.

10.2.10 Causal factor for threatening/ declining of indigenous fish species

Furthermore, necessary data and information for threats to biodiversity and its conservation were collected through the survey on the fishers, fish traders, teachers, students, researchers, Government and NGO personnel and experienced persons related to fisheries sectors, and available literatures (Plate 3). In addition, data of climate was collected from literature, websites and meteorological station.

Plates 3. Collection of data and information for threats to biodiversity from the fishers, fish traders, teachers, students, researchers, Government and NGO personnel, and experienced persons related to fisheries sectors.

10.2.11 Climate change (temperature, rainfall, cyclone, water level rise) on fisheries resources

A long data series (e.g., > 60 to 100 years, Source: Bangladesh Meteorological Department, Agargaon, Dhaka) on temperature and rainfall was used to observe its changes pattern. The correlation and regression analysis between the annual average temperature and rainfall and its year showed either an increasing or decreasing trend of temperature over the period of study in the project area which might be a big effect of temperature and rainfall on movement, growth, reproduction, mortality and survival of fishes in the BoB. In addition, the relationships between air/water temperature, rainfall, cyclone, high water level, and indicators of reproductive investment and stocks of fish were analyzed.

Finally, the management strategy was also adjusted based on the feedback between mthe onitoring, modeling, and adaptive learning. To estimate the population parameters of the fishes, required mathematical and statistical approaches were applied to all parameters studied. Temperature, rainfall, cyclone, and water level rise was collected from the Bangladesh Meteorological Department and from the literature to prepare a baseline-data compendium.

10.2.12 Statistical analyses

Statistical analyses were performed using Microsoft® Excel-add-in-DDXL and GraphPad Prism 8. Tests for normality of each group was conducted by visual assessment of histograms and box plots, and confirmed using the Kolmogorov-Smirnov test. However, in case of non-parametric statistics, the Spearman rank test was used to correlate body measurements with condition factors. The Wilcoxon signed rank test was used to compare the mean relative weight (W_R) with 100. Where test for normality assumption was not met, the spearman's rank correlation analysis was used to determine the degree of correlation between GSI and TL for males and females. All statistical analyses were considered significant at 5% ($p<0.05$).

10.3 Component 2 (SAU)

10.3.1 Collection of samples and DNA data for genetic stocks, diversity and divergence study

For stock assessment by molecular approach by SAU component, about one hundred samples of each species of ten marine fishes (Table 1 & Plates 4) were collected between October 2020 and April 2022 mainly from coast and rivers of two ecological regions of the coastal areas of Bangladesh (Fig 2): the South-east (Borguna-Khulna-Patuakhali, KP) coastal zone and the South-west (Chattogram-Cox's Bazar, CC) coastal zone based on different physico-chemical characteristics of habitat (KP: high brackish water area with dense clayed particle in river and estuaries; CC: sandy area with more clear saline water river and estuaries), and biology of species (e.g. migratory, amphidromous, anadromous etc.). For amphidromous (migrate between freshwater and marine water but not for breeding purpose) or anadromous fish, samples were collected from coastal rivers. Fish/tissue samples or DNA sequence data of other seas (Fig 3) in the Indian Ocean region (e.g. Southern BoB, Andaman Sea, Arabian Sea, Persian Gulf etc.) and South-west Pacific (e.g. South China Sea, Gulf of Thailand etc.) were collected by personal communication and collaboration with foreign scientists, and from the scientific literatures such as Zafar *et al.* (2012), Kathirvelpandian et al. (2014), Li *et al.* (2019), Menezes *et al.* (2006), Norfatimah et al. (2009), Sun *et al.* (2013), Xu *et al.* (2014). A piece of muscle tissue was cut from each of the collected fish individuals and stored in a sterile 1.5 ml tube containing 98% alcohol for molecular work in the lab (Plates 7 to 9).

Table 1. List of the commercially important marine fish species selected for genetic stock assessment in the present study

Sl. No.	Local Name	English Name	Scientific Name
1.	রূপচান্দা (Rupchanda)	Chinese pomfret	*Pampus chinensis*
2.	ফলি চান্দা (Foli chanda)	Silver pomfret	*Pampus argenteus*
3.	ফাসা (Fasha)	Gangetic hairfin anchovy	*Setipinna tenuifilis*
4.	তুলার ডান্ডি (Tular dandi)	Flathead sillago	*Sillaginopsis panijus*
5.	তাপসী (Taposhi, Topshe)	Paradise threadfin	*Polynemus paradiseus*
6.	অলুয়া (Olua)	Gold-spotted grenadier anchovy	*Coilia dussumieri*
7.	বোম মাইট্যা (Bom maitta)	Kawakawa	*Euthynnus affinis*
8.	টুনা (Tuna)	Frigate tuna	*Auxis thazard*
9.	কাউয়া (Kawa)	Torpedo scad	*Megalaspis cordyla*
10.	কোরাল (Koral)	Seabass	*Lates calcarifer*

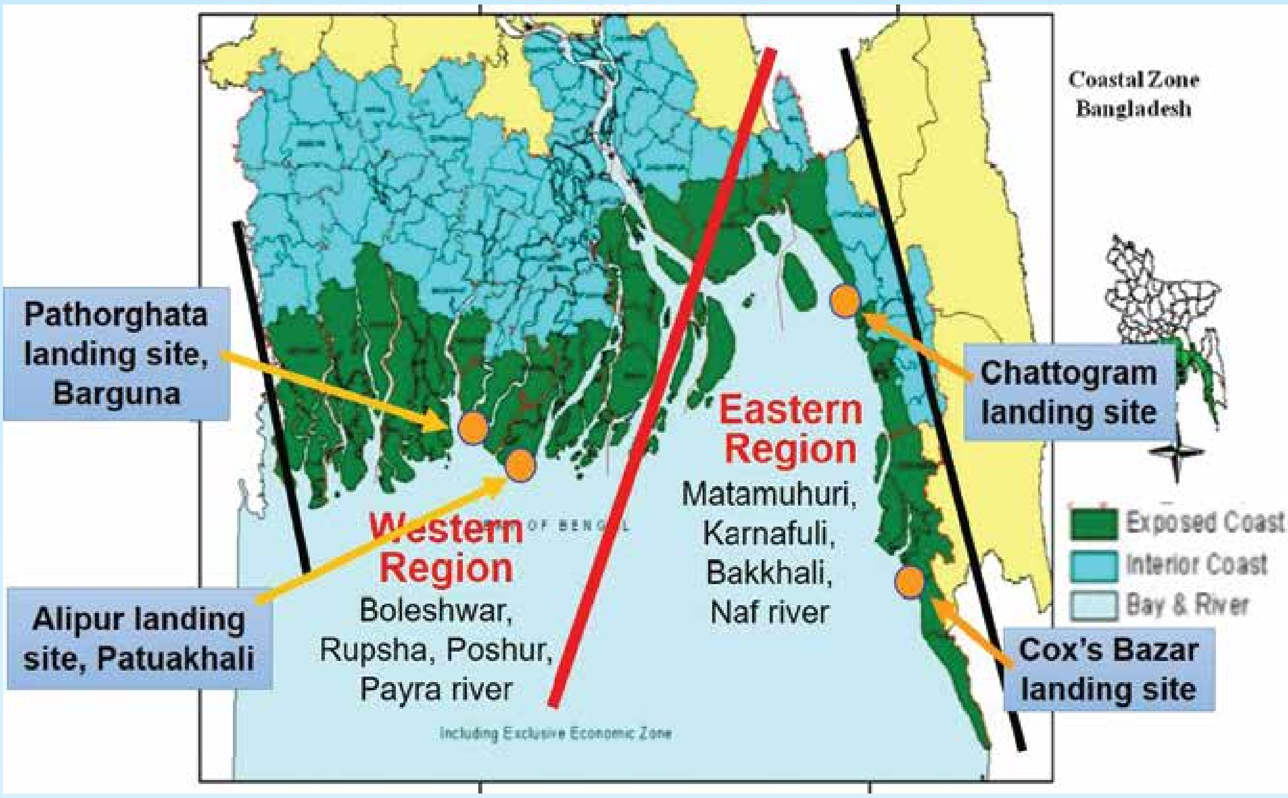
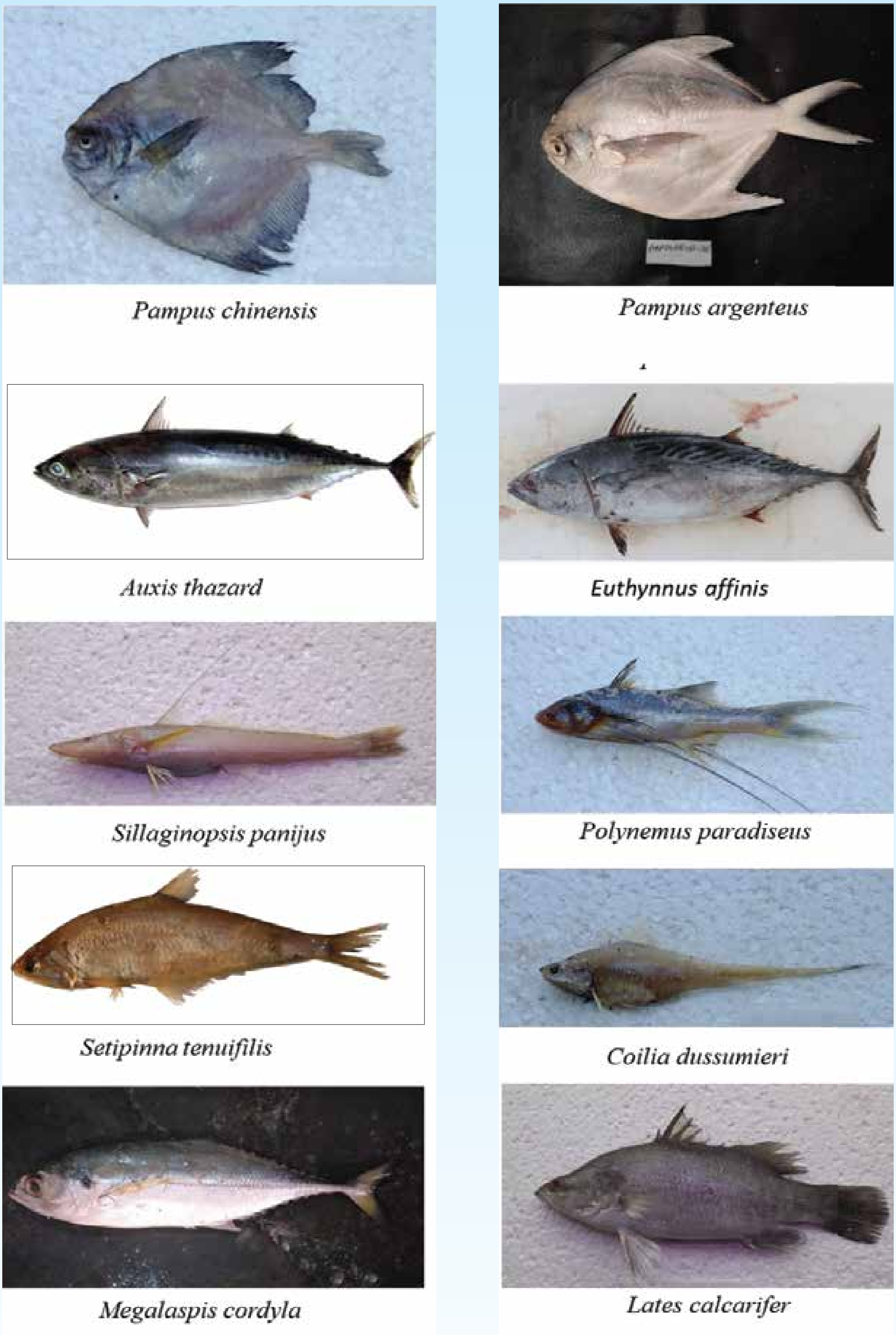


Fig 2. Locations of two major ecological regions of Bangladesh coast and respective coastal and river areas, and landing stations (Pathorghata, Barguna; Alipur, Patuakhali; Chattogram and Cox's Bazar) from where fish samples were collected in the present study

Fig 3. Different seas in the Indian Ocean or South-West Pacific regions from where fish samples or genetic data were collected for genetic stock assessment of the selected fishes of the BoB



Plates 4. Marine fish species selected for genetic stock (population) assessment in the present study










Plates 5. Sample collection from different landing centers

Plates 6. Sample collection from coastal rivers and estuaries

10.3.2. Specieswise genetic stock assessment of the selected commercially important marine fish species

11.3.2.1. Sampling information on genetic stock assessment of *P chinensis* in BoB, BD & other sea area

The fish species *P chinensis* (Chinese pomfret or Rupchanda) is distributed to Indo-West Pacific: Persian Gulf to eastern Indonesia, north to Japan. This fish occurs seasonally singly or in small schools over muddy bottoms; may enter estuaries. We collected 92 samples from two ecological regions of the coastal area of the BoB (BoB), Bangladesh. Besides, for comparing the Bangladeshi populations of the BoB with other marine areas, mtDNA D-loop sequences of 84 samples from 4 regions viz. Sonmiani and Omara of Pakistan in Arabian Sea (ArS); Beihai, and Xiamen of China in South China Sea (SCS) (Fig 4 and Table 2) were collected and analyzed.

Fig 4. Sampling location of *P. chinensis* in the present study

Table 2. Sampling information for *P. chinensis* used in the present study

Sampling regions	Sampling Locality (Population ID)	Sampling size (N)	Colour code
Bay of Bangal (BoB)	Kuakata and Pathorghata (KP)	40	
	Chattogram and Cox's Bazar (CC)	52	
Arabian Sea (ARS)	Sonmiani (Son)	17	
	Omara (Om)	20	
South China Sea (SCS)	Beihai (Bei)	24	
	Xiamen (Xia)	23	

10.3.2.2. Sampling information on genetic stock assessment of *P argenteus* in BoB, BD & other sea areas

The species *P argenteus* (Silver pomfret or Foli chanda) is distributed to Indo-West Pacific: Persian Gulf to Indonesia, north to Hokkaido, Japan. It occurs seasonally singly or in small schools over muddy bottoms; may enter estuaries. A total of 75 samples were collected from the two coastal sites of the BoB, Bangladesh. For comparing Bangladeshi samples (i.e. BoB, BoB) with other seas, mtDNA d-loop sequences of 165 samples from 8 populations of 6 marine regions [Myanmar population (MM) of Andaman Sea (AnS), Thailand population (TH) of Gulf of Thailand (GoT), India (IN) and Pakistan (PK) of Arabian Sea (ArS), Kuwait (KT) of Persian Gulf (PsG) and China (CH) of South China Sea (ScS); (Fig. 5)] were collected and analyzed. The details of the sampling information are given in Table 3.

Fig 5. Sampling location of *P argenteus* in the present study

Table 3. Sampling information for *P argenteus* used the present study.

Seas	Location name	Sample size	Color code
BoB (BoB)	Kuakata-Pathorghata (KP)	36	
	Chattogram-Cox's Bazar (CC)	39	
South China Sea (ScS)	Qionghai, China (CH)	22	
Gulf of Thailand (GoT)	Ngao, Thailand (TH)	30	
Andaman Sea (AnS)	Khindan, Myanmar (MM)	30	
Arabian Sea (ArS)	Mumbai, India (IN)	30	
	Karachi, Pakistan (PK)	30	
Persian Gulf (PsG)	Kuwait (KT)	23	
	Total	**240**	

10.3.2.3. Sampling information on genetic stock assessment of *E affinis* in BoB, BD & other sea areas

E affinis (Kawakawa or Bom maitta) is a marine, pelagic-neritic and oceanodromous species. It is distributed to Indo-West Pacific: in warm waters including oceanic islands and archipelagos. It is a highly migratory species. A total of 106 samples were collected from two locations, Kuakata-Pathorghata (KP) and Chattogram-Cox's Bazar (CC), located on the South-west and South-east coast Bangladesh, respectively in the northern BoB. For the other populations of Southern BoB (Pondicherry: PO and Vizag: VI) and Arabian Sea (Veraval: VE, Ratnagiri: RA, Kochi: KO, Kavaratti: KA and Tuticorin: TU) 150 sequences of mtDNA D-loop regions were collected. The details of the sampling localities, sample size and collection time are given in Fig 6 and Table 4.

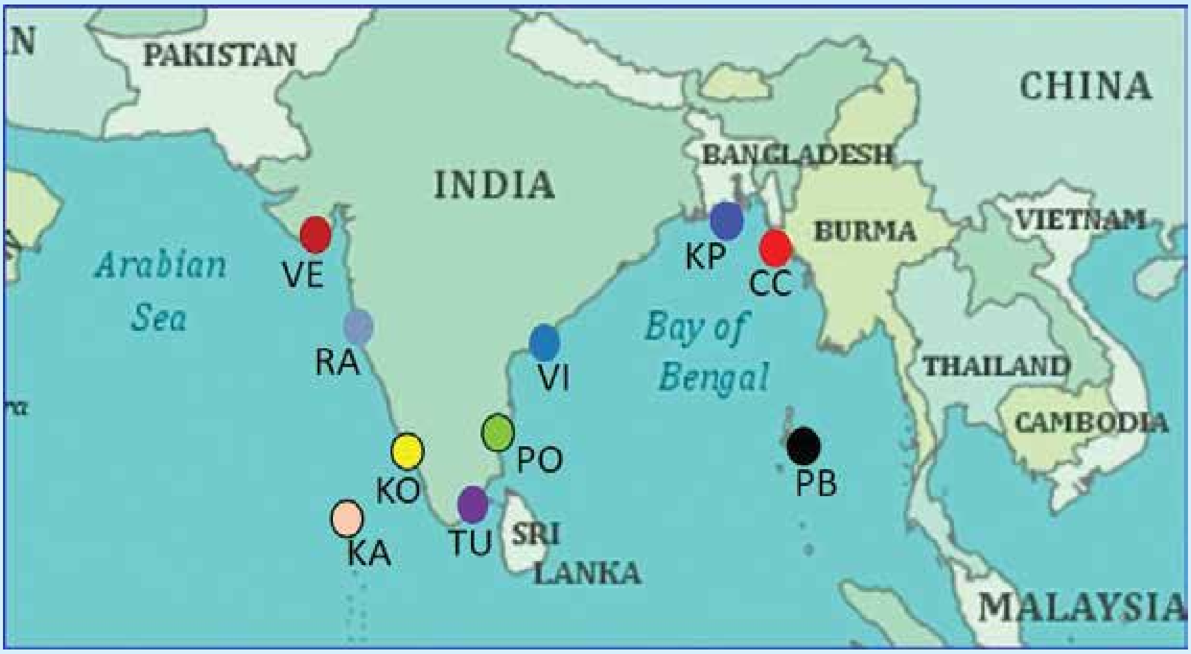


Fig 6. Sampling location of *E affinis* in the present study

Table 4. Sampling information for *E affinisi* used in the present study

Sampling regions	Population (ID)	Sampling size (N)
BoB	Kuakata-Pathorghata (KP)	54
	Chattogram-Cox's Bazar (CC)	52
	Pondicherry (PO)	50
	Vizag (VI)	50
Arabian Sea (AS)	Veraval (VE)	50
	Ratnagiri (RA)	50
	Kochi (KO)	50
	Kavaratti (KA)	50
	Tuticorin (TU)	50
Andaman Sea (AnS)	Port-Blair (PB)	50

10.3.2.4. Sampling information on genetic stock assessment of *A thazard* in BoB, BD & other sea areas

The fish *A thazard* (Frigate tuna or Tuna) is a marine, pelagic-neritic and oceanodromous species. It is distributed to Atlantic, Indian and Pacific (Western Central) ocean region. It is a highly migratory species. Fish samples of *A. thazard* and its mtDNA d-loop sequence data were collected from five localities over its range of distribution including Patharghata (PG) and Cox's Bazar (CB) of the northern BoB, Bangladesh; Pondicherry (PO) and Vizag (VI) of Southern BoB; Veraval (VE), Ratnagiri (RA), Kochi (KO), Kavaratti (KA), Tuticorin (TU) of Arabian Sea; & Port-Blair (PB) of Andaman Sea (Fig 7 & Table 5).

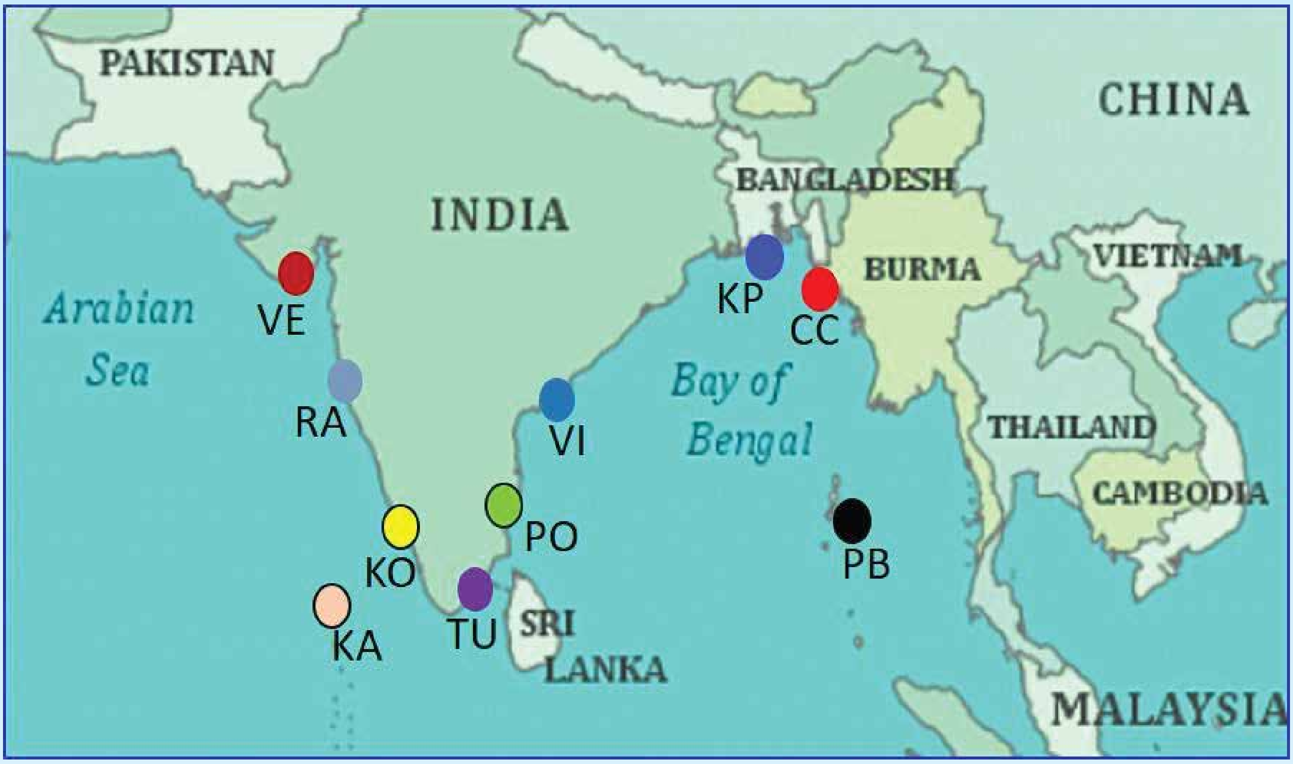


Fig 7. Sampling location of *A thazard* in the present study

Table 5. Sampling information for *A thazard* used in the present study

Sampling regions	Population (ID)	Sample size (N)
Arabian Sea	Verava (VE)	50
	Ratnagiri (RA)	47
	Kochi (KO)	45
	Kavaratti (KA)	50
	Tuticorin (TU)	50
Andaman Sea	Port-Blair (PB)	8
Bay of Bengal	Pondicherry (PO)	49
	Vizag (VI)	50
	Coxs Bazar (CB)	48
	Pathorghata (PG)	46
	Total	**443**

10.3.2.5. Sampling information on genetic stock assessment of *M cordyla* in BoB, BD & other sea areas

M cordyla (Torpedo scad or Kawa) is a brackish, marine and oceanic species. It is distributed to Indo-West Pacific: East Africa to Japan and Australia. Adults are primarily oceanic, pelagic schooling species rarely seen on reefs. A total of 100 samples of *M. cordyla* were collected from two locations of Bangladesh coast viz. Cox's Bazar (CB) and Kuakata (KK) of the BoB (BoB). For comparing population genetic structure of the populations of Bangladesh as well as the BoB with other seas, mtDNA COI sequences of 73 fish samples were collected from 5 different seas' populations namely Sulu Sea (SS), South China Sea (SCS), Arabian Sea (AS), Persian Gulf (PG) and Western Indian Ocean (WIO) (Fig 8 and Table6).

Fig 8. Sampling location of *M. cordyla* in the present study

Table 6. Sampling information for *M cordyla* in the present study

Sea area	Population (ID)	Sample size (N)
BoB	Kuakata (KK)	61
	Cox's Bazar (CB)	39
South China Sea	South China Sea (SCS)	44
Sulu Sea	Sulu Sea (SS)	14
Arabian Sea	Arabian Sea (AS)	5
Persian Gulf	Persian Gulf (PG)	4
Western Indian Ocean	Western Indian Ocean (WIO)	6
	Total	**173**

10.3.2.6. Sampling information on genetic stock assessment of *L calcarifer* in BoB, BD & other seas areas

The fish *L calcarifer* (Seabass or Koral) is basically a marine and brackish water species. It is demersal and catadromous in nature. It is distributed to Indo-West Pacific: eastern edge of the Persian Gulf to China, southern Japan, southward to southern Papua New Guinea and northern Australia. This species is a diadromous fish, inhabiting coastal rivers before returning to the estuaries for spawning. A total of 56 samples of *L. calcarifer* were collected from the coastal district Shatkhira (SK) and Cox's Bazar region of Bangladesh (i.e. northern BoB). Besides, mtDNA cytb sequences (307 bp) of 52 samples from Malay peninsula (MP) were collected. The details of the sampling localities, Sample size and collection time are given in Fig 9 & Table 7.

Fig 9. Sampling location of *L. calcarifer* in the present study

Table 7. Sampling information for *L. calcarifer* in the present study.

Seas	Population (ID)	Sampling size (N)	Color
BoB	**Satkhira (SK)**	**42**	Red
	Cox's Bazar	**42**	Green
Straits of Malacca		**13**	Yellow
South China Sea		**19**	Blue

10.3.2.7. Sampling information on genetic stock assessment of *S tenuifilis* in BoB, BD

The fish *S tenuifilis* (Gangetic hairfin anchovy or Fasha) lives in marine and brackish water. It is also found sometimes in freshwater river near to coast. It is a pelagic-neritic and amphidromous species. It is distributed to Eastern Indian Ocean: northern and eastern BoB coasts, including the Andaman Islands. A total of 84 samples were collected from two different locations of Bangladesh coast: Bishkhali river of Kuakata region (45 individuals) and Matamuhuri river of Chattogram-Cox's Bazar region (84 individuals) of the BoB (Table 8 and Fig. 10).

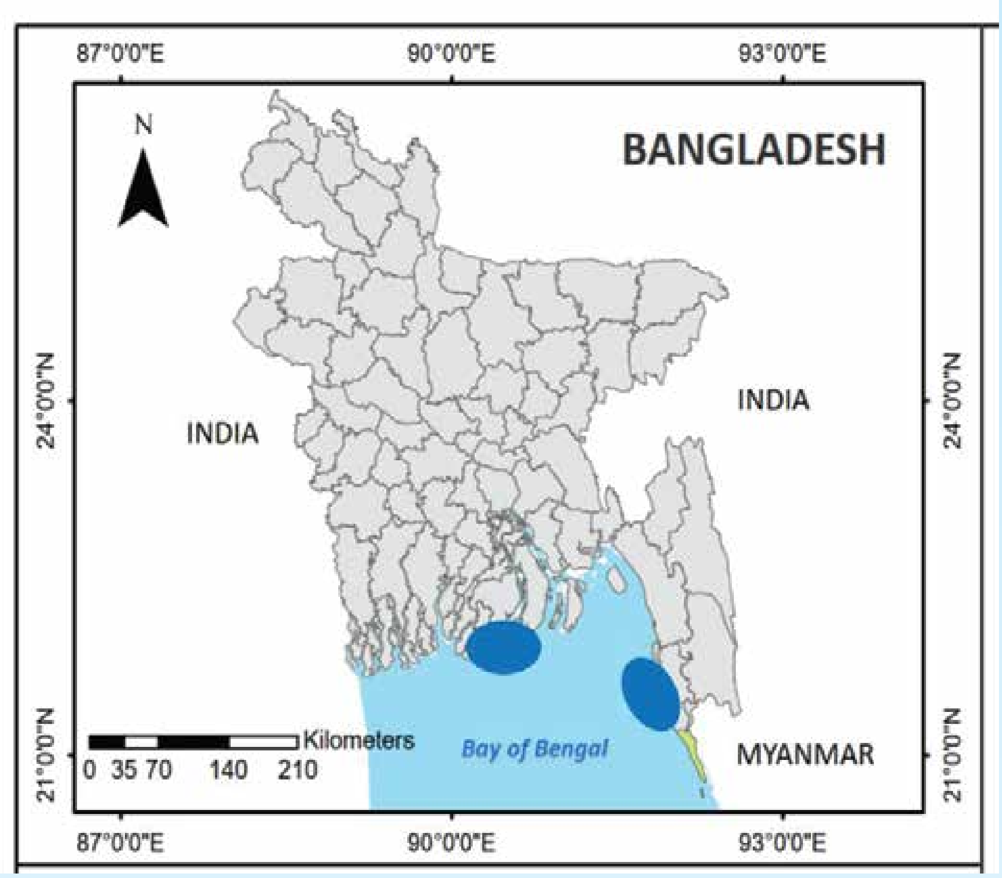


Fig 10. Sampling location of *S. tenuifilis* in the present study

Table 8. Sampling information for *S tenuifilis* in the present study.

Sampling regions	Population (ID)	Sampling size (N)
Northern BoB (BoB)	Bishkhali river (BK)	45
	Matamuhuri river (MR)	39
	Total	**84**

10.3.2.8. Sampling information on genetic stock assessment of *S panijus* in BoB, BD

The fish *S panjius* (Flathead sillago or Tular dandi) lives in marine and brackishwater environment. It is a demersal and amphidromous species. This species is distributed to Eastern Indian Ocean: Ganges delta and Myanmar. This species is found in shallow, open muddy bays and estuaries. Spawn twice a year during the months of November to February and August to September and the juveniles migrate toward the upper reaches during March and April and during December where they remain for 2 to 3 months. We collected 130 samples from two coastal regions (mouths of Bishkhali river and Baleshwar River and Meghna River) of the BoB, Bangladesh (Fig 11). The details of the sampling information (sampling localities, number of collected samples) are given in Table 9.

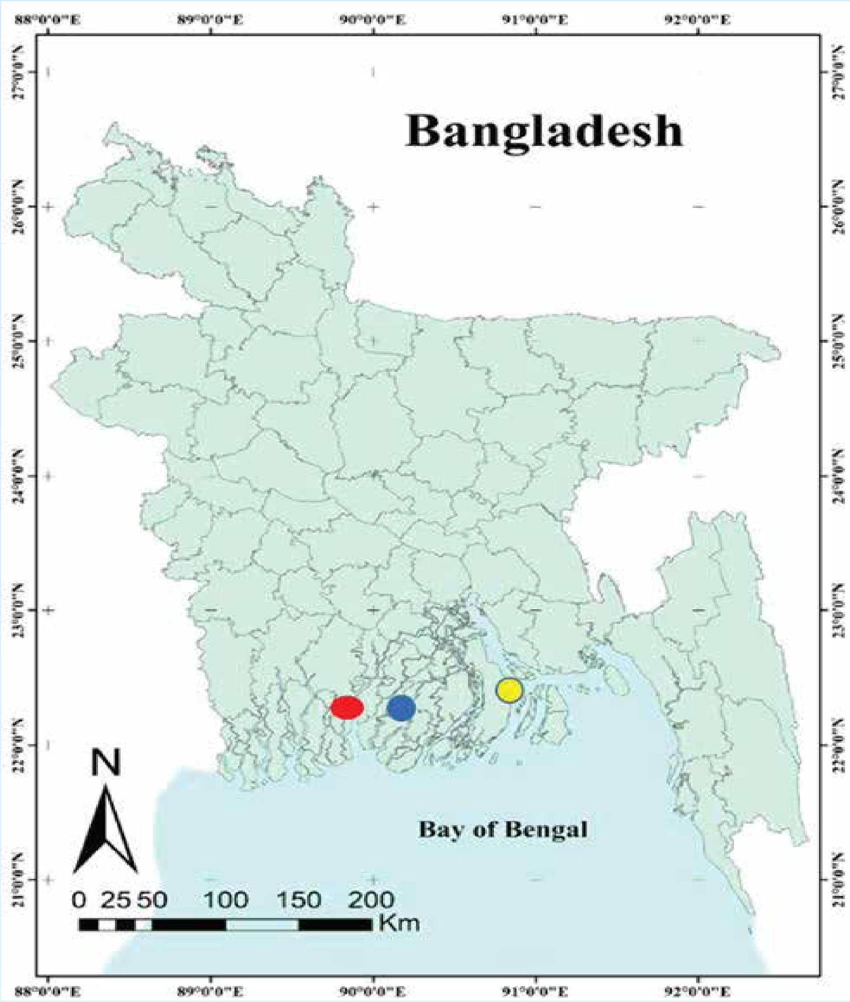


Fig 11. Sampling location of *S. panijus* in the present study

Table 9. Sampling information for *S. panijus* in the present study.

Sampling regions	Population (ID)	Sampling size (N)	Color
BoB (BoB)	Bishkhali river (BK)	50	
	Baleshwar river (BR)	42	
	Meghna river (MR)	38	
	Total	**130**	

10.3.2.9. Sampling information on genetic stock assessment of *P paradiseus* in BoB, BD

The fish *P paradiseus* (Paradise threadfin or Taposhi/ topshe) is a marine and brackishwater species. It is demersal and amphidromous. It is distributed to Eastern Indian Ocean and Western Pacific: west coast of India to Thailand. This species lives over sandy bottoms, regularly entering freshwaters during breeding season. We have collected a total of 174 samples from four coastal regions, Karnofuli (KF), Kirtonkhola (KK), Bishkhali river (BK) and Baleshwar River (BR) of the BoB coast, Bangladesh (Fig 12 and, Table 10).

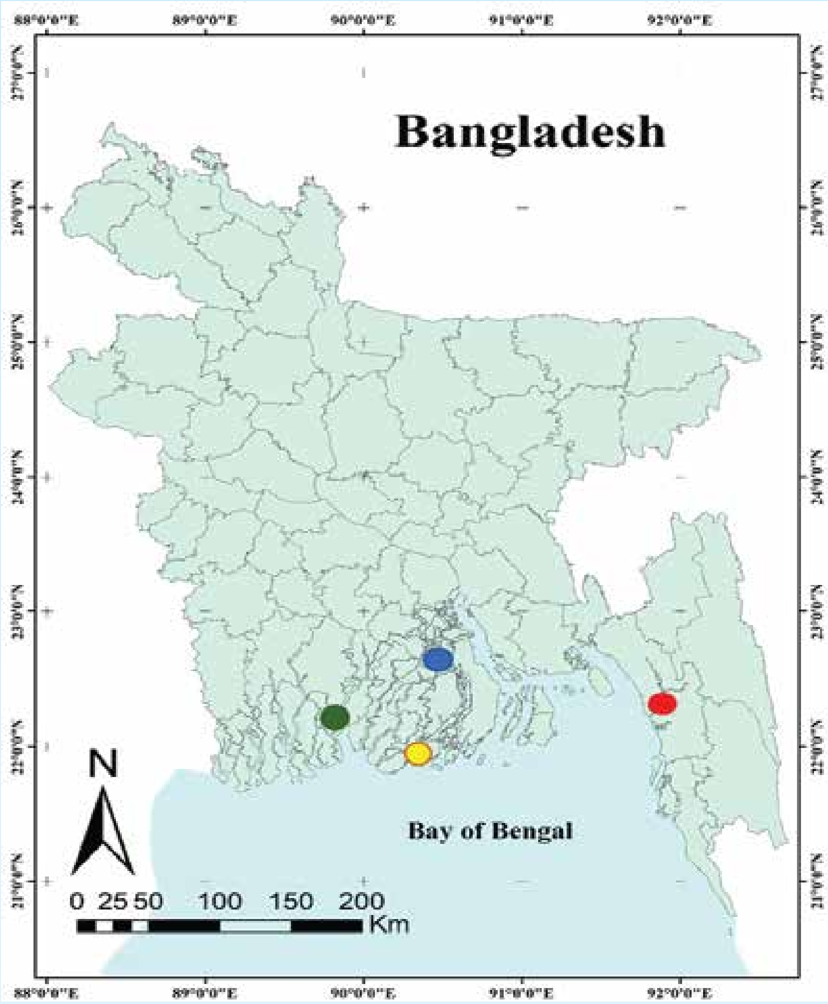


Fig 12. Sampling location of *P. paradiseus* in the present study

Table 10 Sampling information for *P. paradiseus* in the present study

Sampling regions	Population (ID)	Sampling size (N)	Color code
BoB (BoB)	Karnofuli river (KF)	40	
	Kirtonkhola river (KK)	60	
	Bishkhali river (BK)	38	
	Baleshwar river (BS)	36	
	Total	**174**	

10.3.2.10. Sampling information on genetic stock assessment of *C dussumieri* in BoB, BD & other seas

The species *C dussumieri* (Gold spotted grenadier anchovy or Olua) is found in marine and brackish water environment. It is pelagic-neritic and amphidromous in nature. This species is distributed to Indian Ocean, mainly in Indian coast, from Bombay to Bangladesh. And, rarely found in Myanmar and Thailand. A total of 108 individuals of *C. dussumieri* were collected from two populations i.e Pasur river estuary (PR) and Naf river (NR) of Bangladesh. For comparing the populations of Bangladesh (i.e., Nort BoB) with other populations of different regions, 42 samples from Gujarat (GUJ), West Bengal (WB), Maharashtra (MAH), and Andhra Pradesh (AP) were collected. The details of the sampling information are given in Table 11 & Fig 13.

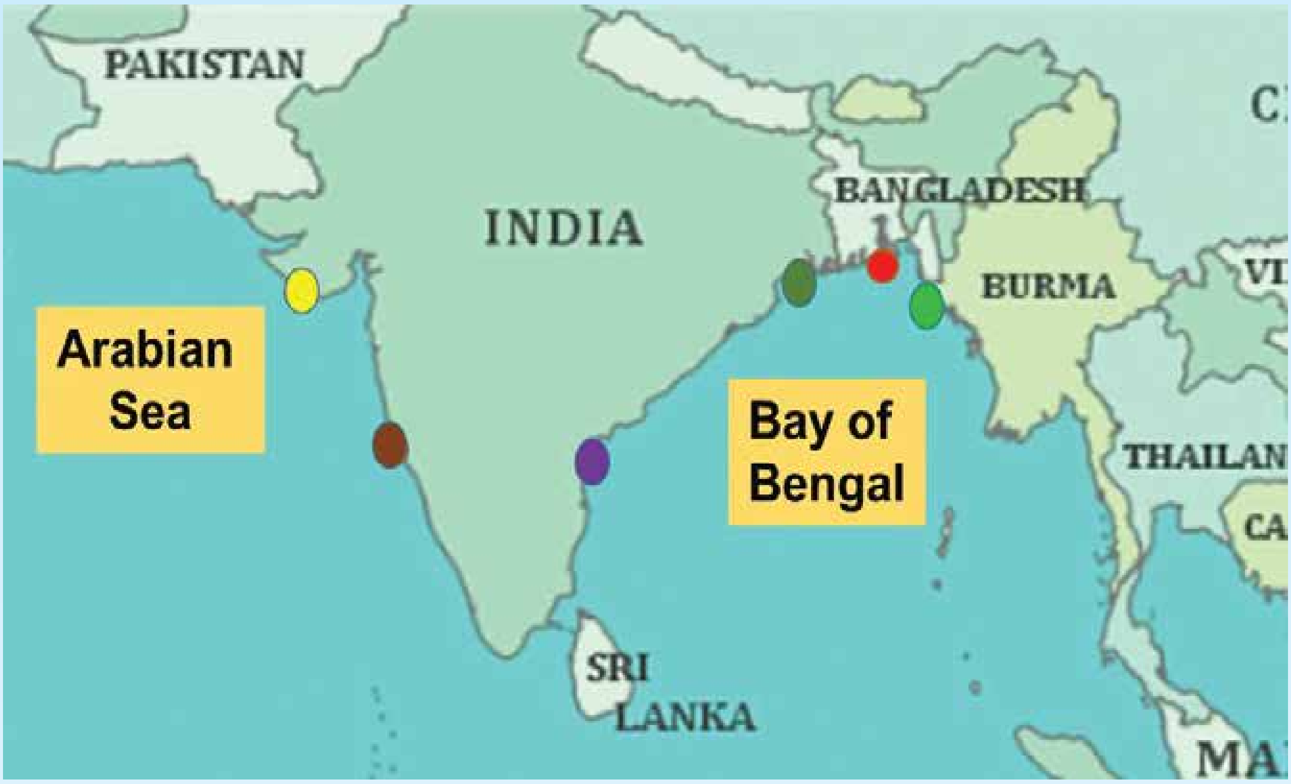


Fig 13. Sampling location of *C. dussumieri* in the present study

Table 11. Sampling information for *C. dussumieri* in the present study.

Seas	Population	Sample size	color
BoB (BoB)	Pasur river estuary (PR)	50	red
	Naf river (NR)	58	green
	West Bengal (WB)	12	dark green
	Andhra Pradesh (AP)	06	purple
Arabian Sea	Maharashtra (MAH)	11	brown
	Gujarat (GUJ)	13	yellow
		150	

10.3.3. Morphological identification and DNA barcoding

Before genetic stock (i.e. population genetic structure) assessment of ten selected species (viz. *Auxis thazard, Coilia dussumieri, Euthynnus affinis, Lates calcarifer, Megalaspis cordyla, Pampus chinensis, Pampus argenteus, Polynemus paradiseus, Setipinna tenuifilis, Sillaginopsis panijus*), 3 to 5 individuals of each species were collected and assured their taxonomic identification status through morphological study and DNA barcoding. This was done since some of these species are closely resembled with their sister species. For example, the genus *Coilia*, *Sillaginopsis* and *Setipinna* have two or more species which are very confusing to identify accurately due to similar appearance. The morphological diagnosis (meristic counts and proportional measurements) of collected specimens were performed according to Talwar and Kacker (1984), Carpenter and Niem (1999a, 1999b, 2001a, 2001b), Allen et al. (2003), Rahman et al. (2009); Smith and Heemstra (2012); Nelson et al. (2016); Psomadakis et al. (2019) and Froese & Pauly (2021). Then the morphological identification of each species was further validated by DNA barcoding tool. For species confirmation by DNA barcoding, we used the mitochondrial COI gene. For analysis of the sequences of DNA barcodes and species confirmation, BLAST search in NCBI was used along with phylogenetic analysis and genetic distance measurement. After confirmation and getting confidence on the accurate identification, genetic stock assement (i.e. population genetic study) was conducted.

Plates 7. Receiving and initial processing of samples in the Laboratory

Plates 8. Samples of different species in the Laboratory

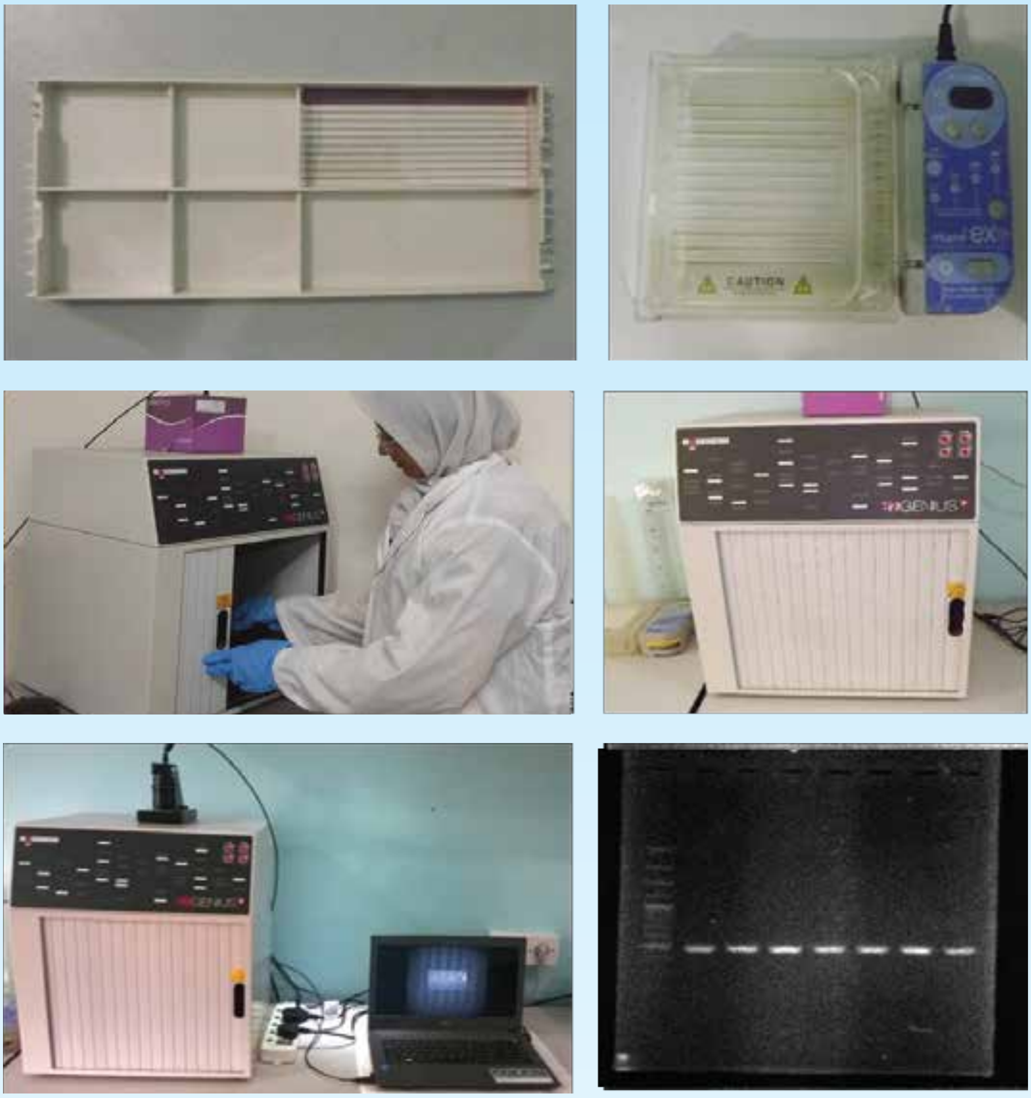
Plate 9. Collection of tissue samples from fish specimens

10.3.4. Genomic DNA extraction, PCR amplification and sequencing

Genomic DNA was extracted from the muscle tissues of collected samples using QIAGEN Blood and Tissue kit following the provided protocol given inside the kit box (Plates 10). Polymerase chain reaction (PCR) was performed in a total volume of 25 µl, including 16.25 µl ultrapure water, 2.25 µl 10X PCR buffer, 1.25mM$MgCl_2$, each dNTP at 0.2 mM, each primer at 2 mM, 1.25 U Taq DNA polymerase and 1 µl DNA template. Taq DNA polymerase was added just before the start of the reaction. Then the PCR tubes containing the PCR mixture were transferred to PCR thermal cycler for the amplification of the reaction. The information on primer sets and PCR conditions (thermocycler profile) used for amplifying the desired gene region of the mitochondrial DNA of respective fish species has been given in the Table 12.

Amplified PCR products were separated on 1% agarose gel (Invitrogen, USA) stained with ethidium bromide in a gel documentation system (Model: Syngene InGenius^3) (Plates 11& Fig 4). PCR products with a clear single band were purified with QIANGEN-Universal DNA Purification Kit following the protocol provided inside the kit box. After measuring concentration, the amplified PCR products were sent to Macrogen Inc., Seoul, South Korea for sequencing via a native commercial DNA sequencing service company. Sequencing was conducted with the same PCR primers by the Sanger method with an automated sequencer (ABI 3730x1 DNA analyzer) at Macrogen Inc. (Korea). The sequencing results were received by email.

Plates 10. Extraction of genomic DNA



Plates 11. Gel electrophoresis and documentation

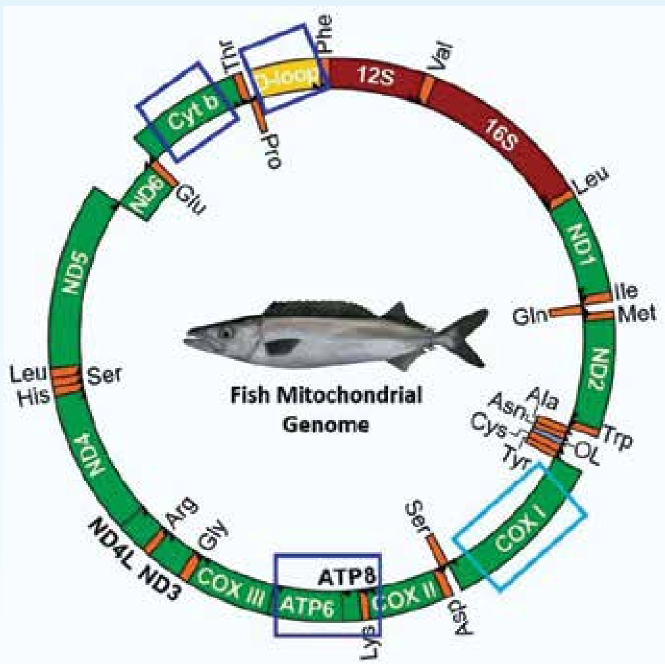


Fig 14. Fish mitochondrial genome & gene regions used in this study

Table 12. Information on the primers used for amplification of desired gene regions

Name of fish species	Gene region	Primer sequence (5' – 3')	Thermocycler profile
All fish species (for identification)	COI	FishF1: TCAACCAACCACAA AGACATTGGCAC FishR1: TAGACTTCTGGGTG GCCAAAGAATCA	Initial denaturation at 94 °C for 2 min, 35 cycles of 94 °C for 30 s, 52 °C for 40 s, and 72 °C for 1 min, with a final extension at 72 °C for 10 min.
A thazard	mtDNA D-loop	Forward: CCGGACGTCGGAGG TTAAAAT Reverse: AGGAACCAAATGCC AGGAATA	Initial denaturation at 95 °C for 5 min; 30 cycles of 1 min at 94°C for denaturation,1 min at 55 °C for annealing, and 1 min at 72 °C for extension; and a final extension at 72 °C for 5 min.
C dussumieri	mtDNA ATP 6/8	ATP8 2L8331: AAAGCRTYRGCCTT TTAAGC COIII 2H9236: GTTAGTGGTCAKGG GCTTGGRTC	Initial denaturation at 95 °C for 5 min followed by 30 cycles of 30s at 95°C for denaturation, 30s at 55 °C for annealing, and 1 min at 72 °C for extension; and a final extension at 72 °C for 10 min.
E affinis	mtDNA D-loop	Forward: CCGGACGTCGGAGG TTAAAAT Reverse: AGGAACCAAATGCC AGGAATA	Initial denaturation at 95 °C for 5 min; 30 cycles of 1 min at 94°C for denaturation,1 min at 55 °C for annealing, and 1 min at 72 °C for extension; and a final extension at 72 °C for 5 min.
L calcarifer	mtDNA D-loop	L14841: AAAAAGCTTCCATC CAACATCTCAGCAT GATGAAA H15149: AAACTGCAGCCCCT CAGAATGATATTTG TCCTCA	Initial denaturation at 98 °C for 1 min; 35 cycles of 1 min at 95°C for denaturation,1 min at 52 °C for annealing, and 1 min at 72 °C for extension; and a final extension at 72 °C for 10 min.
M cordyla	mtDNA COI	FF2d: TTCTCCACCAACCA CAARGAYATYGG FR1d: CACCTCAGGGTGTC CGAARAAYCARAA	Initial denaturation at 94 °C for 2 min, 35 cycles of 94 °C for 30 s, 52 °C for 40 s, and 72 °C for 1 min, with a final extension at 72 °C for 10 min.
P chinensis	mtDNA D-loop	F-gao: AAGTTAAAATCTTC CCTTTTGC R-gao: GGCCCTGAAGTAGG AACCAAA	Initial denaturation at 95 °C for 5 min; 30 cycles of 45 s at 94°C for denaturation, 45 s at 50 °C for annealing, and 45 s at 72 °C for extension; and a final extension at 72 °C for 10min.

P argenteus	mtDNA D-loop	L15926: TCAAAGCTTACACC AGTCTTGTAAACC H16498: CCTGAAGTAGGAAC CAGATG	Initial denaturation at 94° C for 4 min followed by 35 thermal cycles of denaturation at 94°C for 1 min, annealing at 55°C for 1 min, and extension at 72°C for 1 min 30 s. A final extension was performed at 72°C for 8 min
P paradesius	mtDNA D-loop	PpF2: GAGCGCCGGTCTTG TAAAC PpR2 AAAGAGGTCCAGGT GAAAGAC	Initial denaturation at 95 °C for 2 min; 35 cycles of 40s at 94°C for denaturation,40s at 55 °C for annealing, and 1 min at 72 °C for extension; and a final extension at 72 °C for 10 min.
S tenuifilis	mtDNA D-loop	F: CACCCYTRRCTCCC AAAGCYA R: GGAACACCGAGTA ATGCTGAG	Initial denaturation at 94 °C for 5 min; 30 cycles of 45 s at 94°C for denaturation,45 s at 53°C for annealing, and 45 s at 72 °C for extension; and a final extension at 72 °C for 10 min.
S panijus	mtDNA Cytb	SpF2: GCTAACGACGCACT AGTTGA SpR2: GAATGTCAGGCTTC GCTGTT	Initial denaturation at 95 °C for 2 min; 30 cycles of 40 s at 94°C for denaturation,40 s at 54 °C for annealing, and 1 min at 72 °C for extension; and a final extension at 72 °C for 10min.

10.3.5 Data analysis

10.3.5.1 Sequence editing

The received DNA sequences were edited using the Software Geneious 9.1.5 (Kearse *et al.* 2012) and Chromas Lit (Technelysium 2012)

10.3.5.2 Genetic diversity and population genetic structure analysis

The sequence data were edited and aligned with ClustalW (Thompson *et al.* 1994) and DNAssist 2.5 (Patterton and Graves 2000). Molecular diversity indices such as haplotype diversity (*h*), nucleotide diversity (π), the average number of nucleotide differences (k), number of haplotypes (N_h), polymorphic sites (S), transitions (ti), and transversions (tv) for each population were obtained using the program ARLEQUIN (version 3.11, Schneider *et al.* 2000). Pairwise genetic variation and structure between sampled populations were assessed using fixation index (F_{ST}) (Excoffier *et al.* 1992). The statistical significance of the estimates was assessed by 10,000 permutations. The null hypothesis of population panmixia was also tested by the exact test of haplotype differentiation among samples (Raymond and Rousset, 1995).

10.3.5.3 Haplotype network construction

Genealogical relationship among haplotypes for mtDNA gene region was assessed by generating the network of haplotypes using a statistical parsimony method TCS 1.18 (Clement *et al.* 2000).

10.3.5.4 Phylogenetic analysis

Phylogenetic relationship among the haplotypes was reconstructed using the neighbor-joining method implemented in MEGA 6. The genetic distances were estimated following the suitable model which was suggested as the best fit model for the used sequences of respective fish species. Robustness of the phylogenetic relationships was evaluated by bootstrap analysis with 1000 replications.

10.3.5.5 Assessment of demographic history by neutrality test

Genetic signature of population demography was investigated by Tajima's D statistics (Tajima 1989) and Fu's F_S test (Fu 1997) for selective neutrality implemented in ARLEQIN.

11. Results and discussion

11.1 Component 1(RU)

11.1.1 Finding out the fish stocks through morphometric, meristic characteristics and then to estimate the size at sexual maturity, age at sexual maturity, spawning- and peak-spawning season of fishes through multiple functions for the justification of fishing-ban period in the BoB.

11.1.1.1 Find out the fish stocks through morphometric and meristic characteristics

The present study was conducted in the BoB, Bangladesh covering Khulna region (Khulna), Barishal region (Barguna & Patuakhali), Chattogram and Cox's Bazar (Cox's Bazar, Saint Martin) regions (Plate 1). At least 300 marine fish were regularly observed in the landing centers, fish market and fishing boats during sampling during October 2019 to March 2022. To determine the actual number of marine fishes of Bangladesh, we have made a checklist reviewing the valid publications and literature covering about a 50-year span from 1970 to 2020 along with our observation which revealed that the country has a total of 740 marine fish species in its marine environment (Annexure RU: 1.), Fig15 and Plate 12.

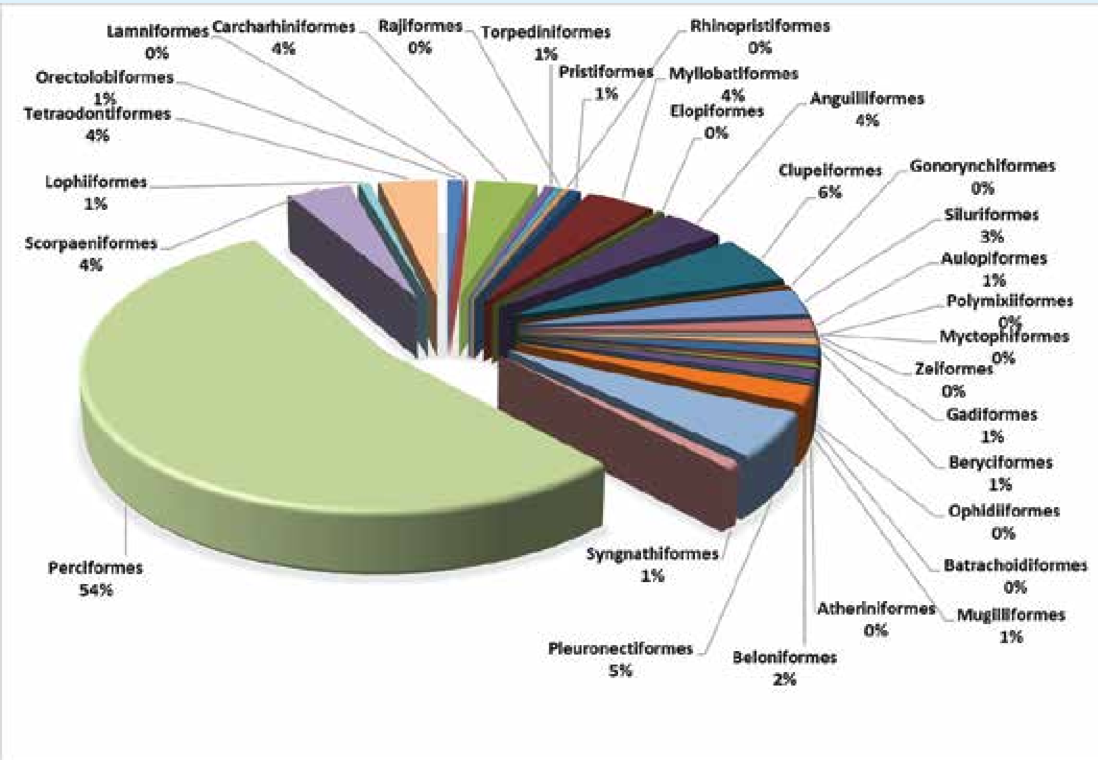


Fig 15. Order wise fish species composition in the BoB.

Hussain et al. (1970) published a list of estuarine and marine fishes in Bangladesh which lasted about 475 species belonging to 133 families after 5 years of field investigation in BoB. An exhausted list of marine fishes of Bangladesh was appeared this publication. Quddus and Shafi (1983) listed 170 species of marine fishes including 149 bony fishes and 21 cartilaginous fishes. Rahman et al. (2009) recorded 402 marine fish species from Bangladesh of which 51 species were cartilaginous including 22 sharks (zebra sharks, carpet sharks, hammerhead sharks, hound sharks, whale etc.), 19 species are rays (sting rays, butterfly rays, devil rays, eagle rays etc.) under 5 families, electric rays including 3 species, guitarfishes including 4 species, saw fishes including 3 species. Haroon et al. (2011) revealed that in Bangladesh a total of 71 species of sharks, rays and skates are available of which 31 species of sharks, 6 species of skates, 4 species of saw fishes, 25 species of rays. Hoq et al. (2014) a total of 69 species of elasmobranch of which 30 species of sharks and 39 species of rays were so far recorded from Bangladesh waters but no skates and chimaerids are found.

Fanning et al. (2019) listed 343 marine fish species in a report 'Marine fisheries survey reports and stock assessment 2019' published by Department of Fisheries (DoF), Bangladesh. This report has also included 14 species of cephalopods (squids, cuttle fishes & octopuses); 45 species of shrimps, crabs & lobsters. Additionally, 50 fish specimens have been identified up to genus level, making the total up to 457 varieties. Habib and Islam (2021) have been accumulated and presented the distribution of marine fish species in the coastal and marine water of Bangladesh. A total of 740 species of fishes of 389 genera, 145 families under 30 orders have been compiled. Among these enlisted fish, cartilaginous fishes (Chondrichthyes: sharks, skates and rays) contain 81 species of 42 Genera and 17 Families under 8 Orders, whereas 659 bony fishes (Osteichthyes) cover 347 genera, 128 families and 22 orders. More than half of the total species (398) were recorded from the Order Perciformes.

Haroon and Kibria (2021) confirmed 82 species of sharks, skates and rays are available in Bangladesh waters. Out of 82 shark species, several species listed under the category of critically endangered (09 species), endangered (06 species), vulnerable (12 species), near threatened (17 species), least concerned (20 species) and no conservation status (18 species). Haque et al. (2021) worked on elasmobranch products trade and expressed their opinion that this circum-global practice negatively impacting elasmobranch populations. Although Asia is at the center of the shark fin trade, countries like Bangladesh, remain data-poor regarding trade dynamics. In this study around 70 species have been recorded and so on.

Ahmed et al. (2021) generated 376 mitochondrial COI barcode sequences from 185 species belonging to 146 genera, 74 families, 21 orders and two classes of marine fishes. Among them 21 species were elasmobranch belonging to 5 order, 8 families, 13 genera where one species was listed as critically endangered, four as endangered, four vulnerable, six as near threatened. Wildlife Conservation Society (WCS) has confirmed 39 sharks and 59 rays in Bangladesh territory (WCS report, 2021; pers.com) and the potential availability of 13 additional shark and ray species. Of the total sharks and rays confirmed or suspected in Bangladesh, 32 sharks and 43 ray species are globally threatened.

Additionally, status of 15 commercially important marine fishes in the BoB was categorized according to IUCN Bangladesh (2015) and IUCN World-wide (2022) (Table 13 and Plate 13). Descriptive statistics on total length ad body weight of 15 commercially important marine fishes from the BoB are listed in Table 14.

Plates 12. Observation of marine fish species in landing center, commercial and hired fishing boat in the BoB, Bangladesh.

Table 13. Status of commercially important marine fishes in the BoB according to IUCN Bangladesh (2015) and IUCN World-wide (2022)

Sl. No.	Species name	English name	Bangla name	IUCN Status	
				BD	WW
1	*L calcarifer*	Sea bass/Barramundi	Vetki/Koral	NE	LC
2	*P heterolepis*	Panna croaker	Choto poa	NE	LC
3	*P chinensis*	Silver pomfert	Rup chanda	NE	NE
4	*E affinis*	Mackerel tuna	Tuna	LC	LC
5	*S taty*	Gangetic hairfin anchovy	Phasa	LC	LC
6	*S panijus*	Flathead silago	Tulardandi	LC	NE
7	*P paradiseus*	Paradise threadfin	Topshe	LC	LC
8	*M cordyla*	Torpedo scad	Kaowa	NE	LC
9	*H nehereus*	Bombay-duck	Loita	NE	NT
10	*C dussumieri*	Anchovy	Olua	LC	LC
11	*T setirostris*	Longjaw thryssa	Tush phasa	NE	LC
12	*A chacunda*	Chacunda gizzard shad	Dumbura	LC	LC
13	*I megaloptera*	Bigeye ilisha	Dhela	LC	LC
14	*P macracanthus*	Blotched tiger toothed croaker	Guti/Lal Poa	NE	LC
15	*A leiogaster*	Smooth-belly sardine	Rash	NE	LC

BD, Bangladesh; WW, worldwide; LC, least concern; NT, near threatened; NE, not evaluated

Lates calcarifer

Panna heterolepis

Pampus chinensis

Euthynnus affinis

Megalaspis cordlyla

Harpondon nehereus

Coilia dussumieri

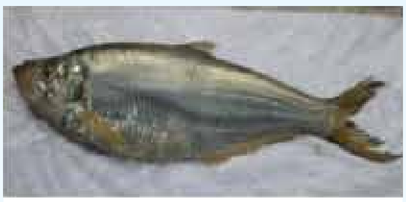
Priacanthus Macracanthus

Sillaginopsis panijus

Polynemus paradiseus

Setipinna taty

Thryssa setirostris



Anosontostoma chacunda

Ilisha megaloptera

Amblygaster leiogas.ter

Plates 13. List of 15 commercially important marine fish species in the BoB, Bangladesh.

Table 14. Descriptive statistics on total length and body weight of commercially important marine fishes from the BoB, Bangladesh

Sl. No.	Species Name	Total length (cm)				Body weight (g)			
		Min	Max	Mean ± SD	95% CL	Min	Max	Mean ± SD	95% CL
01	*L calcarifer*	51.0	105.0	83.16 ± 13.20	81.76 – 84.57	1800.0	15600.0	7645.48 ± 3342.04	7288.43 – 8002.52
02	*P heterolepis*	10.5	34.5	18.01 ± 3.26	17.83 – 18.20	9.02	342.26	47.35 ± 29.38	45.71 – 49.00
03	*P chinensis*	16.5	38.0	25.32 ± 3.54	24.94 – 25.70	24.0	268.0	101.15 ± 48.13	95.96 – 106.34
04	*E affinis*	16.0	68.0	39.64 ± 10.74	39.17 – 40.12	42.0	3554.0	867.60 ± 653.94	838.46 – 896.75
05	*S taty*	8.1	31.8	18.23 ± 4.34	18.04 – 18.42	2.59	198.7	39.38 ± 32.12	37.97 – 40.80
06	*S panijus*	11.5	39.4	20.88 ± 5.53	20.64 – 21.12	6.79	412.9	64.46 ± 63.08	61.69 – 67.23
07	*P paradiseus*	10.0	23.1	16.15 ± 2.14	16.02 – 16.27	7.0	72.39	28.61 ± 12.35	27.91 – 29.31
08	*M cordyla*	16.0	41.0	25.59 ± 5.73	25.30 – 25.88	38.0	600.0	173.94 ± 98.42	168.94 – 178.93
09	*H nehereus*	6.5	36.0	21.83 ± 4.00	21.60 – 22.06	1.28	311.0	61.95 ± 5.08	59.07 – 64.83
10	*C dussumieri*	10.0	23.6	16.11 ± 2.61	15.98 – 16.24	2.1	50.2	15.96 ± 8.71	15.53 – 16.39
11	*T setirostris*	9.0	22.0	14.39 ± 1.78	14.30 – 14.48	8.5	70.0	24.33 ± 8.23	23.89 – 24.76
12	*A chacunda*	12.5	27.0	20.34 ± 2.41	20.23 – 20.46	22.16	230.6	118.01±36.74	116.22 – 119.80
13	*I megaloptera*	11.0	37.0	23.61 ± 6.00	23.33 – 23.89	11.35	389.0	114.37 ± 73.69	110.96 – 117.78
14	*P macracanthus*	14.30	49.00	24.97 ± 4.61	22.68 - 23.26	30.00	912.80	189.02 ± 114.15	182.31 - 195.81
15	*A leiogaster*	12.60	30.50	18.48 ± 1.80	17.38 - 17.59	16.46	142.00	56.49 ± 36.58	53.58 - 55.37

11.1.1.2 Morphometric and meristic characters of commercially important marine fishes

Morphometric measurements of 15 commercially important marine fishes catched from the BoB, Bangladesh are presented in Table 15 as well as meristic features in Table16 and Plate 14. Descriptive statistics and estimated parameters of the length-weight relationships of few selected marine species are shown in Annexure RU:2.

Table 15(a). Descriptive statistics and estimated parameters of the length-weight relationships of *P heterolepis* (Bleeker, 1849) from the BoB, Bangladesh

Equation	Regression parameters		95% CL of *a*	95% CL of *b*	r^2	GT
	a	*b*				
BW= $a \times TL^b$	0.0075	3.001	0.0062 – 0.0090	2.938 – 3.063	0.978	I
BW= $a \times SL^b$	0.0193	2.927	0.0165 – 0.0226	2.868 – 2.986	0.979	A-
BW= $a \times HL^b$	0.8867	2.941	0.7606 – 1.0338	2.831 – 3.051	0.933	A-
BW= $a \times PrDL^b$	1.1359	2.743	0.9680 – 1.3329	2.629 – 2.857	0.919	A-
BW= $a \times PoDL^b$	0.0543	2.630	0.0457 – 0.0645	2.560 – 2.692	0.969	A-
BW= $a \times PcL^b$	0.4788	3.298	0.4182 – 0.5482	3.203 – 3.392	0.959	A+
BW= $a \times PvL^b$	0.7000	2.922	0.6146 – 0.7972	2.834 – 3.010	0.956	A-
BW= $a \times AnsL^b$	0.0969	2.821	0.0801 – 0.1171	2.736 – 2.906	0.956	A-
BW= $a \times PrAnL^b$	0.0400	3.069	0.0309 – 0.0517	2.958 – 3.179	0.938	I
BW= $a \times PoAnL^b$	0.0465	2.887	0.0388 – 0.0558	2.812 – 2.962	0.967	A-

BW, body weight; TL, total length; SL, standard length; HL, head length; PrDL, pre-dorsal length, PoDL, post dorsal length; PcL, pectoral length; PvL, pelvic length; AnsL, anus length; PrAnL, pre-anal length; PoAnL, post anal length; *a* and *b* are the regression parameters of LWRs; CL, confidence limits; r^2, co-efficient of determination; GT, growth type; A-, negative allometric; A+, positive allometric; I, isometric

Table 15(b). Descriptive statistics and estimated parameters of the length-weight relationships of *S panijus* captured from the BoB, Bangladesh

Equation	Regression parameter		95% CL of *a*	95% CL of *b*	r^2	GT
	a	*b*				
BW $=a \times TL^b$	0.0089	2.82	0.0056 - 0.0143	2.66 - 2.98	0.859	A-
BW$=a \times FL^b$	0.0082	2.88	0.0051 - 0 .0132	2.72 - 3.05	0.858	A-
BW$=a \times SL^b$	0.0171	3.05	0.0147 - 0.0200	2.67 - 2.98	0.866	I
BW$=a \times HL^b$	0.4070	2.91	0.3094 - 0 .5361	2.74 - 3.09	0.840	A-
BW$=a \times PrDL_1{}^b$	0.4498	2.66	0.3535 - 0.5723	2.52 - 2.801	0.867	A-
BW$=a \times PrDL_2{}^b$	0.0204	2.80	0.0135 - 0.0308	2.65 - 2.96	0.864	A-
BW$=a \times PoDL_1{}^b$	0.1658	2.71	0.1214 - 0.2263	2.55 - 2.87	0.854	A-
BW$=a \times PoDL_2{}^b$	0.0204	2.80	0.0135 - 0.0308	2.65 - 2.96	0.864	A-
BW$= a \times PcL^b$	0.4749	2.72	0.3680 - 0.6127	2.57 - 2.88	0.851	A-
BW$= a \times PvL^b$	0.3753	2.75	0.2799 - 0.5033	2.58 - 2.93	0.826	A-
BW$=a \times AnsL^b$	0.1462	2.61	0.1067 - 0.2004	2.46 - 2.76	0.857	A-
BW$=a \times PrAnL^b$	0.0968	2.73	0.0703 - 0.1334	2.59 - 2.88	0.869	A-
BW$=a \times PoAnL^b$	0.0190	2.84	0.0120 - 0.0300	2.67 - 3.01	0.840	A-
BW$=a \times GrL^b$	0.1577	2.82	0.1154 - 0.2155	2.66 - 2.98	0.855	A-

Table 15(c). Descriptive statistics and estimated parameters of the length-weight relationships of *S taty* captured from the BoB, Bangladesh.

Equation	Regression parameter		95% CL of *a*	95% CL of *b*	r^2	GT
	a	*b*				
BW = a*TL^b	0.0058	2.96	0.0047 - 0.0071	2.89 - 3.03	0.962	A^-
BW = a*FL^b	0.0079	2.96	0.0066 - 0.0095	2.90 - 3.03	0.968	A^-
BW = a*SL^b	0.0131	2.87	0.0107 - 0.0160	2.79 - 2.94	0.958	A^-
BW = a*HL^b	1.5605	3.30	1.4258 - 1.7079	3.20 - 3.40	0.943	A^+
BW = a*PrDL^b	0.1379	2.85	0.1192 - 0.1596	2.78 - 2.93	0.954	A^-
BW = a*PoDL^b	0.0446	3.17	0.0354 - 0.0563	3.06 - 3.28	0.923	A^+
BW = a*PcL^b	7.5006	1.59	7.1635 - 7.8537	1.54 - 1.64	0.939	A^-
BW = a*PvL^b	1.2408	2.21	1.0974 - 1.4029	2.12 - 2.29	0.912	A^-
BW = a*AnsL^b	1.1423	1.91	1.0124 - 1.2889	1.84 - 1.98	0.918	A^-
BW = a*PrAnL^b	0.5158	2.29	0.4380 - 0.6075	2.29 - 2.39	0.904	A^-
BW = a*PoAnL^b	0.0208	2.78	0.0169 - 0.0256	2.70 - 2.86	0.950	A^-

Table 15(d). Descriptive statistics and estimated parameters of the length-weight relationships of *M cordyla* captured from the BoB, Bangladesh.

Equations	Regression parameters		95% CL of *a*	95% CL of *b*	r^2	GT
	a	*b*				
BW = $a \times$ TL^b	0.062	2.43	0.046-0.083	2.34-2.52	0.979	A^-
BW = $a \times$ FL^b	0.084	2.41	0.064-0.111	2.33-2.50	0.970	A^-
BW = $a \times$ SL^b	0.110	2.40	0.087-0.139	2.33-2.48	0.976	A^-
BW = $a \times$ HL^b	3.251	2.41	2.745-3.849	2.31-2.50	0.961	A^-
BW = $a \times$ OprL^b	2.086	2.30	2.024-2.148	2.20-2.40	0.910	A^-
BW = $a \times$ $PrDL_1^b$	1.881	2.37	1.486-2.382	2.25-2.49	0.942	A^-
BW = $a \times$ $PoDL_1^b$	0.828	2.41	0.640-1.072	2.30-2.52	0.949	A^-
BW = $a \times$ $PrDL_2^b$	0.691	2.39	0.536-0.891	2.29-2.50	0.953	A^-
BW = $a \times$ $PoDL_2^b$	0.319	2.42	0.232-0.438	2.31-2.54	0.944	A^-
BW = $a \times$ PcL^b	2.627	2.49	2.166-3.184	2.38-2.60	0.955	A^-
BW = $a \times$ PvL^b	2.477	2.46	2.028-3.027	2.35-2.57	0.952	A^-
BW = $a \times$ AnsL^b	0.925	2.53	0.786-1.088	2.28-2.42	0.978	A^-
BW = $a \times$ PrAnL^b	0.452	2.41	0.376-0.542	2.34-2.48	0.969	A^-
BW = $a \times$ PoAnL^b	0.234	2.45	0.173-0.315	2.34-2.55	0.954	A^-

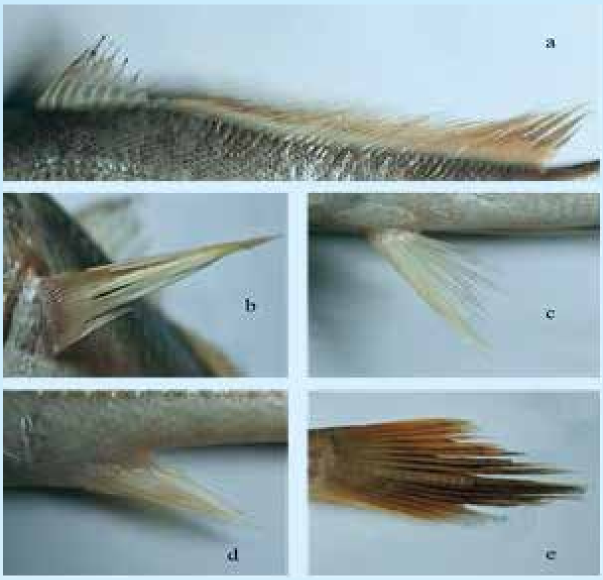
Table 16. Meristic characters of *P heterolepis, S panijus* and *S taty* commercially important marine fishes captured from the coastal water of Bangladesh.

Meristic data	Numbers	Spine	Unbranched	Branched
		L calcarifer		
Dorsal fin rays	17 - 20		VIII-IX	9-10
Pectoral fin rays	10-14			10-14
Pelvic fin rays	6		I	5
Anal fin rays	10-11		III	7-8

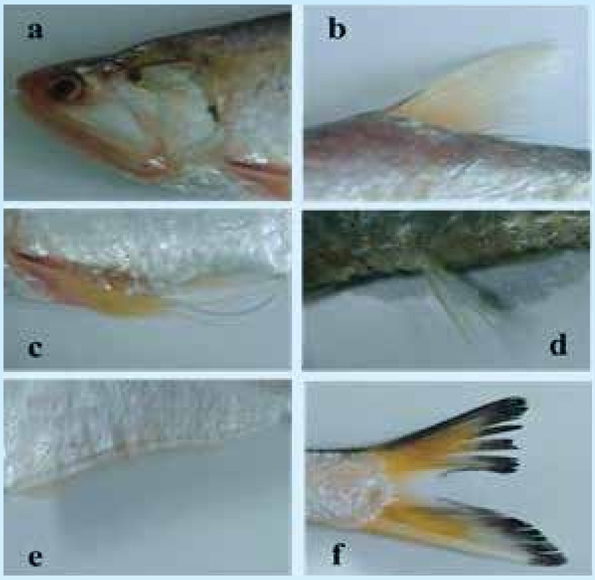
Meristic data	Numbers	Spine	Unbranched	Branched
		P heterolepis		
Dorsal fin rays	43 - 55	VIII - X	I	34 - 44
Pectoral fin rays	15 - 17	-	I	14 - 16
Pelvic fin rays	6	I	-	5
Anal fin rays	7 -10	II	-	5 - 8
Caudal fin rays	17 - 19	-	II	15 - 17
		P chinensis		
Dorsal fin rays	43-50			43-50
Pectoral fin rays	25-27			25-27
Pelvic fin rays	-			
Anal fin rays	39-42			39-42
		E affinis		
First dorsal fin rays	11-14		XI-XIV	
Second dorsal fin rays	12-13			12-13 (8 filaments)
Pectoral fin rays	25-27			25-27
Pelvic fin rays	6		I	5
Anal fin rays	12-14			12-14 (7 filaments)
		S taty		
Dorsal fin rays	9 - 12	-	1 - 2	7-11
Pectoral fin rays	12 - 13	-	1	11-12
Pelvic fin rays	7	-	1 - 2	5-6
Anal fin rays	42 - 49	-	1 - 2	40-48
Caudal fin rays	18 - 22	-	2	16-20
		S panijus		
First Dorsal fin rays	9	IX	-	-
Second Dorsal fin rays	25 - 29	I	-	24 - 28
Pectoral fin rays	17 - 20	-	-	17 - 20
Pelvic fin rays	5 - 6	-	i	5
Anal fin rays	26 - 28	I-II		25 - 26
Caudal fin rays	18 - 20	-	2	16 - 18
		P paradiseus		
First Dorsal fin rays	7		VII	
Second Dorsal fin rays	15-16		I	14-15
Pectoral fin rays	15-18			15-18 (7 filaments)
Pelvic fin rays	6		I	5
Anal fin rays	14		II	12
		M cordyla		
First dorsal fin rays	VIII	-	I	VII
Second dorsal fin rays	15-18	-	I	14-17 + (6-8 finlets)
Pectoral fin rays	22-26	-	-	22-26
Pelvic fin rays	6	-	I	5
Anal fin rays	15-19	-	III	12-16+ (5-7 finlets)
Scutes	51-58	-		-
		H nehereus		
Dorsal fin rays	12-13			12-13

Meristic data	Numbers	Spine	Unbranched	Branched
Pectoral fin rays	11			9
Pelvic fin rays	9			9
Anal fin rays	13-15			13-15
C dussumieri				
Dorsal fin rays	14		III	11
Pectoral fin rays	10-13			10-13
Pelvic fin rays	6-7		I	5-6
Anal fin rays	100-110		II	98-110
T setirostris				
Dorsal fin rays	12-15			
Pectoral fin rays	12-14		I	11-13
Pelvic fin rays				
Anal fin rays	32-37			
A chacunda				
Dorsal fin rays	17-19			17-19
Pectoral fin rays	15-16			15-16
Pelvic fin rays	8			8
Anal fin rays	19-20			19-120
I megaloptera				
Dorsal fin rays	15			15
Pectoral fin rays	10			10
Pelvic fin rays	6			6
Anal fin rays	40			40
P macracanthus				
First dorsal fin rays	22-24	X		12-14
Pectoral fin rays	18-19			18-19
Pelvic fin rays	6	I		6
Anal fin rays	16-17		III	13-14
A leiogaster				
Dorsal fin rays	17 – 18		2	15 – 16
Pectoral fin rays	15 – 16		1	14 – 15
Pelvic fin rays	7		1	6
Anal fin rays	18 – 20			18 – 20
Caudal fin rays	19 – 20		2	17 – 18

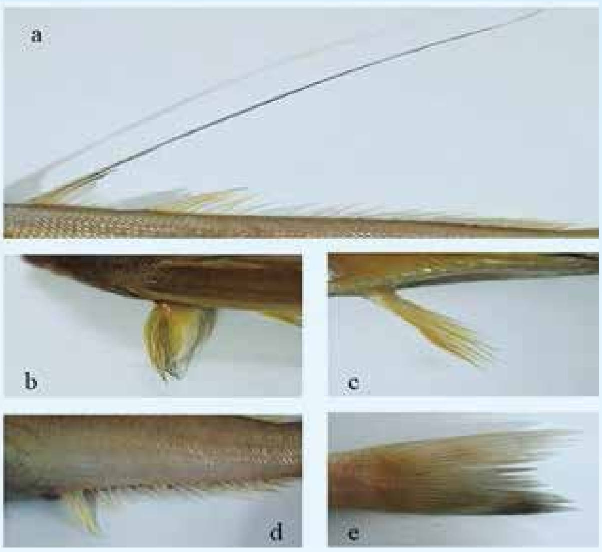
Spine, upper portion of single sharp ray; Unbranched, single fin ray; Branched, upper portion of fin is divided into several rays



Plates 14(a). Different fins such as (a) dorsal, (b) pectoral, (c) pelvic, (d) anal and (e) caudal of *Pheterolepis* from the BoB, Bangladesh



Plates 14(b). (a) Head and different fins (b) Dorsal, (c), Pectoral (d) Pelvic, (e) Anal, (f) Caudal of *S taty* in the BoB, Bangladesh.



Plates 14(c). Photos showing the meristic counts for these fins: (a) dorsal, (b) pectoral, (c) pelvic, (d) anal, and (e) caudal of *S panijus* from the BoB, Bangladesh

Plates 14(d). Photos showing the meristic counts for these fins: (a) dorsal, (b) pectoral, (c) pelvic, (d) anal, and (e) caudal of *A leiogaster* from the BoB, Bangladesh

Meristic counts appear to be favorable and easy to assess, and maximum counts can be done from live fish. In this study, 8-10 spine fin rays were found in dorsal fin, which is similar to Shafi & Quddus (1982), Talwar & Jhingran (1991), and Rahman (1989), but the branched fin rays exceeded their findings. In this study, pectoral fins had 15-17 fin rays with 1 unbranched ray, which is also similar to Rahman (1989). Observed pelvic (I/5) and anal fin-ray counts (II/5-7) were identical to those of Shafi & Quddus (1982), Talwar & Jhingran (1991), and Rahman (1989). Caudal fin rays (ii/15-17) were in agreement with Shafi & Quddus (1982). Hence, meristic counts were inadequate to distinguish among different populations or stocks of the same species.

The meristic characteristics were essential tools for species and stock identification for the purpose of fishery. The recorded dorsal fin rays of *S. phasa* were 9-12 which is dissimilar to the findings of Talwar and Jhingran (1991) (15-16) and Rahman (2005) (14-16). The fin rays of pectoral fin (12- 13) and pelvic fin (7) is nearby to the findings of Talwar and Jhingran (1991) (pectoral fin 15 and pelvic fin 7) and Rahman (2005) (pelvic fin 13-14 and pectoral fin 7), respectively. The observed anal fin rays were 42-49 which is too far different from Shafi and Quddus (1982) (70- 80), Talwar and Jhingran (1991) (69-81) and Rahman (2005) (64-72). The caudal fin rays were 18-22 which is similar (19) to Shafi and Quddus (1982).

There is very limited published information on the meristic count of *M. cordyla* from the BoB. However, we counted the first dorsal fin rays D_1 was I+VII which is similar to the previous results of Jaiswar and Devaraj (1989), FAO/SIDP (2000), Sarker et al. (2004), Habib et al. (2017) and Hossain et al. (2020). For the second dorsal fin rays, we observed D_2 I/14-18 with 6-8 dorsal finlets, then again other study showed slightly dissimilar findings (Jaiswar and Devaraj, 1989): 11-13 with 6-9 dorsal finlets; FAO/SIDP (2000): I+18-20 with 7-9 finlets; Sarker et al. (2004): 1+9-14 with 5-9 finlets; Habib et al. (2017): I/11+8 dorsal finlets and Hossain et al. (2020): I/18-20+7-9 finlets). Pectoral fin (P_1 20-26) also showed different results reported from Jaiswar and Devaraj (1989): 19-22; Sarker et al. (2004): 1+19-20; Habib et al. (2017): 22 and Hossain et al. (2020): 25-30. Further, pelvic fin (P_2 I/5) showed similar results with the other studies. Anal fin (II+I/12-16)) was more or less similar to the observation of Jaiswar and Devaraj (1989): 9-11with 5-7 anal finlets; FAO/SIDP (2000): I+16-17 with 8-10 finlets; Sarker et al. (2004): 1+9-11 with 5-8 finlets; Habib et al. (2017): II+I/10 with 6 finlets and Hossain et al. (2020): II+I/16-17 with 8-10 finlets). We found 51-58 scutes on the lateral line, while Habib *et al*. (2017) observed 54-56 and Hossain et al. (2020) reported 51-59 scutes.

These variations among different studies may ascribe due to factors such as the geographical population differences as well as difference in counting methods, developmental period and temperature during larval development (Barlow, 1961). Many species belong under one genus have very similar characteristics that make it too difficult to identify or differentiate from each other. Hence, this study demonstrates the comprehensive information on morphometric and meristic features of commercially important marine fishes from the BoB using multi-linear dimensions. We also added meristic characteristics as pictorial form which is very helpful to recognize the commercially important marine fishes and is comparable with the future study.

11.1.1.3 Estimation of size and age at sexual maturity

The size of sexual maturity is of special awareness in fisheries management and is widely used as an indicator for minimum acceptable capture size. Size and age at sexual maturity of 15 commercially important fishes from the BoB was calculated based on maximum length (Table 17). The relationship between TL vs. GSI of female marine fishes was presented in figure 16 that indicate their sexual maturity based on GSI. The minimum length was recorded 10.0 cm in TL for *C dussumieri*, *C cynoglossus*, and *T setirostris*, and the maximum length was recored for *Lates calcarifer*. The estimated lowest L_m was 11.8, 12.8, and 13.7 cm for *T. setirostris* and the highest L_m was 23.3, 20.5, and 22.0 cm for *P. macracanthus* through L_{max}, GSI, and logistic-based models, respectively.

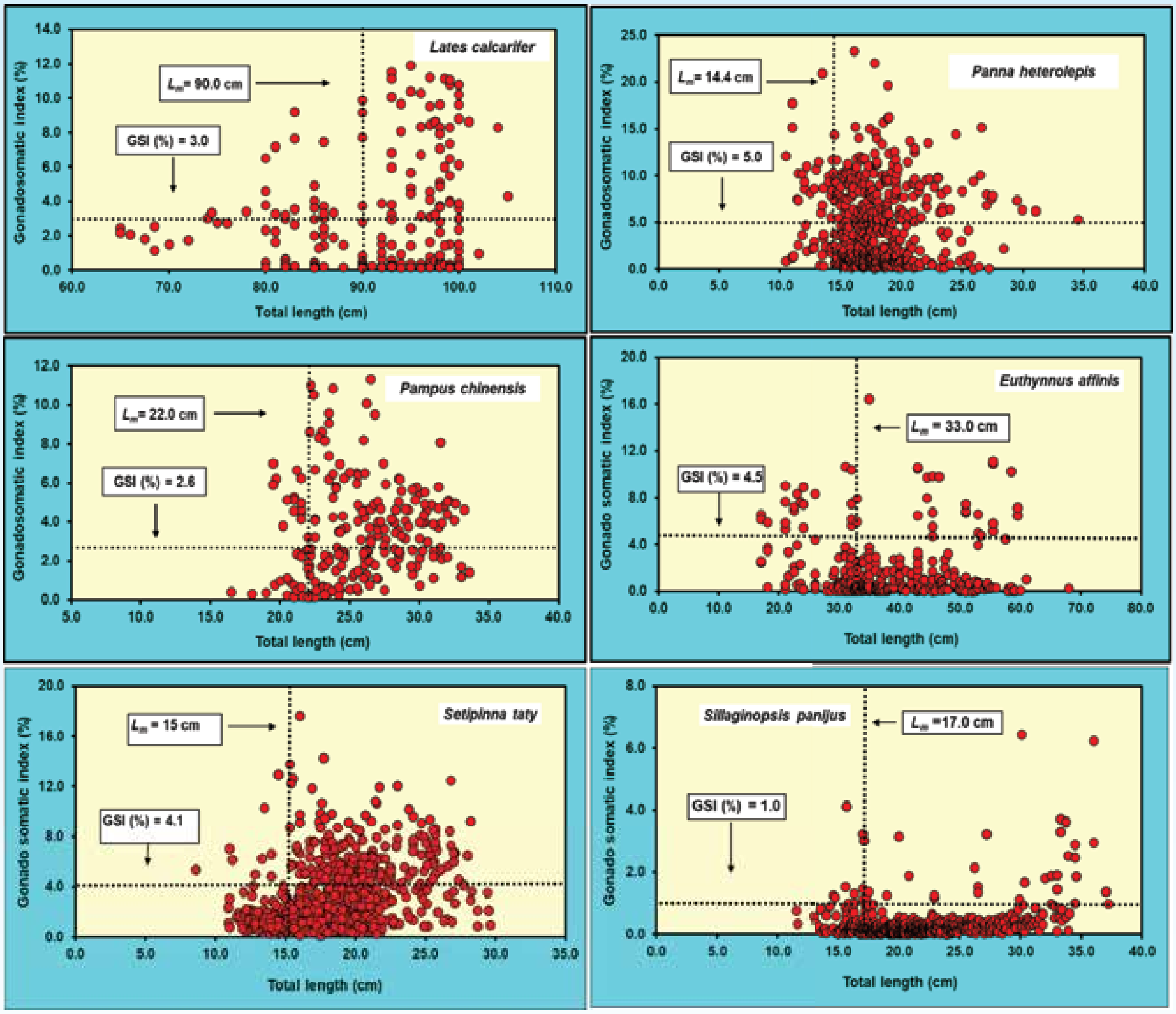
Table 17. Estimated size (L_m) and age (T_m) at first sexual maturity of 15 commercially important fishes from the BoB, Bangladesh

Sl. No.	Species Name	Size at first sexual maturity (cm)			T_m (year)
		L_{max} based	GSI based	Logistic model	
01	*L calcarifer*	52.30	90.0	-	0.66
02	*P heterolepis*	19.47	14.4	15.00	0.78
03	*P chinensis*	20.46	22.0	-	0.84
04	*E affinis*	36.24	33.0	-	0.72
05	*S taty*	18.07	15.0	18.00	0.78
06	*S panijus*	21.98	17.0	-	0.76
07	*P paradiseus*	13.89	14.5	15.00	0.81
08	*M cordyla*	22.50	20.0	-	0.76
09	*H nehereus*	20.24	17.5	-	0.77
10	*C dussumieri*	13.75	13.5	14.10	0.81
11	*T setirostris*	12.89	12.8	13.70	0.81
12	*A chacunda*	16.05	17.8	-	0.80
13	*I megaloptera*	20.75	16.7	22.50	0.77
14	*P macracanthus*	26.84	19.0	22.00	0.75
15	*A leiogaster*	17.15	16.5	-	0.79

For the identification and prevention of over-exploitation, information on the L_m of the fish is extremely significant (Sujatha et al. 2015). The L_m is also used as a guideline for selecting the least permitted size limits for catch fisheries (Nurdin et al. 2016). There is a fair possibility that 50% of the fish captured would have already spawned and thus have contributed to the recovery of the stock by allowing fish to touch or surpass this size before capture (Achmad et al. 2020). From the logistic equation, available information on the L_m of fish from plots of percentage occurrence of mature females against length class can be acquired (King 2007). In the estimation of L_m of fishes using this logistic equation, some studies have reported low accuracy (Hossain et al. 2013), but its accuracy for short life cycle species is under investigation. Garcia (1985) also stated that it was highly prejudiced to use the proportion of mature females as an indicator of population reproduction.

Determining size at first sexual maturity is critical for (a) differentiating among diverse stocks of an identical species and (b) assessment whether changes in length at first maturity are due to fisheries pressure or other reasons (Hossain et al. 2010). This is essential for fisheries biologists to manage and conserve a particular fish population (Lucifora et al. 1999). Our study revealed that L_m of female *P. heterolepis* was 15.0 cm based on GSI, MGSI, and DI values. Moreover, precise estimations of TL m benefit management of particular fish stock (Rahman et al. 2018). The maturity size may differ according to habitat and other environmental factors (Sinovcic and Zorica 2006). Comparisons cloud not be done due to scarcity of literature on *P. heterolepis* maturity.

As it is totally the first work on this content for these 15 species, comparison was not possible, but we estimated the L_m for these fishes by using the L_{max} values from previous published articles where we observed that the the L_m was 28.0 cm for *I. megaloptera* in the estuarine region of the Diamond Harbour, West Bengal, India. (need ref) For a given species, the mean L_m can differ among stocks. The L_m of fishes might differ due to several factors such as feeding rate, sex and gonadal development, behavior, season, flow of water, population's density, water temperature, and food (Muchlisin et al. 2010; Hossain et al. 2012; Sabbir et al. 2021). The FAO responsible fisheries strategy strongly recommends selecting the optimum catchable size above the mean L_m for the preserve stock abundance by permitting a sufficient quantity of the stock to become reproductively able prior to catch (Achmad et al. 2020)



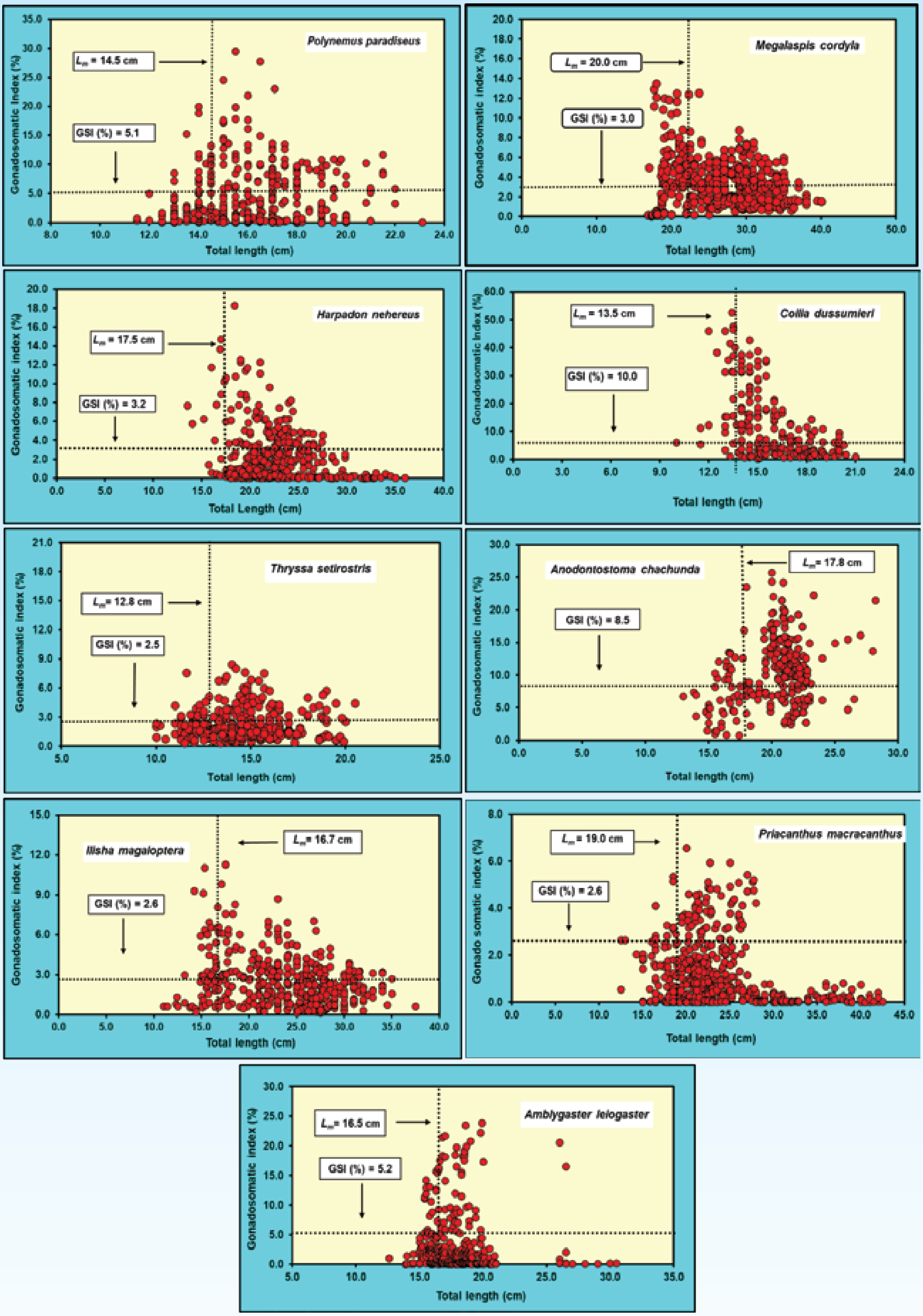


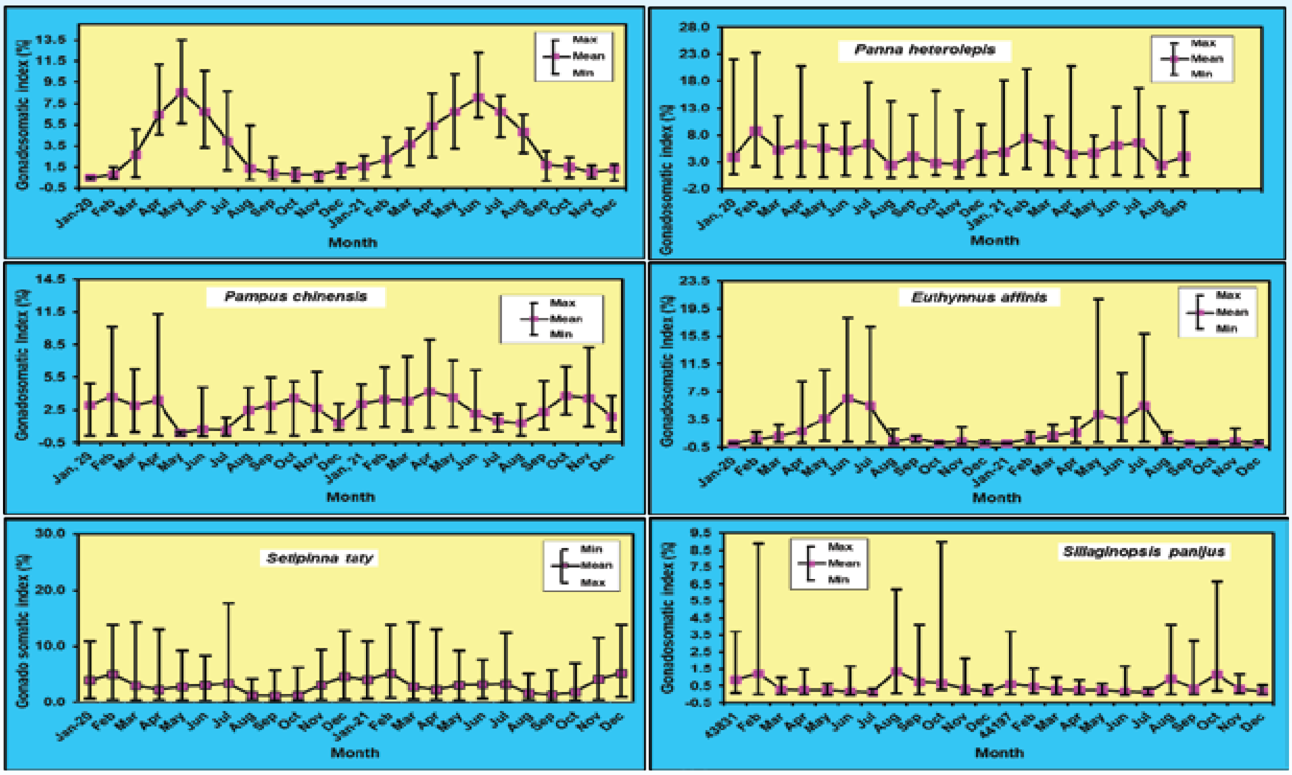
Fig 16. Size at first sexual maturity (L_m) of commercially important fishes from the BoB, Bangladesh based on gonadosomatic index.

11.1.1.4 Estimation of spawning and peak spawning season

Spawning season of 15 commercially important marine fishes were estimated based on gonadosomatic index (GSI). Highest value of GSI indicated peak spawning season. Most of the commercially important marine fishes spawn from April to September (Fig 17). May to July is the peak spawning season of studied 9 species. Estimated spawning season for 15 species showed in Table 18. Spawning season of commercially important marine fishes was studied and confirmed through histological studies (Plate 15).

Table 18. Estimated spawning and peak spawning season of 15 commercially important fishes from the BoB, Bangladesh

Sl. No.	Species Name	Spawning Season	Peak Spawning Season
01	*L calcarifer*	April - September	April - May
02	*P heterolepis*	January - July	February
03	*P chinensis*	April - August	June
04	*E affinis*	April - July	June - July
05	*S taty*	January - April	March
06	*S panijus*	February, August - September	August
07	*P paradiseus*	March - July	May - June
08	*M cordyla*	April - August	June
09	*H nehereus*	April - June	May
10	*C dussumieri*	April - July	May
11	*T setirostris*	March - May, July - August	April, July
12	*A chacunda*	May - August	June – July
13	*I megaloptera*	January - May	February - April
14	*P macracanthus*	January - March	February
15	*A leiogaster*	April - June	May



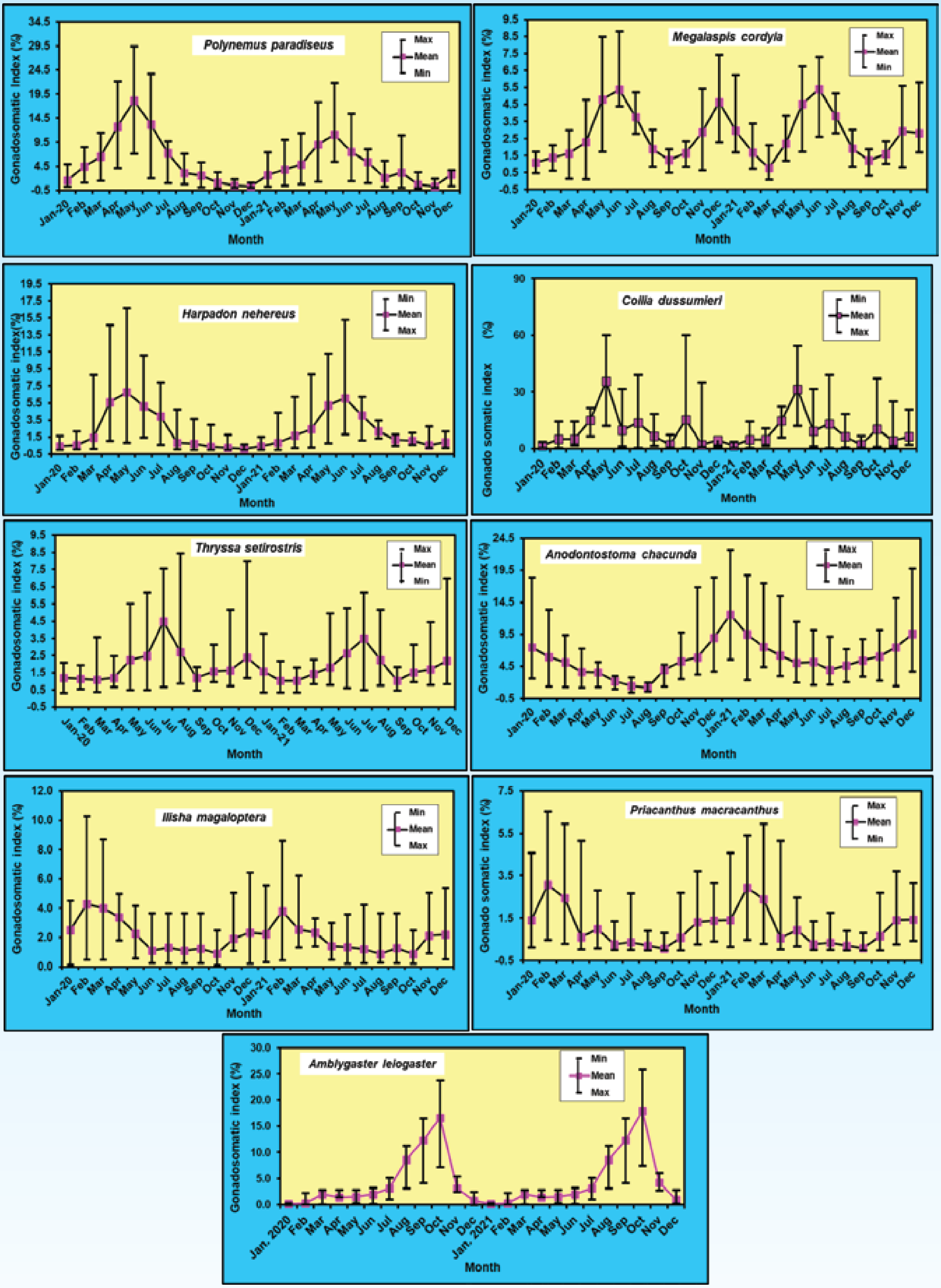
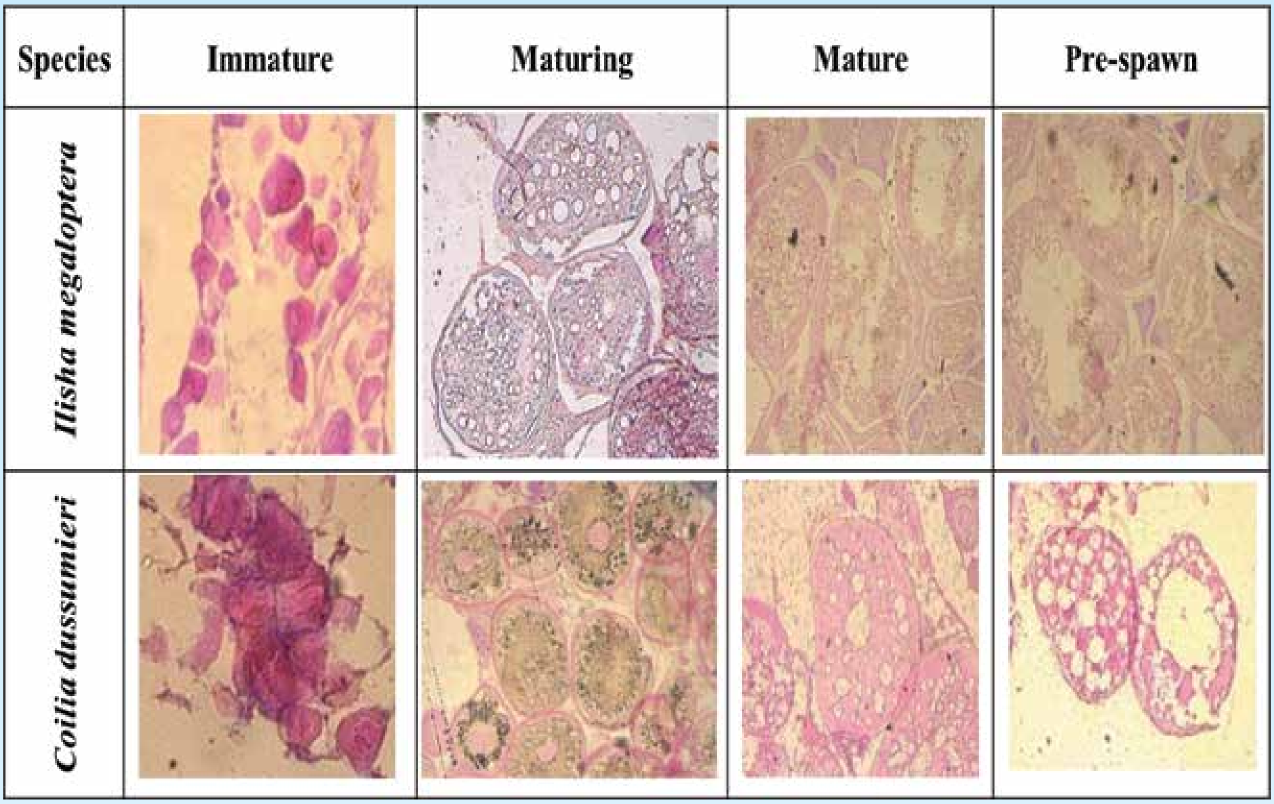


Fig 17. Monthly variation of gonadosomatic index (GSI) of commercially important fishes from the BoB, Bangladesh.



Plates 15. Histology of gonads for two marine fishes from the BoB, Bangladesh.

11.1.1.5 Justification of fishing ban period in the BoB, Bangladesh

A yearly fishing ban was imposed by the Bangladesh Government from 20 May to 23 July in the BoB, to conserve the depleted marine fish stocks and allow adequate spawning (DoF, 2019). However, the spawning and peak spawning seasons for most of the marine fish stocks are unknown. On the other hand, the prolonged fishing ban has a negligible impact on the income and livelihoods of the poor subsistence coastal fishers. Therefore, it is necessary to identify the spawning and peak-spawning period in spite of different fishes dwelling in the BoB. Analyses of spawning season are crucial to assess spawning time and migration of a fish population for spawning purposes (Vadas, 2000; Khatun et al., 2019).

To fulfil the gap and justify the imposed ban period, we studied the spawning and peak spawning season of commercially important marine fishes from the BoB, Bangladesh. We found that, most of the commercially important marine fishes spawn from April to September. However, May to July is the peak spawning season of studied 9 species from studied 15 commercially important fishes (Fig 18 & 19). Furthermore, different studies by the Marine Fisheries Technology Station (MFTS), Bangladesh Fisheries Research Institute (BFRI) (Table 19) and other researchers (Fig 20 & 21) provide similar results. Thus, the banning period in the BoB need to be justified and that should be from April (or mid-April) to June (or mid-June).

Consequently, all types of fishing ought to be banned during the peak spawning period to ensure sustainable management of marine fish species depending on estimated peak spawning season and allow the coastal fisher folks to continue fishing after that period in the BoB, Bangladesh.

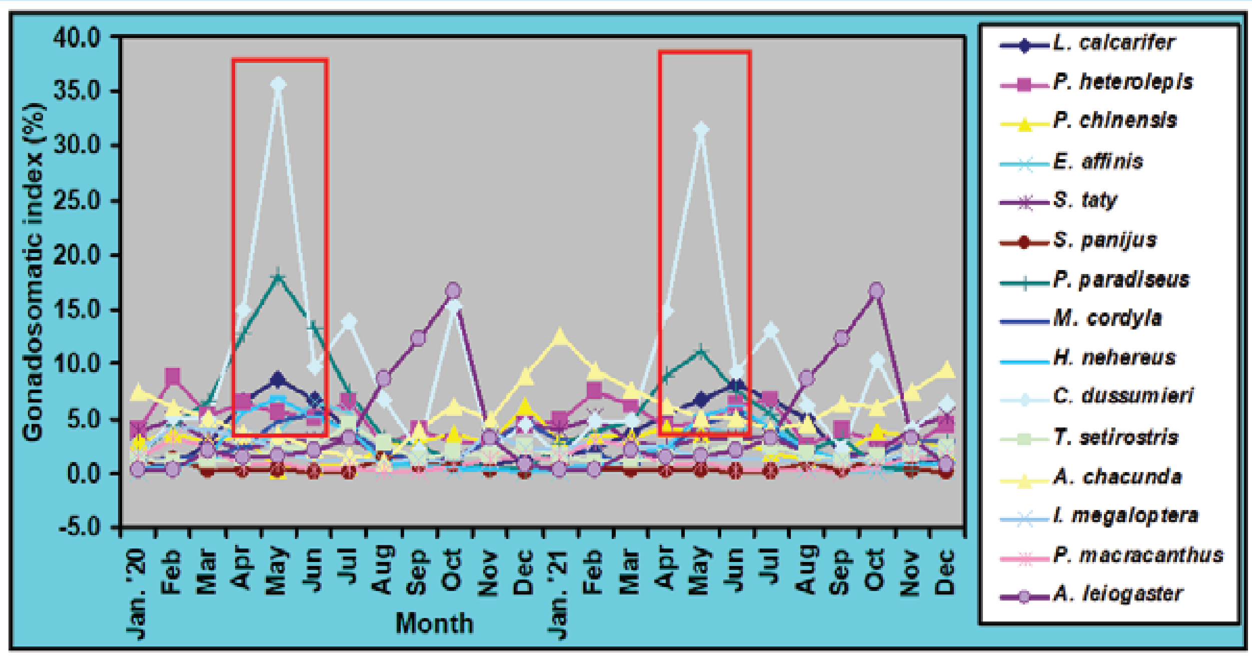


Fig 18. Peak spawning season of commercially important marine fishes in the BoB, Bangladesh

Sl.	Species name	J	F	M	A	M	J	J	A	S	O	N	D
01	*L calcarifer*				■	■	■	■	■				
02	*P heterolepis*	■	■	■	■	■	■	■					
03	*P chinensis*	■	■	■	■	■						■	■
04	*E affinis*					■	■	■					
05	*S taty*	■	■	■			■	■				■	■
06	*S panijus*	■	■						■				
07	*P paradiseus*			■	■	■	■	■					
08	*M cordyla*				■	■	■	■	■				
09	*H nehereus*				■	■	■	■					
10	*C dussumieri*				■	■	■	■					
11	*T setirostris*					■	■	■	■				
12	*A chacunda*	■	■	■	■								■
13	*I megaloptera*	■	■	■	■	■						■	■
14	*P macracanthus*	■	■	■								■	■
15	*A leiogaster*								■	■	■		

Fig 19. Spawning season of commercially important marine fishes in the BoB, Bangladesh.

Table 19(a). Spawning season of commercially important marine fishes in the BoB.

Local name	English name	Scientific name	Spawning season
Baim	Short fin eel	*A bicolor*	PSS: Nov - March
Kamila	Yellow pike conger	*C talabon*	PSS: April-May; Sept. - Oct
Kamila	Indian pike conger	*C taalabonoides*	PSS: April-May; Sept. - Oct
Kamila	Common pike conger	*M bagio*	PSS: July; September-October
Bullet myitta	Bullet tuna	*A rochei*	May – August; PSS: June – July
Frigate myitta	Frigate tuna	*A thazard*	May – August; PSS: June – July
Bom myitta	Kawakawa	*E affinis*	May – August; PSS: June – July
Myitta	Skipjack tuna	*K pelamis*	May – August; PSS: June – July
Yellow fin myitta	Yellowfin tuna	*T albacares*	May – August; PSS: June – July
Big eye myitta	Big eye tuna	*T obesus*	Throughout the year
Long tail myitta	Long tail tuna	*T tonggol*	
Snapper			
Ranga chowkkha	Yellowfin red snapper	*L guilecheri*	April - October
Ranga chowkkha	John's snapper	*L johni*	April - October
Kata fish	Threadfin sea catfish	*A arius*	April - October
Kata fish	Sagor catfish	*H sagor*	April - October
Apia kata fish	Solidier catfish	*O militaris*	April - October
Kata sona	Sona sea catfish	*Sciades sona*	April - October

Bangladesh (source: Annual report 2018-19) PSS, peak spawning season

Table 19(b). Spawning season of commercially important marine fishes in the BoB, Bangladesh (Studied by the MFTS, BFRI; source: Proposal for ban period published 31.05.2020)

Species	Spawning season	Peak spawning season
T ilisha	September - November	September – October
S gibbose	October – February	December – February
S. fimbriata	April – October	April – June
S gutters, S. commerson	May – September	June – July
R kanagurta	March - June	April - May
T albacares, E affinis, K pelamis	April – August	June - July
T obesus	Throughout the year	
P parsia	April - September	July – August
M cephalus	February - March	February - March
C dussumieri	April - September	May – June
P niger, P argenteus, P. chinensis	October - July	May - June
L savala	December - June	April – May
H nehereus	October - July	March - June
P anea	January - August	April – June
J argentatus	June – September	June – July
L calcarifer	October - July	June – July
C talabonoides	October - July	March – June
A arius, M gulio	April - July	May – June
S commersonianus	March - June	April – May
E fuscogunaris	April - August	July – August
Lutjanus spp.	April - October	July - August
Cynoglossus/Hippoglossus spp.	January – March, September - November	March, September – October
L lentjan	December - February	December – February
E tetradactylum, L indicum	March - July	May – June
S sihama	September - February	November – December
S tumbil	March - June	May – June
T jarbua	March – May, September - October	May, September
U moluccensis	January - August	April – June
C sorrah	January - May	

Group	Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cat Fish	*Tachysurus thalassinus*		■	■	■	■			■				
	Osteogeneiosus militaris	■	■	■	■	■					■	■	■
	Mystus gulio				■	■			■	■			
Eel	*Muraenesox talabonoides*				■	■				■	■		
Croaker	*Johnius carutta*	■	■	■	■								
	Pennahia anea	■	■	■									
	Otolithes cuvieri	■	■	■	■	■	■	■				■	■
	Protonibea diacanthus						■	■	■	■			
Ribbon Fish	*Trichiurus lepturus*					■	■					■	■
	Trichiurus haumela						■	■					
Bombay duck	*Harpadon nehereus*				■	■	■				■	■	■
Ilish	*Hilsa ilisha*	■	■							■	■		
Sardin	*Sardinella longiceps*	■	■	■							■	■	■
	Sardinella fimbriata	■	■	■									
	Dussumieria hasselti		■	■	■	■	■	■					
Indian Mackerel	*Rastrelliger kanagurta*					■	■	■	■	■			
Mackerel	*Scomberomorus guttatus*				■	■	■	■					
Pomfret	*Pampus argenteus*				■	■	■	■	■		■	■	
Nemipteridae	*Nemipterus japonicus*	■	■	■	■		■				■	■	
	Upeneus sulphureus	■	■	■	■	■	■	■	■				
Koral Mach	*Lates calcarifer*										■	■	■
	Lethrinus lentjan	■	■				■	■	■				■
Tiger Perches	*Terapon jarbua*			■	■	■				■	■		
	Pelates quadrilineatus		■	■	■								
Thylla mach	*Eleutheronema tetradactylum*	■	■	■	■	■	■	■					
Puti	*Anodontostoma chacunda*	■	■	■								■	■
Mullet	*Mugil parsia*	■	■	■									■
	Mugil cephalus								■	■	■	■	■
	Liza macrolepis	■	■				■	■	■	■	■	■	■
Karati	*Chirocentrus dorab*							■	■	■			
Halibut	*Psettodes erumei*	■		■						■	■	■	
Lady Fish	*Sillago sihama*	■	■							■	■	■	■
Lizard Fish	*Saurida tumbil*			■			■						
Anchovies	*Thrissocles dussumieri*		■	■	■	■	■	■	■	■			
	Coilia spp				■	■	■	■	■	■			
Pony Fish	*Leiognathus bindus*				■	■	■		■		■	■	
Flying Fish	*Cypselurus oligolepis*			■	■	■							
Shark & Rays	*Rhizoprionodon acutus*	■	■	■	■	■	■	■			■	■	■
	Pristis microdon	■				■	■						■
	Dasyatis imbricatus		■	■	■	■			■	■			
Cephalopod	*Loligo duvauceli*	■		■	■	■		■	■	■	■	■	
	Sepia pharaonis				■	■		■	■	■			

spawning ■

Fig 20. Spawning season of commercially important marine fishes in the BoB, Bangladesh (collected from relevant literature)

Family	Common Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Harpadontidae	Bombay duck (Loitta)					Peak	Peak	Peak			Secondary	Secondary	Secondary
Synodontidae	Lizard Fish (Achila Mach)					Peak	Peak	Peak				Peak	Peak
Belonidae	Needlefish (Kakia)					Peak	Peak	Peak					
chirocentridae	Herring (Korati Chhela)		Secondary	Secondary	Secondary	Peak	Peak						
Clupeidae	Hilsa (Ilish)			Secondary	Secondary		Secondary	Secondary		Peak	Peak		
	Sardine (Takia)						Peak	Peak	Peak		Secondary	Secondary	
	Ganges gizzard shad (Chapila)	Secondary					Peak	Peak	Peak			Secondary	Secondary
Engraulidae	Anchovy (Olua)					Peak	Peak	Peak	Peak		Secondary	Secondary	
	Hairfin anchovy (Fesa)						Peak	Peak	Peak		Secondary	Secondary	
Pristigasteridae	Bigeye Ilisha (Chokkha)						Peak	Peak	Peak				
Mugilidae	Mullet (Bata)		Peak	Peak			Peak	Peak			Peak	Peak	
Carangidae	Scads/trevally (Chapa/Mouri/Nilambori)				Peak	Peak	Peak						
	Black Pomfret (Hail Chanda)				Peak	Peak	Peak						
Gobiidae	Goby (Nona Bele)				Peak	Peak	Peak	Peak					
	Goby (Chiring/Chewa)				Peak	Peak	Peak	Peak					
Istiophoridae	Sailfish (Pal Mach)										Peak	Peak	
Latidae	Seabass (Koral)				Peak	Peak	Peak						
Leiognathidae	Ponyfish (Tek Chanda)					Peak	Peak	Peak					
Lobotidae	Tripletail (Somudro Koi)						Peak	Peak	Peak				
Lutjanidae	Snapper (Ranga Chokkha)				Peak	Peak	Peak				Peak	Peak	
Nemipteridae	Breams (Rupban)					Peak	Peak	Peak	Peak				
Polynemidae	Threadfin (Tailla)		Secondary	Secondary	Peak	Peak	Peak	Peak			Secondary	Secondary	
	Threadfin (Lakhua)				Peak	Peak	Peak	Peak			Secondary	Secondary	Secondary
	Paradise threadfin (Taposhi)					Peak	Peak	Peak					
Scatophagidae	Spotted scat (Chitra/Payra)					Peak	Peak	Peak			Secondary	Secondary	
Sciaenidae	Croaker (Rupali/kala/Gutipoa)		Secondary	Secondary	Peak	Peak	Peak	Peak			Secondary	Secondary	
Scombridae	Spanish Mackerel (Chompa/Maitta)				Peak	Peak	Peak						
	Tuna (Tuna Mach)				Peak	Peak	Peak						
Serranidae	Grouper (Bol)					Peak	Peak	Peak					
Sillaginidae	Sillago (Tular Dandi)			Peak	Peak	Peak	Peak				Secondary	Secondary	
Sparidae	Seabream (Datina)	Peak	Peak									Peak	Peak
Stromateidae	Pomfret (Rupchanda)	Peak			Peak	Peak	Peak					Peak	Peak
Terapontidae	Jarbua terapon (Barguni)				Peak	Peak	Peak	Peak			Secondary	Secondary	Secondary
Trichiuridae	Hairtail (Chhuri)				Peak	Peak	Peak						
Cynoglossidae	Sole (Kukur Jib)	Peak	Peak	Secondary	Secondary							Peak	Peak
Soleidae	Pan Sole (Panpata Serboti)	Peak	Peak	Secondary	Secondary							Peak	Peak
Ariidae	Catfishes (Kata Mach)						Peak	Peak	Peak				
Plotosidae	Eel-catfish (Kail Magur)					Peak	Peak	Peak					
Pangasiidae	River catfish (Pangas)						Peak	Peak	Peak				

Peak spawning (red) | Secondary spawning (yellow)

Fig 21. Family wise spawning season of commercially important marine fishes in the BoB, Bangladesh (Source: Hossain et al., 2020)

11.1.1.6 Relation between environmental factors *vs.* GSI

In the study, nine environmental factors, i.e., dissolved oxygen (DO), temperature (water & air), pH, total dissolved solid (TDS), salinity, resistivity, conductivity, and rainfall were examined for potential impact on gonadal maturation of commercially important marine fishes in the BoB, Bangladesh. Different factors significantly related or has potential impact on the gonadal maturation of marine fishes. However, relationships between environmental factors and GSI presented in Table 20 & Fig 22a – 22c. Fig 23 shown the annual average maximum temperature (°C) in the BoB region, Bangladesh during 1964 to 2016. Annual average maximum temperature (°C) and annual average rainfall (mm) in Bangladesh during 1900 to 2020 shown in Fig 23 & 24. Relationship between environmental factors with GSI of more marine fish spieces are presented in Annexure RU:3 added with Fig. Anx1-4.

Table 20. Relationship between environmental factors with GSI of commercially important marine fishes in the BoB, Bangladesh

Relationships	r_s value	95% CL of r_s value	p value	Significant
L. calcarifer				
DO *vs*. GSI	0.6962	0.1850 – 0.9108	0.0144	*
pH *vs*. GSI	-0.3357	-0.7706 – 0.31266	0.2869	*ns*
TDS *vs*. GSI	-0.3776	-0.7894 to 0.2686	0.2276	*ns*
Salinity *vs*. GSI	-0.5944	-0.8757 to -0.01182	0.0457	*
Resistivity *vs*. GSI	0.6760	0.1480 to 0.9041	0.0187	*
Conductivity *vs*. GSI	-0.4266	-0.8104 to 0.2136	0.1689	*ns*
Water Temp. *vs*. GSI	0.7951	0.3906 to 0.9423	0.0030	**
Rainfall *vs*. GSI	0.5664	-0.03037 to 0.8655	0.0591	*ns*
Air Temp. *vs*. GSI	0.7285	0.2477 to 0.9214	0.0092	**
P. heterolepis				
DO *vs*. GSI	-0.5433	-0.8067 to 0.7741	0.0421	*
pH *vs*. GSI	-0.2098	-0.7093 to 0.4300	0.5137	*ns*
Water Temp. *vs*. GSI	0.4042	-0.2394 to 0.8010	0.1922	*ns*
Rainfall *vs*. GSI	0.3333	-0.3151 to 0.7696	0.2874	*ns*
P. chinensis				
DO *vs*. GSI	-0.4700	-0.8283 to 0.1612	0.1247	*ns*
pH *vs*. GSI	0.4266	-0.2136 to 0.8104	0.1689	*ns*
TDS *vs*. GSI	0.3007	-0.3473 to 0.7543	0.3424	*ns*
Salinity *vs*. GSI	0.7832	0.3636 to 0.9386	0.0038	**
Resistivity *vs*. GSI	-0.6690	-0.9018 to -0.1355	0.0203	*
Conductivity *vs*. GSI	0.6014	0.02270 to 0.8782	0.0428	*
Water Temp. *vs*. GSI	-0.5114	-0.8447 to 0.1076	0.0917	*ns*
Rainfall *vs*. GSI	-0.7413	-0.9255 to -0.2735	0.0078	**
Air Temp. *vs*. GSI	-0.3783	-0.7897 to 0.2679	0.2239	*ns*

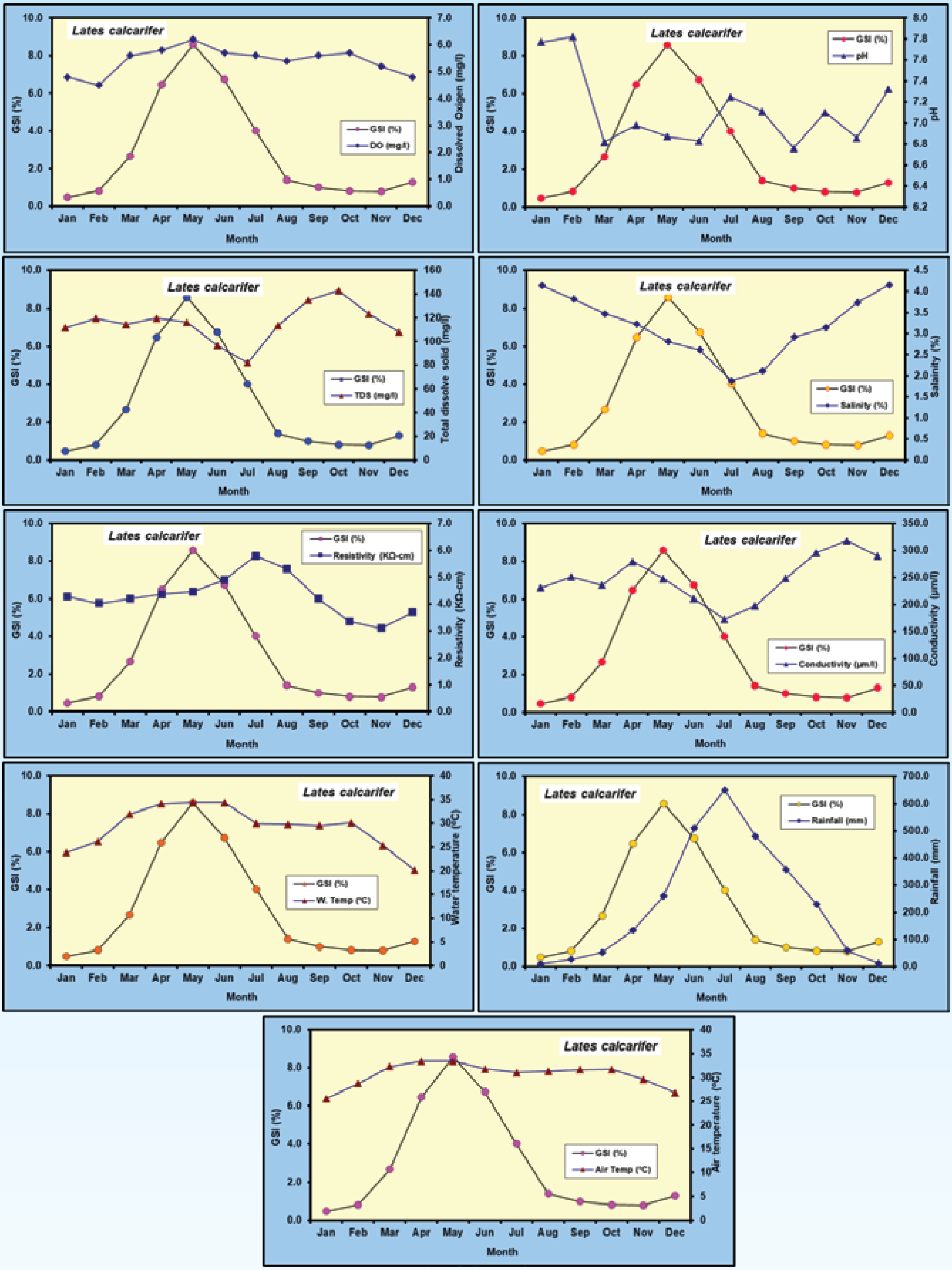


Fig 22(a). Relationship between gonadosomatic index (GSI) with environmental factors of female *L calcarifer* in the BoB, Bangladesh

The reproductive behavior of female *P. heterolepis* may be influenced by water temperature. Throughout the study, the maximum water temperature was recorded in May–June (34.4 °C) and minimum temperature was found in January (19.8 °C). The highest GSI (peak spawning period) was detected in February when water temperature was relatively low (24.7 °C). Alternatively, reproductive behavior was not significantly influenced by rainfall, DO, or pH in the BoB (SW Bangladesh). Maximum rainfall recorded in August (370 mm) and no rainfall occurred in January. But DO is important for the aerobic metabolism of fish (Timmons et al. 2001) and optimum DO level exceeds 3.5 mg/l for marine fisheries resources (EPA 2000). Similarly, pH is considered an important ecological factor for any aquatic ecosystem. If an aquatic ecosystem is more acidic (pH < 4.5) or alkaline (pH > 9.5) for an extended time, growth and reproduction will be reduced (Ndubuisi et al. 2015). In our study, the monthly DO level ranged from 5.42 to 6.15 mg/l and pH was 6.76–7.32 indicating an appropriate habitat for marine fisheries resources in the BoB, Bangladesh. These factors were not closely related with reproduction of P. *heterolepis* in the study site. However, further comprehensive studies are recommended for its sound clarification.

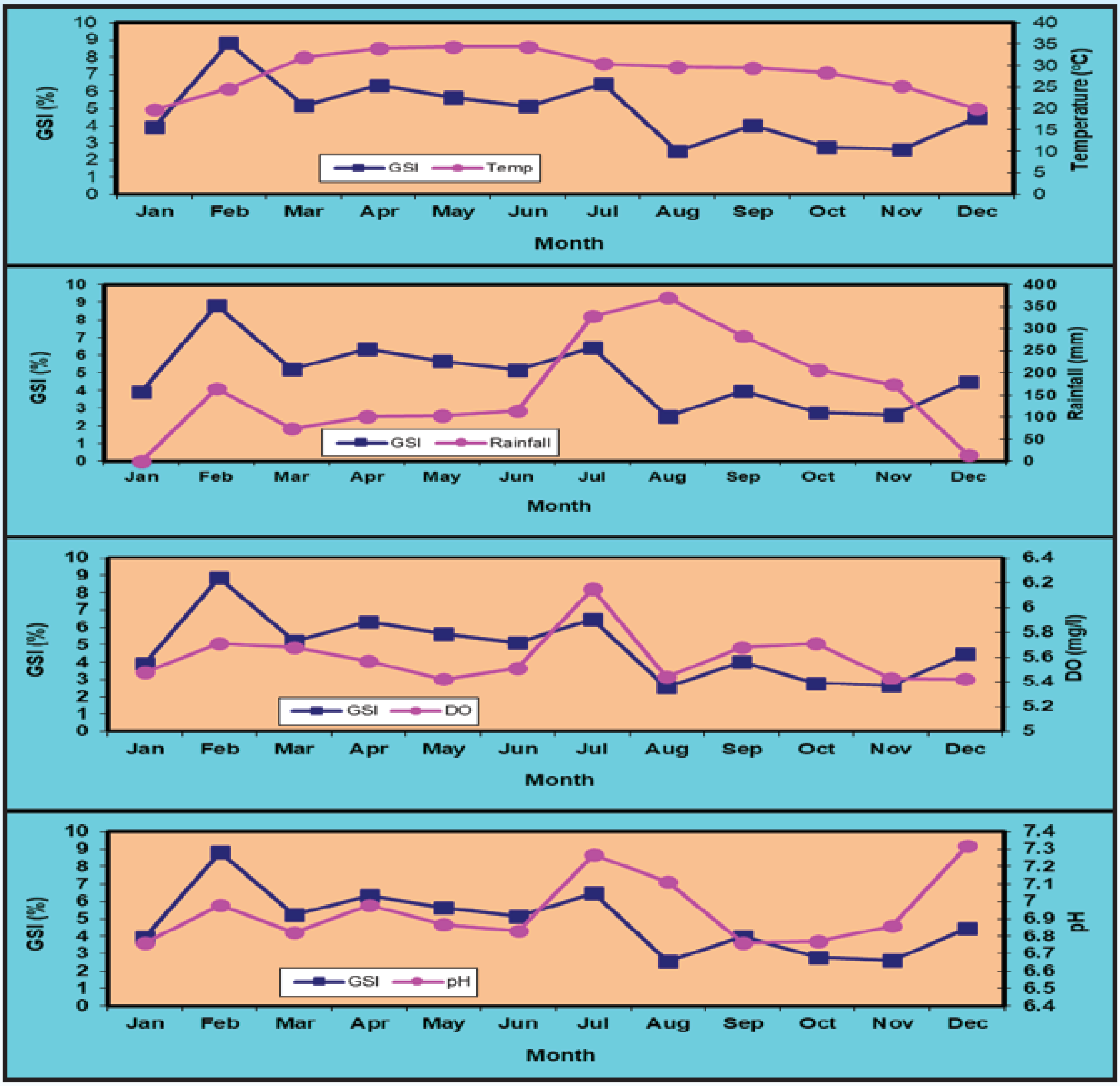


Fig 22 (b). Relationship between gonadosomatic index (GSI) with environmental factors of female *P heterolepis* in the BoB, Bangladesh

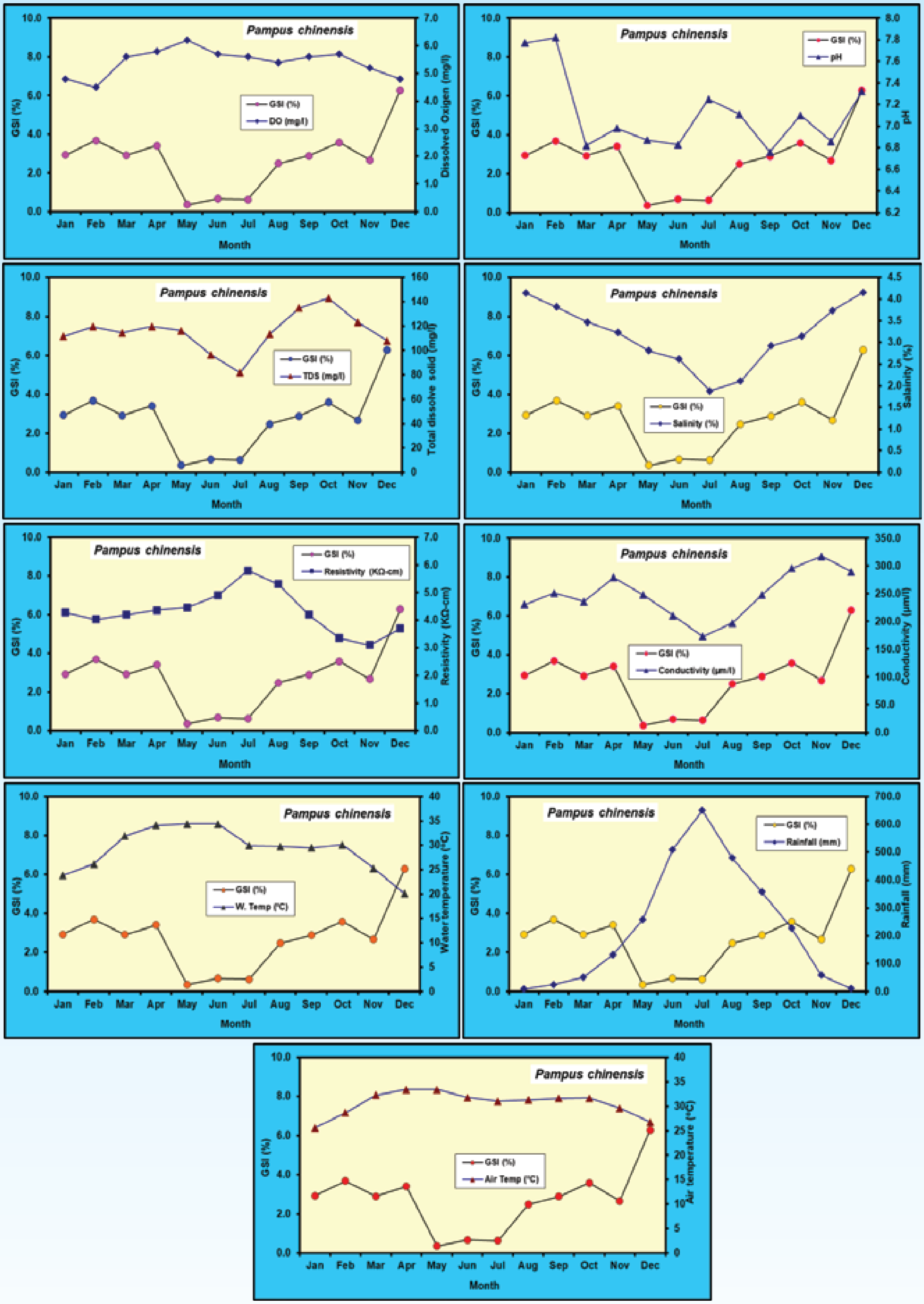


Fig 22 (c). Relationship between gonadosomatic index (GSI) with environmental factors of female *P chinensis* in the BoB, Bangladesh.

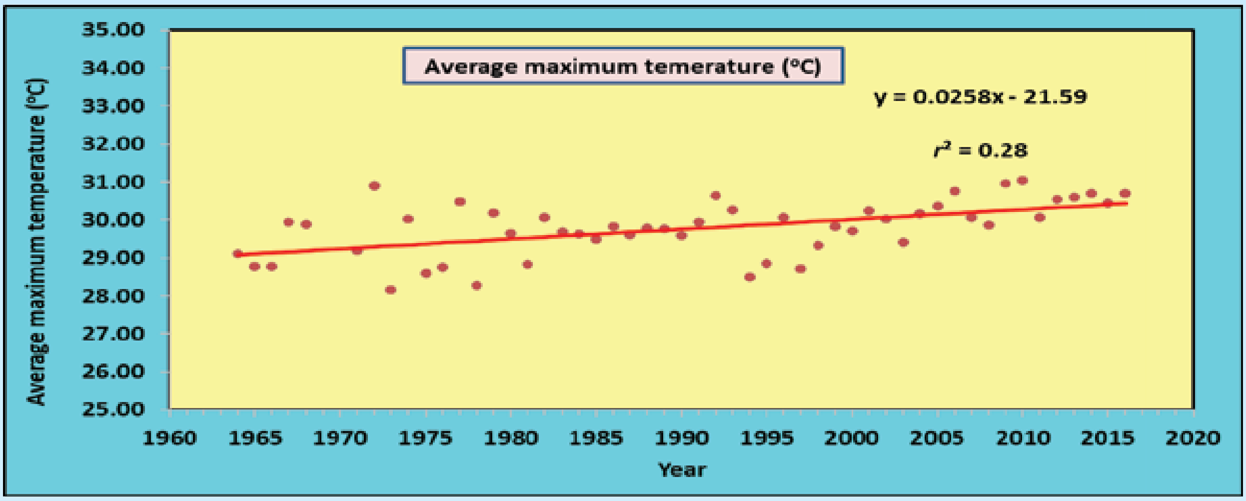


Fig 23. Annual average maximum temperature (°C) in the BoB region, Bangladesh during 1964 to 2016

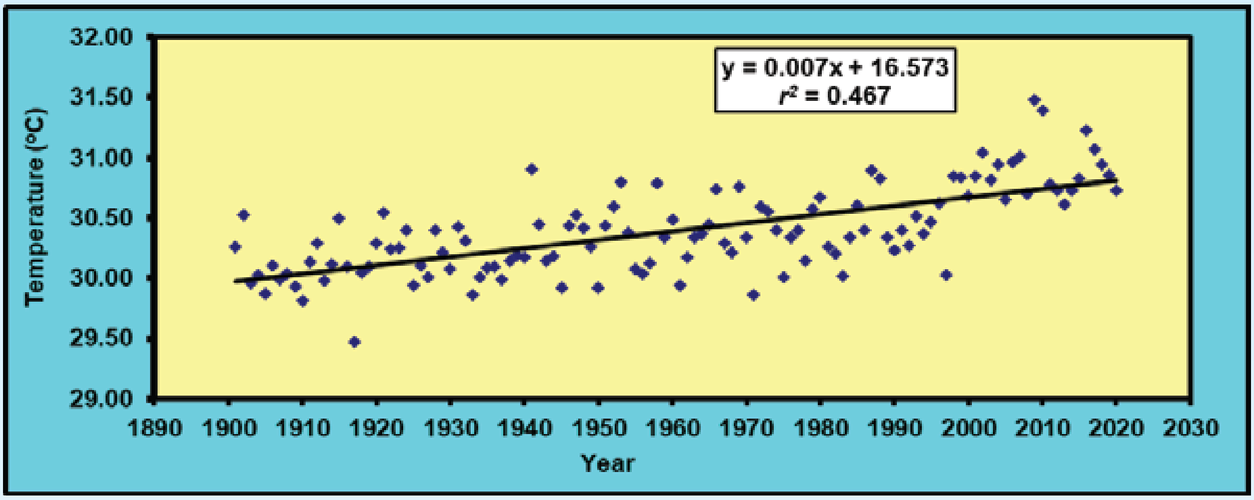


Fig 24. Annual average maximum temperature (°C) in Bangladesh during 1900 to 2020

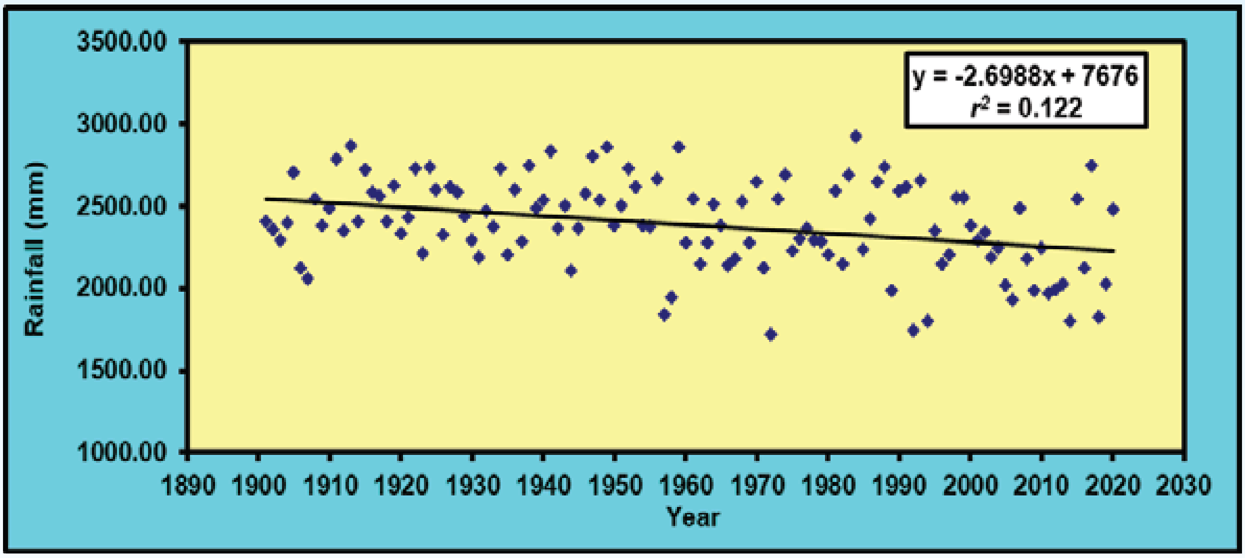


Fig 25. Annual average rainfall (mm) in Bangladesh during 1900 to 2020

11.1.2 Calculation of the growth parameters through multi-models using length-frequency analysis and then to assess the stock's status of commercially important fishes in the BoB

11.1.2.1 Population structure of commercially important marine fishes

The population structure (Fig 26) showed that, minimum and maximum length for different fishes obtained from the BoB were 51.0-105.0 cm for *L. calcarifer,* however, Patnaik and Jena (1976) reported 101.00 cm TL in the Chilka lake, India which is higher than the present study. In our study, the maximum length was 34.50 cm TL for *P. heterolepis*, which is higher than that of (Sasaki,1995). In our study, the maximum length was 38.0 cm TL for *P. chinensis*, which is lower than the recorded value of (Mustafa, 1999) from BoB. The maximum length of *E. affinis* was found 68.0 cm TL in the present study which is higher than the maximum recorded value of 35.90 cm TL in the Eastern region of Java Sea (Saleh and Soergianto, 2017).

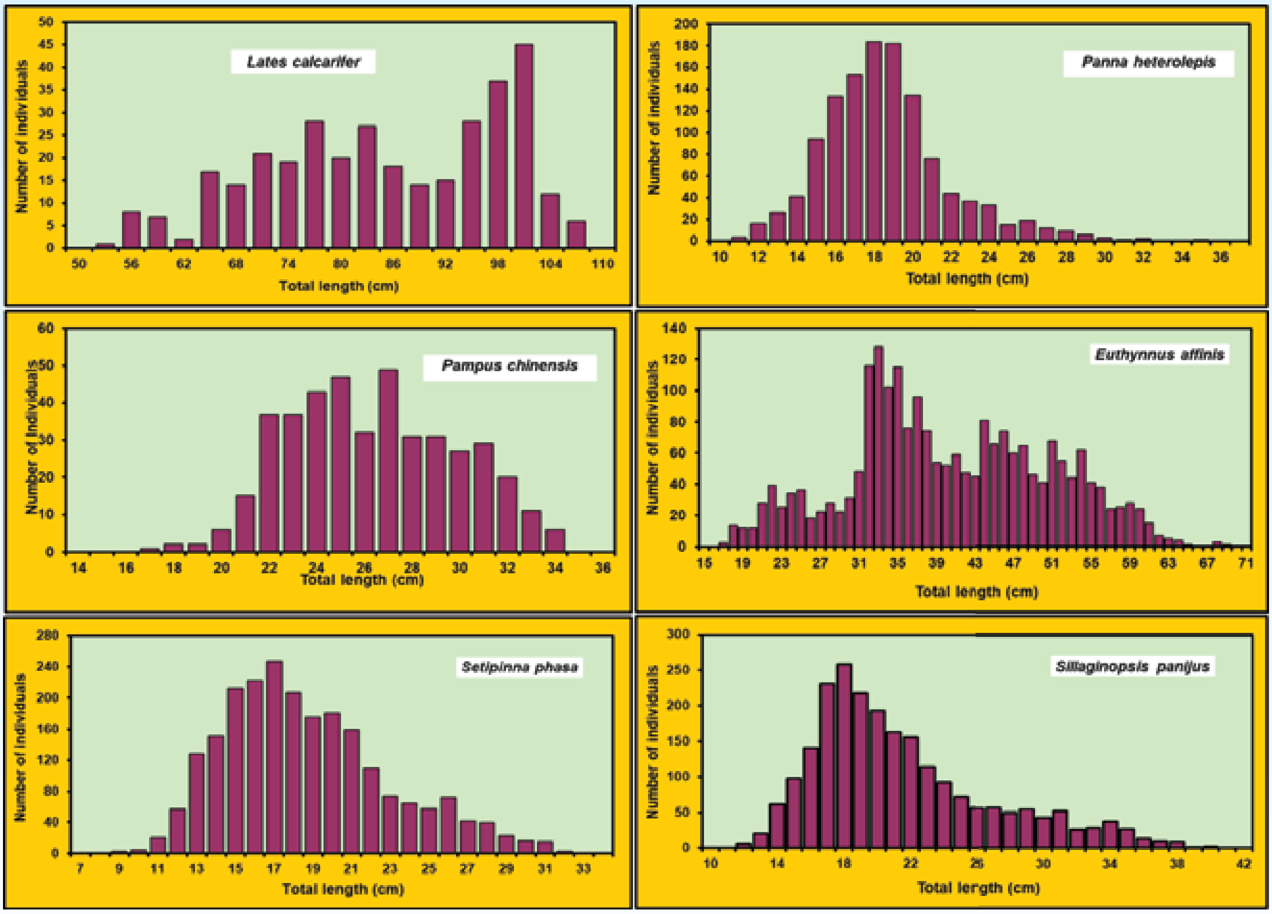
The maximum length of *S. taty* was found as 31.8 cm TL in the present study which is higher than the recorded value of 15.30 cm TL Bangladesh (Rahman, 1989). The maximum TL of *S. phasa* was 28.4 cm for combined sex which is lower than the reported value of Jhingran (1963) and Whitehead et al. (1988). Jhingran (1963) and Whitehead et al. (1988) reported that the maximum TL of this species was 32.4 cm and 40 cm, respectively. The maximum length of *S. panijus* was found as 39.4 cm TL in the present study which is higher than the value of 14.5 cm TL in the Daya Bay (Xu et al., 1994). The maximum length (TL) recorded was 37.2 cm, which is noticeably larger than from our previous Tentulia river study (34.0 cm TL)17 and the study of Siddik et al. (2015) in the Tentulia, Meghna, and Baleswar rivers (29.30, 28.7, and 27.7 cm TL, respectively (Islam, 2003; Siddik et al., 2015).

In the study, the maximum observed length of *P. paradiseus* was 23.10 cm which is higher than the recorded value of 17.10 cm (Hossain et al. 2015) from the Tentulia River, Bangladesh. The maximum length of *M. cordyla* was found as 36.6.0 cm TL in the present study which is lower than the recorded value of 69.0 cm TL in the Red Sea (Al Sakaff and Essen, 1999) and is smaller than (43.1 cm) that reported by Jaiswar and Achiarya (1991) from North-west coast of India; 40.2 cm recorded by Jadhav and Mohite (2014) from Ratnagiri coast of Maharashtra, India; 40.1 cm found by Saker et al. (2004) from Mumbai coast, India and we also reported TL of 41.0 cm from the BoB in previous year (Sarmin et al., 2021). But our observed length was higher than the 35.0 cm size that reported by Zafar et al. (2000) from BoB. In our study, the observed maximum length of *H. nehereus* was 36.6 cm which is lower than the recorded value of 38.0 cm (Biradar, 1989) from India. In our study, the maximum length was found 23.6 cm TL, which is lower than the recorded value of (Hossain et al., 2015) *C. dussumieri* (29.2 cm) from Bangladesh.

The maximum length of *T. setirostris* was found 22.0 cm TL in the present study which is higher than the maximum recorded value of 17.5 cm SL in China (Xu et al., 1994). The maximum length of *A. chacunda* was found as 27.0 cm TL in the present study which is higher than the recorded value of 22.0 cm SL in the South Pacific, New Caledonia (Randall, 2005). In our study, the maximum length of *I. megaloptera* was found 37.0 cm TL, which is higher than the recorded value of 36.50 cm SL (Mousavi-Sabet et al., 2016) from the Parsian Gulf and Oman Sea. In our study, the observed maximum length of *P. macracanthus* was 49.0 cm which is higher than the recorded value of 30.5 cm SL (Wang et al, 2011) from China. The maximum length was found 30.5 cm TL of *A. leiogaster* which is higher than the recorded value of (Rafail, 1972) from Red Sea coast.

P. macracanthus is found in southern Japan, Indonesia, Bangladesh, the Arafura Sea, Australia, and the Great Bay. It occurs in inshore and offshore reefs. Apparently, aggregations form in open bottom areas and are very abundant in the South China Sea and Andaman Sea. The maximum length is recorded 30.0 cm (SL). *P. paradiseus* is distributed in the west coast of the India Ocean to Thailand. It is probably present in Malaysia and Laos. It enters freshwaters during the breeding season. The maximum length is recorded 30.0 cm (SL). *I. megaloptera* is mostly found in the Indian Ocean and the Java Sea (Singapore). It is an inshore species but also is present in rivers (Ganges at Allahabad and rivers of eastern Uttar Pradesh, but not in Velar estuary). The maximum length is recorded 36.5 cm (SL). *S. taty* is mostly found in the BoB south to Penang, Thailand south to Java, and southern Kalimantan. A schooling species found mainly in coastal waters, but also found entering estuaries. The maximum length is recorded 15.3 cm (TL). *Coilia ramcarati* is widely distributed in Ganges delta and Andaman Sea south of Rangoon. A schooling species found in coastal waters and estuaries. The maximum length is 25.0 cm (TL). *C. dussumieri* is found in India, Myanmar, Thailand, and Malaysia. It is present in saline water. The maximum length is 20.0 cm (SL). *T. setirostris* is mostly found in the Indian Ocean from Gulf of Oman south to Port Alfred, Madagascar, coasts of Pakistan, India, Thailand, Indonesia, the Philippines, Taiwan, Papua New Guinea, Solomon Islands, and New Hebrides. This fish inhabited marine, pelagic, and presumably schooling, presenting mostly close inshore, entering bay sand estuaries. The maximum length is 18.0 cm (SL) (Froese and Pauly 2022).

The variation in the fishing gear used and the selectivity on the target species may greatly influence the size distribution of the individuals caught resulting in highly biased estimations of the various populatioon parameter including the maximum size. Information on maximum length /size is essential to calculate population parameters including asymtotic length and growth coefficient of fishes, which is vaital for fisheries resource conservation and management. The maximum length is necessary to estimate population parameters important for fishery resource planning and management (Hossain, 2010). Size differences might be attributed to variations in environmental factors, geographical distribution, particularly water temperature and food availability (Hossain and Ohtomi 2010).



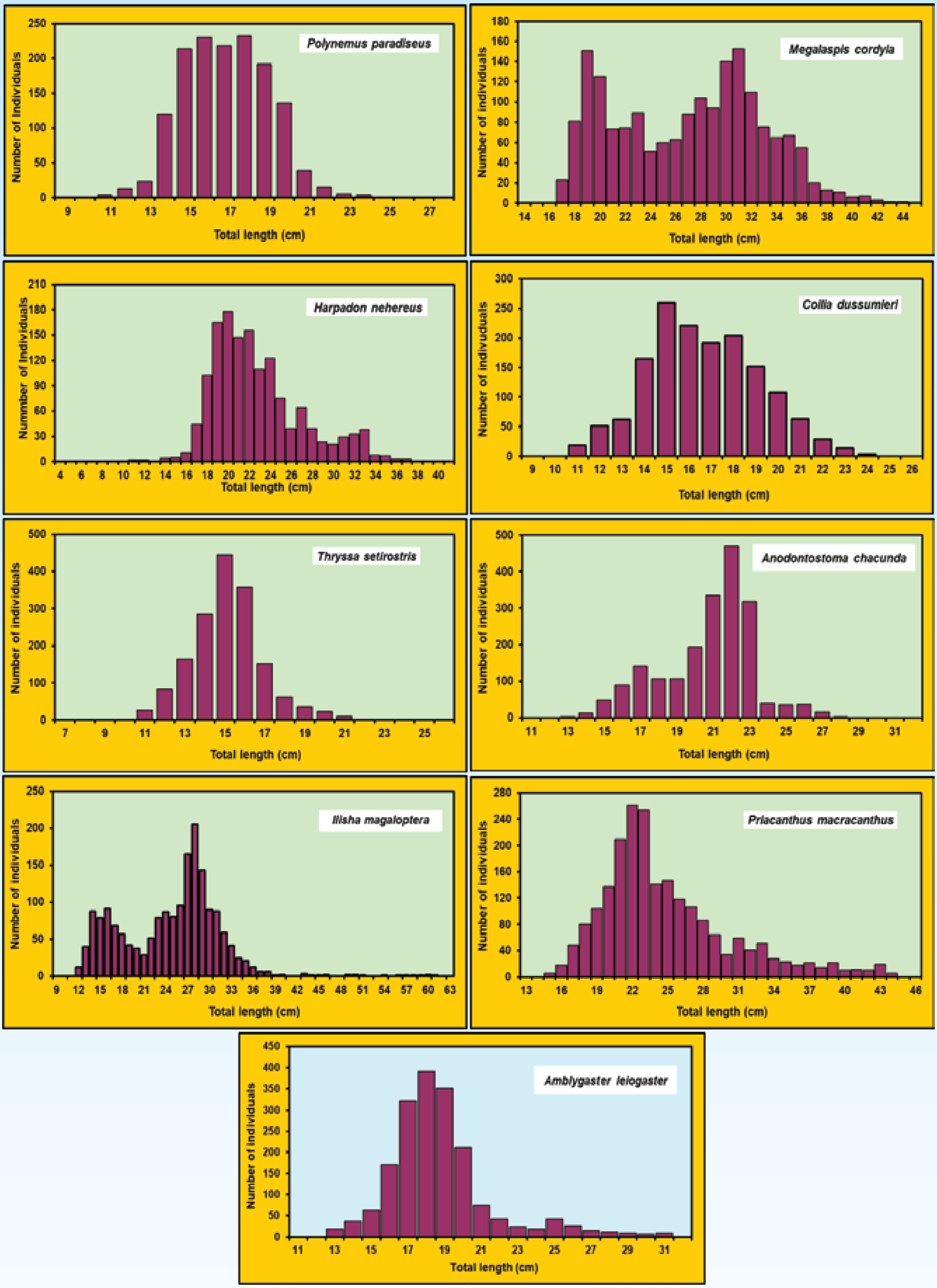


Fig 26. Length frequency distribution of commercially important fishes from the BoB, Bangladesh.

11.1.2.2 Growth pattern and form factor ($a_{3.0}$)

Growth pattern of 15 commercially important marine fishes of the BoB were determined from the calculation of length weight relationship (Table 21 and Fig 27). Generally, *b* values near 3 indicate that fish growth is isometric, else growth is allometric (> 3 indicates positive allometry and < 3 indicates negative allometry)

From these calculation, positive allometric growth was found for *L. calcarifer* (*b* = 2.82) which is similar growth pattern with (Akel and Karachle, 2017) (*b* = 2.48) and also similar result was observed by Patnaik and Jena 1976 from the Chilka lake, India (*b* = 2.92); for *P. heterolepis* (*b* = 2.83) growth pattern was found negative allometric in this study. There were no available literatures on this species so it was not possible to compare with other study. For *P. chinensis* (*b* = 3.07) growth pattern is similar with (Mustafa, 1999) in BoB, Bangladesh. For *E. affinis* (*b* = 3.12) isometric growth pattern was found, whereas negative (*b* = 2.78) growth recorded by (Saleh and Soegianto, 2017) in the eastern Region of Java Sea.

Additionally, negative allometric growth was found for *S. taty* (*b* = 3.02). The previous recorded *b* was recorded 3.09 at Mathabhanga River, southwestern Bangladesh (Hossain *et al.*, 2006) which is close to the previous value. For *S. panijus* (*b* = 3.18) positive growth pattern was found, whereas negative (*b* = 2.78) growth recorded by (Xu et al., 1994) in the Daya Bay. For *P. paradiseus* (*b* = 3.18) positive allometric growth was found which is similar (*b* = 3.23) with (Hossain et al, 2015) in the Tentulia River, Bangladesh. Negative allometric growth was found for *M. cordyla* (*b* = 2.63), similar result recorded by (Al Sakaff and Essen,1999) and Biradar (1989) but dissimilar for *H. nehereus* (*b*=3.63). The overall *b* value for combined sex was also negative allometric reported by Reuben et al. (1992) from east, north-west and south-west coast of India (*b* = 2.94, 2.52, 2.72); Saker et al. (2004) from Mumbai coast, India (*b* = 2.88); Das *et al*. (2014) from Tanjung Sepat, Selangor, Malaysia (*b* = 2.64); and Zafar et al. (2000) from BoB (*b* = 2.82) for *M. cordyla*. But dissimilarity found by Oktaviani *et al*. (2020) reported positive allometric growth from Java Sea, Indonesia (*b* = 3.15). The positive allometric growth was found for *C. dussumieri* (*b* =3.32) which is similar with (Hossain et al., 2015) from the Tetulia River, Bangladesh. For *T. setirostris* (*b* =2.54) negative growth pattern was found in this study whereas positive (*b*=3.12) growth recorded by (Xu et al., 1994) in China. The *b* value of *T. setirostris* from different water bodies of Australia, China, and India were higher (2.945–3.637) than our present finding (Willing and Pender, 1989; Xu et al., 1994; Harrison, 2001; Roul et al., 2020). *A. chacunda* (*b*=3.03), *I. megaloptera* (*b*=2.94) and *P. macracanthus* exhibited negative growth (*b*=2.81) which is similar with (Mousavi-Sabet et al. (2016) and Wang et al (2011). For *A. leiogaster* (*b* =2.27) negative growth pattern was found whereas positive (*b*=3.14) growth recorded by Rafail, 1972 in the eastern Red coast Sea.

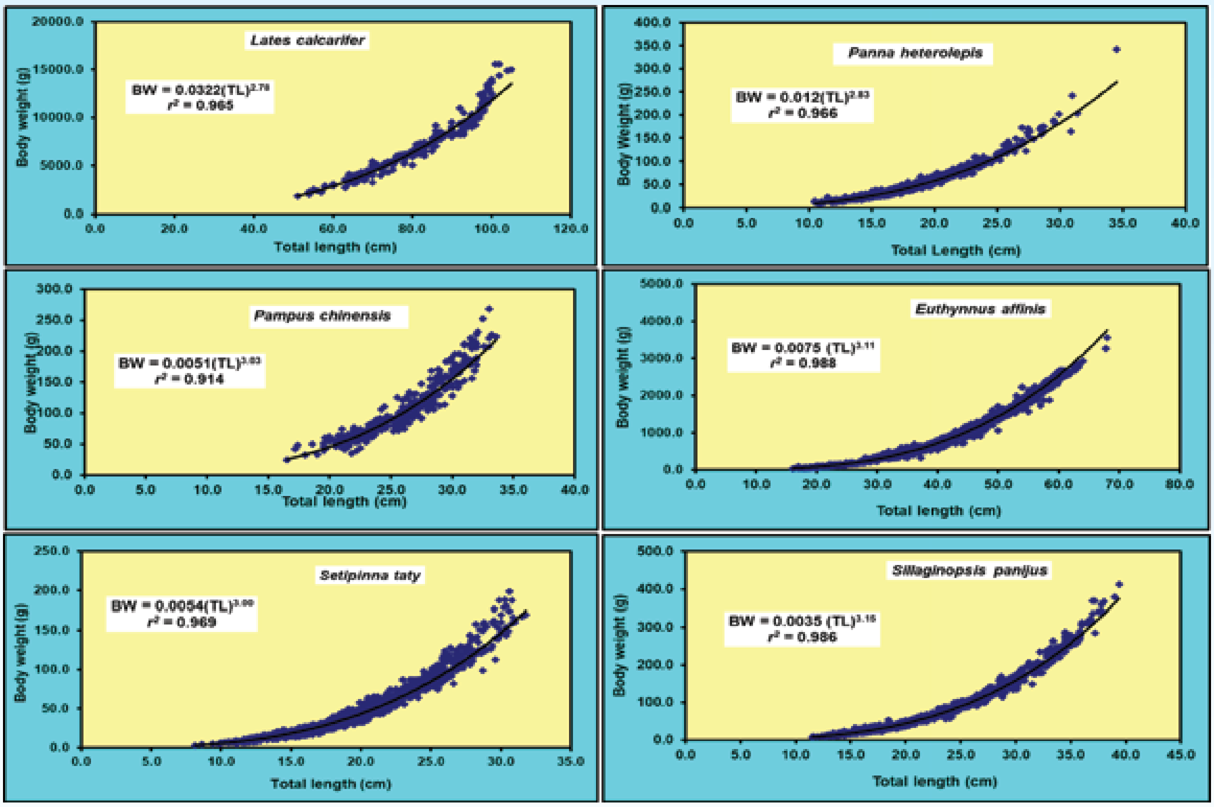
However, the *b* values may vary in the same species due to mixture of one or more factors including variations of growth in different body parts, sex, physiology, preservation methods, and differences in the observed length ranges of collected specimens (Tesch, 1971; Hossen et al., 2018; Nawer et al., 2017), which were not counted during this study.

The calculated form factor for *P. heterolepis* was 0.0071. It was not possible to find any references for the form factor of *P. heterolepis*, making it difficult to compare the findings of the present study. The form factor ($a_{3.0}$) was observed as 0.0097 for *M. cordyla* in the BoB (Table 8). The world-wide calculated form factor ($a_{3.0}$) for *M. cordyla* were found between 0.0069- 0.0182 (Sarmin et al., 2021) with a mean of 0.0116 (mean ± SD = 0.0116 ± 0.0032). The median and mode of $a_{3.0}$ was 0.0102. Based on Froese's (2006) establishment, *M. cordyla* has the typical body shape 'fusiform' relying on median 0.0137 and 95% confidence limit (0.0099-0.0132). Literature on form factor is not available for those species. Estimated form factor and their comparisons are snapshot pictures which is useful for fisheries management.

Table 21. Descriptive statistics and estimated parameters of the length-weight relationships (BW= $a \times TL^{b}$) and form factor ($a_{3.0}$) commercially important fishes from the BoB, Bangladesh

Sl. No.	Species Name	Regression parameters		95% CL of *a*	95% CL of *b*	r^2	$a_{3.0}$
		a	*b*				
01	*L calcarifer*	0.0322	2.78	0.0252 - 0.0412	2.73 - 2.84	0.965	0.0146
02	*P heterolepis*	0.0120	2.83	0.0110 - 0.0131	2.80 - 2.86	0.966	0.0071
03	*P chinensis*	0.0051	3.03	0.0039 - 0.0069	2.94 - 3.12	0.914	0.0057
04	*E affinis*	0.0072	3.12	0.0069 - 0.0076	3.11 - 3.13	0.989	0.0104
05	*S taty*	0.0051	3.02	0.0047 - 0.0055	3.00 - 3.05	0.967	0.0054
06	*S panijus*	0.0035	3.15	0.0033 - 0.0037	3.14 - 3.17	0.987	0.0055
07	*P paradiseus*	0.0046	3.11	0.0039 - 0.0055	3.05 - 3.18	0.858	0.0063
08	*M cordyla*	0.0309	2.63	0.0287 - 0.0333	2.61 - 2.65	0.970	0.0097
09	*H nehereus*	0.0007	3.63	0.0006 - 0.0009	3.57 - 3.68	0.934	0.0050
10	*C dussumieri*	0.0014	3.32	0.0013 - 0.0016	3.28 - 3.36	0.943	0.0038
11	*T setirostris*	0.0271	2.54	0.0242 - 0.0303	2.50 - 2.58	0.910	0.0064
12	*A chacunda*	0.0083	3.16	0.0074 - 0.0094	3.12 - 3.20	0.928	0.0069
13	*I megaloptera*	0.0089	2.94	0.0077 - 0.0099	2.90 - 2.98	0.932	0.0073
14	*P macracanthus*	0.0207	2.81	0.0189 - 0.0225	2.78 - 2.84	0.949	0.0113
15	*A leiogaster*	0.0786	2.27	0.0576-0.0947	2.17-2.26	0.869	0.0080

a and *b*; regression parameters of LWRs; CL, confidence limits; r^2, co-efficient of determination



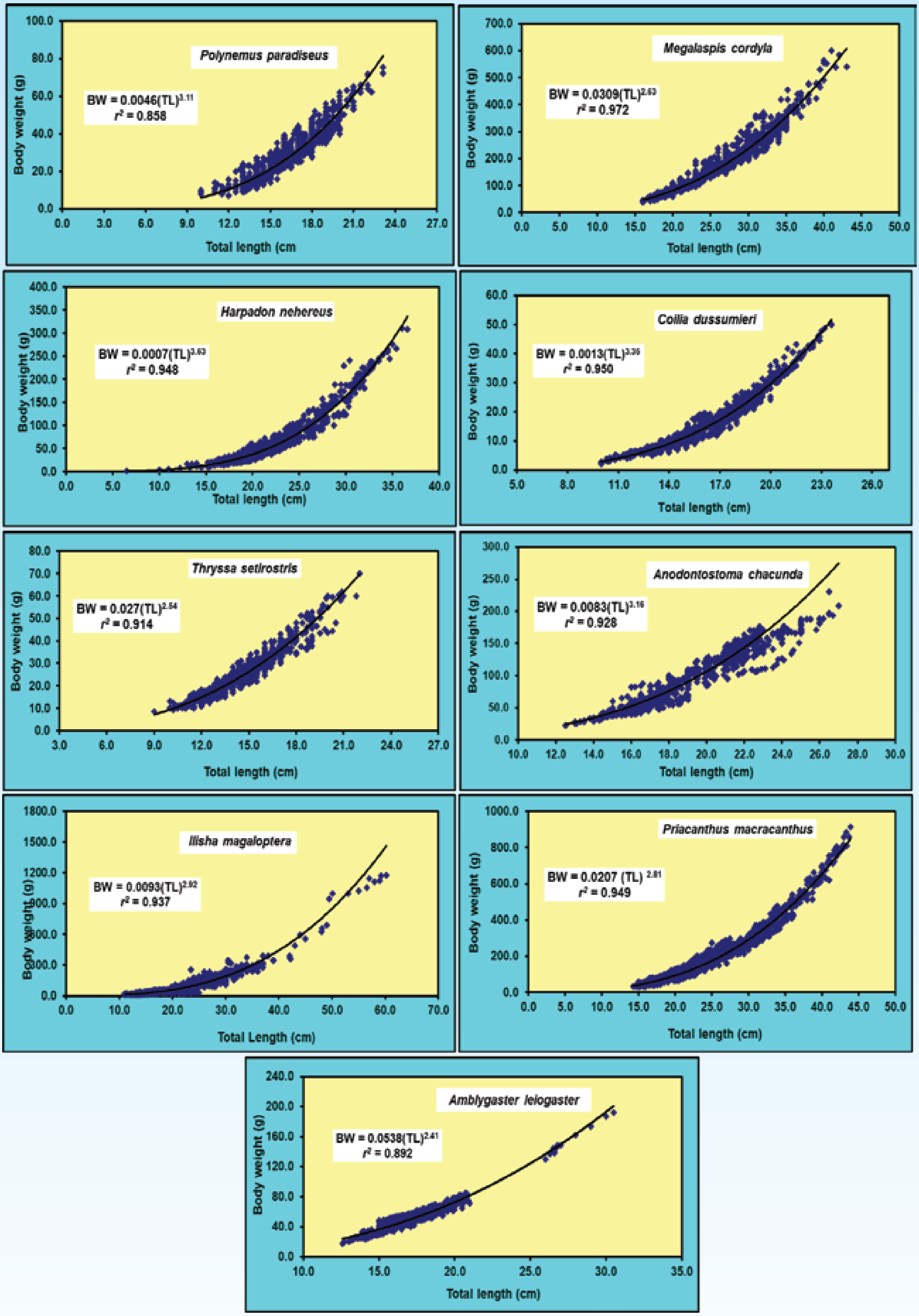


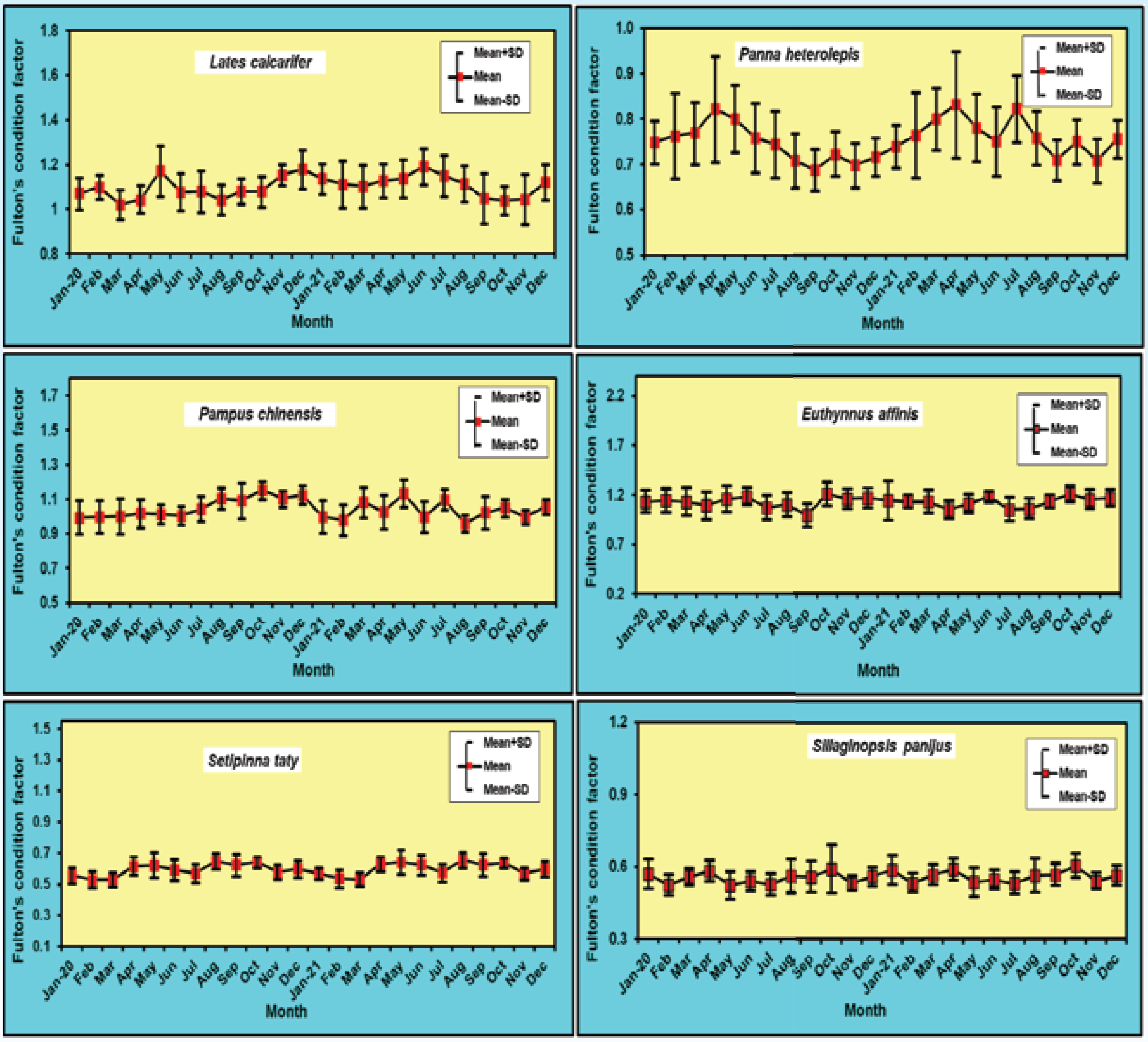
Fig 27. Growth pattern through length weight relationship of commercially importantfishes from the BoB, Bangladesh

11.1.2.3 Condition factors of commercially important fishes

During the present study, we have worked on four condition factors (K_A, K_F and K_R) to assess the physical and environmental condition of 15 commercially important marine fishes in the BoB. The values of all condition factors (K_A, K_F, and K_R) are given in Table 22. It can be assumed that, the Fulton′s condition factor (K_F) is the best for determining the wellbeing of commercially important marine fishes in the BoB. Therefore, Monthly variation of Fulton's condition factor showed in Fig 28.

Information on condition factor of *P. heterolepis* is inadequate in literature elsewhere. Consequently, the present study is the first effort to describe condition factor as well as relative weight of *P. heterolepis* and other commercially important marine fishes in the the BoB (SW) Bangladesh.

Condition factor indicates the status of well-being of a fish population in their natural ecosystem (Hossain et al., 2012). Besides, it reveals several bio-ecological interactions i.e., level of fitness, maturity status and impassableness of a habitat with respect to feeding behavior (Hossen et al., 2019). Moreover, the condition value is a widespread biological index for fish which specifies the overall health of a stock (Richter, 2007). The higher value of condition factor indicates that the fish are in better condition (Hossain et al., 2017).



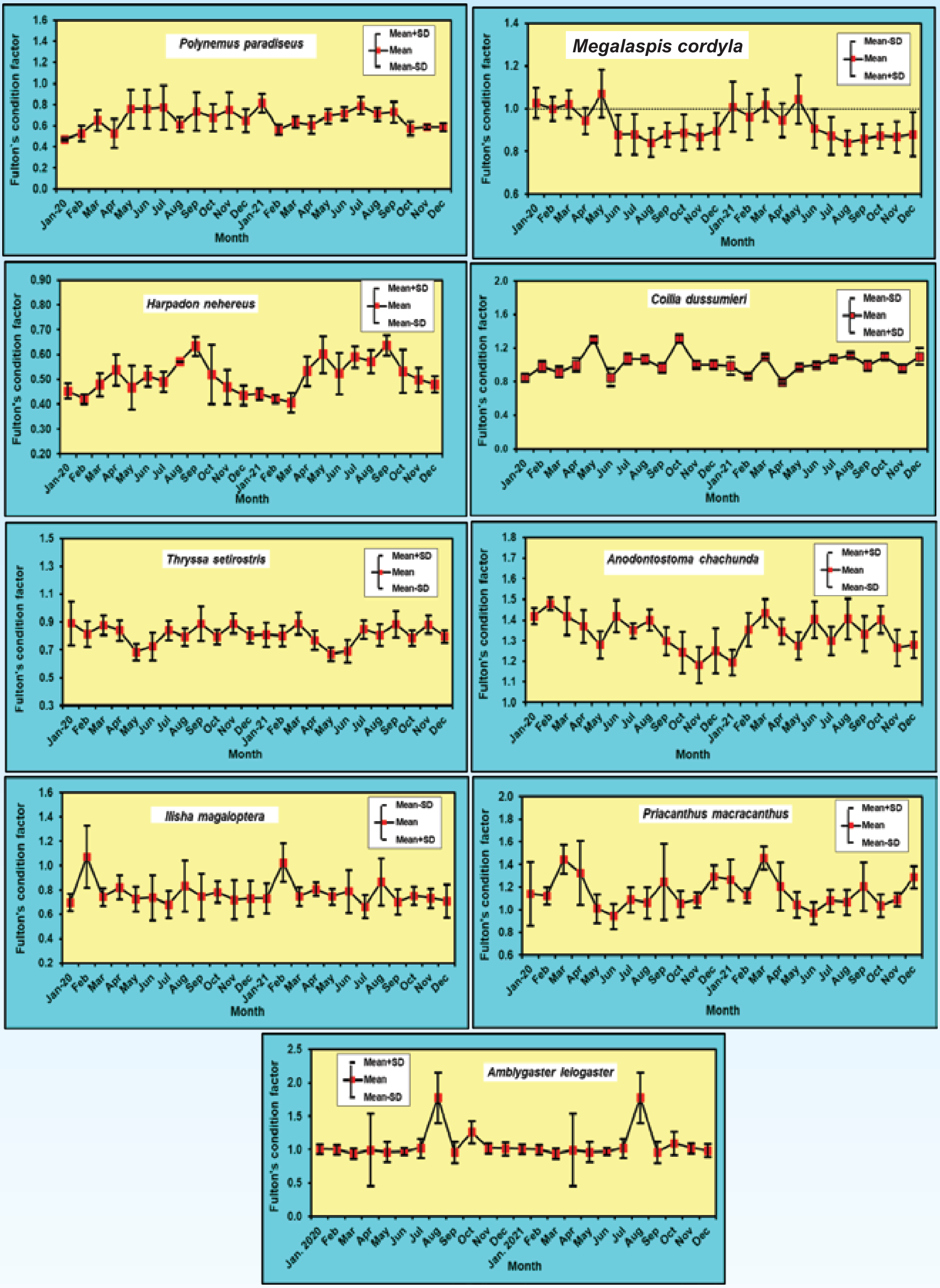


Fig 28. Monthly variation of Fulton's condition factor (Best condition factor) of commercially important fishes from the BoB, Bangladesh

Table 22. Estimation of condition factors of commercially important fishes in the BoB, Bangladesh

Sl. No.	Species Name	Fulton's condition factor (K_F)				Allometric condition factor (K_A)				Relative condition factors (K_R)			
		Min	Max	Mean ± SD	95% CL	Min	Max	Mean ± SD	95% CL	Min	Max	Mean ± SD	95% CL
01	*L calcarifer*	0.948	1.586	1.250±0.119	1.238 - 1.269	0.0204	0.0347	0.0276±0.0025	0.0274 - 0.0279	0.743	1.268	1.008±0.090	0.999 - 1.018
02	*P heterolepis*	0.560	1.451	0.743±0.077	0.739 - 0.747	0.0091	0.0219	0.0120±0.0012	0.0120 - 0.0121	0.756	1.824	1.004±0.098	1.000 - 1.009
03	*P chinensis*	0.338	0.911	0.584±0.077	0.576 - 0.592	0.0027	0.0075	0.0047±0.0006	0.0046 - 0.0047	0.579	1.587	0.992±0.131	0.978 - 1.006
04	*E affinis*	0.651	1.934	1.121±0.112	1.116 - 1.126	0.0042	0.0138	0.0073±0.0007	0.0072 - 0.0073	0.588	1.917	1.009±0.098	1.005 - 1.014
05	*S taty*	0.351	0.768	0.545±0.061	0.542 - 0.548	0.0033	0.0073	0.0051±0.0007	0.0051 - 0.0052	0.654	1.425	1.003±0.128	0.998 - 1.009
06	*S panijus*	0.387	0.907	0.554±0.057	0.552 - 0.557	0.0023	0.0056	0.0033±0.0003	0.0032 - 0.0033	0.725	1.747	1.016±0.096	1.012 - 1.020
07	*P paradiseus*	0.401	1.052	0.641±0.112	0.635 - 0.648	0.0025	0.0068	0.0039±0.0007	0.0038 - 0.0039	0.656	1.798	1.025±0.179	1.014 - 1.035
08	*M cordyla*	0.659	1.553	0.951±0.132	0.944 - 0.958	0.0220	0.0496	0.0312±0.0035	0.0310 - 0.0313	0.711	1.603	1.008±0.112	1.003 - 1.014
09	*H nehereus*	0.288	0.865	0.503±0.103	0.497 - 0.509	0.0004	0.0014	0.0007±0.0001	0.0006 - 0.0007	0.639	2.067	1.034±0.182	1.03 - 1.044
10	*C dussumieri*	0.210	0.492	0.346±0.048	0.343 - 0.348	0.0009	0.0021	0.0014±0.0002	0.0013 - 0.0014	0.662	1.503	1.009±1.131	1.002 - 1.015
11	*T setirostris*	0.531	1.300	0.797±0.089	0.793 - 0.802	0.0200	0.0375	0.0270±0.0026	0.0269 - 0.0272	0.737	1.383	0.998±0.095	0.993 - 1.003
12	*A chacunda*	0.871	2.026	1.351±0.148	1.344 - 1.359	0.0079	0.0186	0.0123±0.0013	0.0123 - 0.0124	0.639	1.504	0.996 ± 0.109	0.991 - 1.001
13	*I megaloptera*	0.188	1.973	0.741±0.161	0.733 - 0.749	0.0023	0.0238	0.0089±0.0019	0.0089 - 0.0090	0.259	2.709	1.017±0.219	1.006 - 1.028
14	*P macracanthus*	0.766	1.760	1.143±0.175	1.135 - 1.151	0.0122	0.0296	0.0191±0.0028	0.0190 - 0.0192	0.648	1.569	1.010±0.147	1.003 - 1.017
15	*A leiogaster*	0.500	1.420	0.990 ±0.110	0.980 - 0.989	0.0520	0.1021	0.0789±0.0067	0.0785 - 0.0793	0.660	1.300	1.000 ± 0.078	0.990 - 1.001

Min, minimum; Max, maximum; SD, standard deviation; CL, confidence limit for mean value

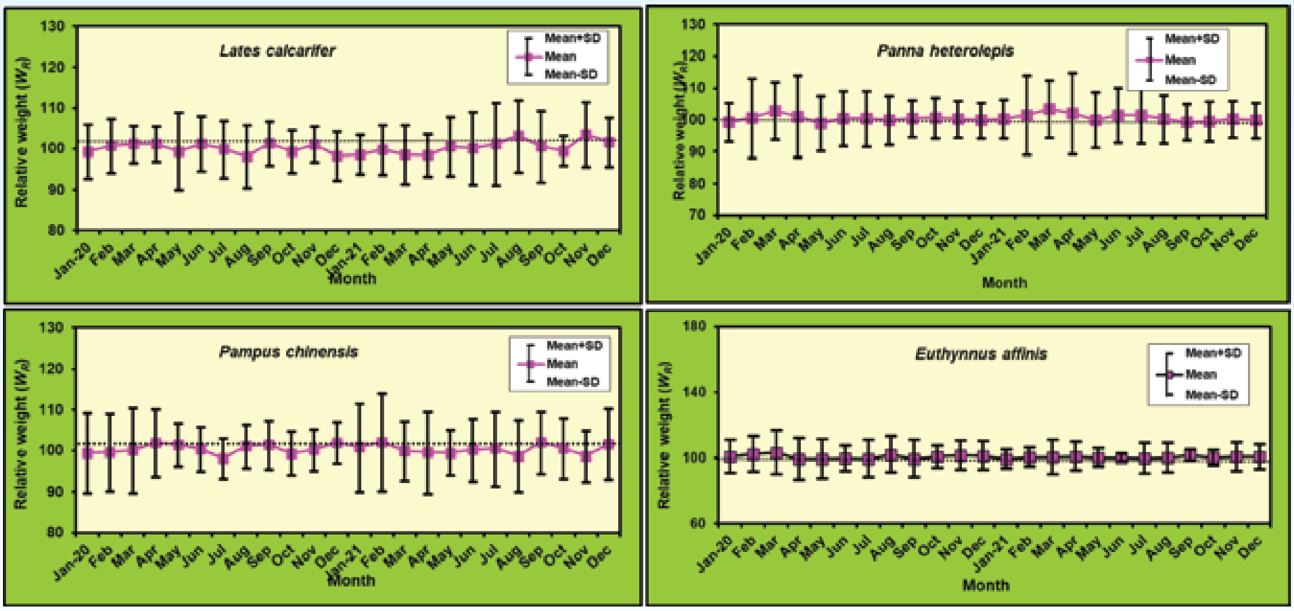
11.1.2.4 Relative weight (W_R)

During the present study, we have worked on relative weight (W_R) to assess the prey-predator status of 15 commercially important marine fishes in the BoB (Table 23). Wilcoxon signed rank test specify that W_R was not significantly different from 100 indicating the population of studied commercially important marine fishes was in balanced condition with availability of food and lower predators (Fig 29).

Table 23. Estimated relative weight (W_R) of commercially important fishes from the BoB, Bangladesh

Sl. No.	Species Name	Min	Max	Mean ± SD	95% CL
01	*L calcarifer*	74.93	129.79	101.38 ± 9.04	100.47 – 102.30
02	*P heterolepis*	75.60	182.41	100.41 ± 9.78	99.86 – 100.96
03	*P chinensis*	60.39	163.99	102.37 ± 13.22	101.11 – 103.63
04	*E affinis*	58.40	189.05	100.86 ± 9.72	100.45 – 101.26
05	*S taty*	64.99	142.26	101.15 ± 12.58	100.64 – 101.67
06	*S panijus*	72.53	174.66	101.62 ± 9.65	101.20 – 102.05
07	*P paradiseus*	65.60	179.77	102.47 ± 17.97	101.44 – 103.50
08	*M cordyla*	71.08	160.38	100.83 ± 11.20	100.26 – 101.40
09	*H nehereus*	63.93	206.73	103.40 ± 18.23	102.35 – 104.44
10	*C dussumieri*	66.19	150.30	100.86 ± 13.10	100.21 – 101.51
11	*T setirostris*	73.67	138.35	99.79 ± 9.50	99.29 – 100.30
12	*A chacunda*	63.30	156.67	99.95 ± 11.15	99.46 – 100.45
13	*I megaloptera*	26.16	273.05	102.45 ± 21.29	101.46 – 103.43
14	*P macracanthus*	64.76	156.86	100.99 ± 14.68	100.33 – 101.66
15	*A leiogaster*	66.22	129.91	100.43 ± 8.53	99.93 – 100.93

Min, minimum; Max, maximum; SD, standard deviation; CL, confidence limit for mean values



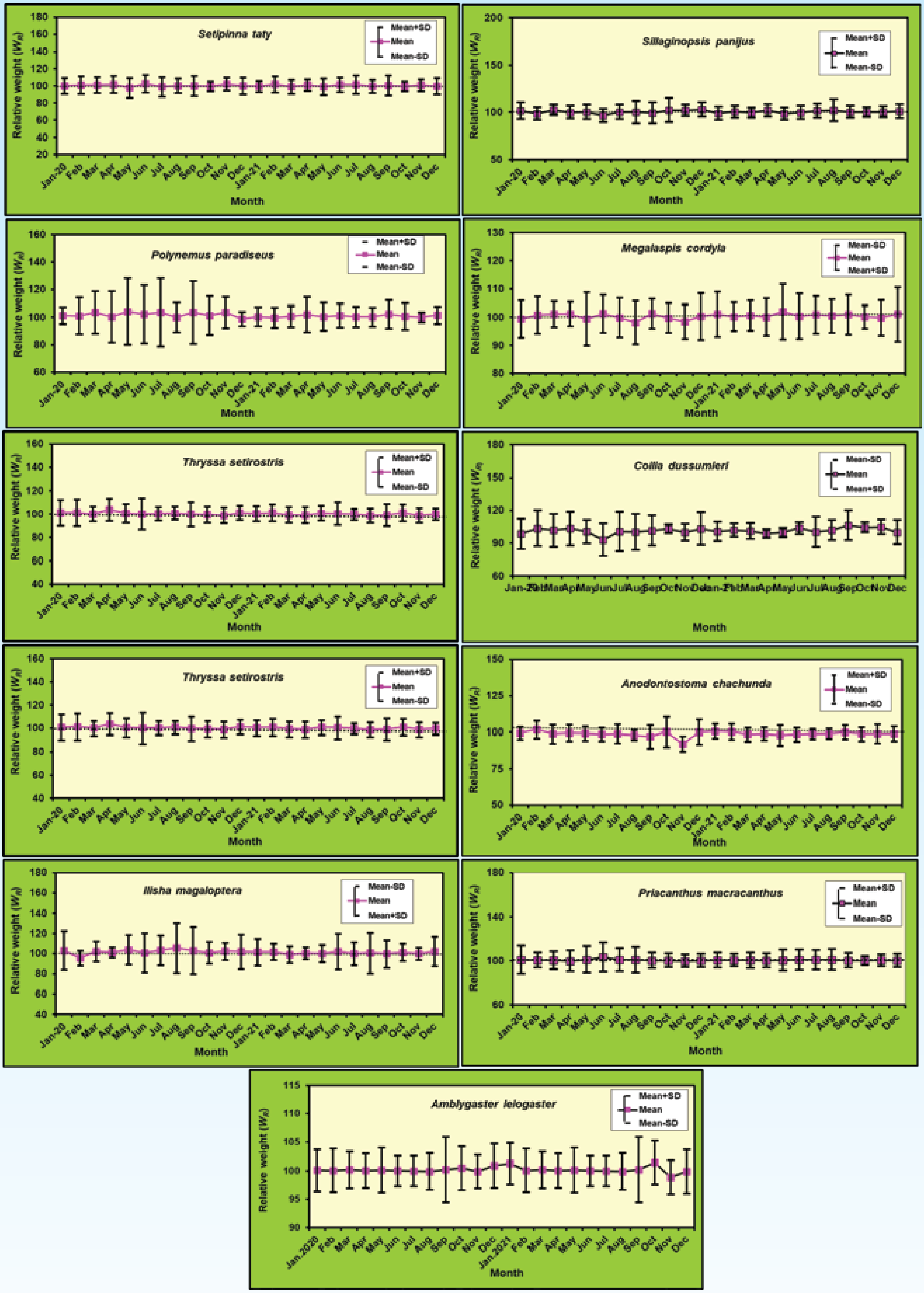


Fig 29. Monthly variation of relative weight (W_R) of commercially important fishes from the BoB, Bangladesh

11.1.2.5 Growth parameters of commercially important fishes

To assess the stock's status of commercially important fishes in the BoB, growth parameters through multi-models using length-frequency analysis presented in Table 24.

Table 24(a). Growth parameters obtained from fitting von Bertalanffy models based on maximum total lengths of commercially important fishes from the BoB, Bangladesh.

Sl. No	Species	L_{max} (cm)	L_∞ (cm)	K ($year^{-1}$)	ϕ	t_0 (year)	t_{max} (year)	L_m (cm)	L_{opt} (cm)
1.	*L calcarifer*	105.0	107.91	1.26	4.17	0.006	2.38	53.94	69.90
2.	*P heterolepis*	34.50	36.09	1.08	3.15	0.011	2.79	19.47	22.32
3.	*P chinensis*	38.00	39.69	1.00	3.20	0.013	3.00	21.27	24.65
4.	*E affinis*	68.00	70.37	1.16	3.76	0.007	2.59	36.24	44.77
5.	*S taty*	31.80	33.31	1.08	3.08	0.012	2.79	18.07	20.53
6.	*S panijus*	39.40	41.13	1.10	3.27	0.011	2.73	21.98	25.58
7.	*P paradiseus*	23.10	24.32	1.03	2.78	0.014	2.90	13.48	14.79
8.	*M cordyla*	41.00	42.77	1.10	3.10	0.010	2.73	22.80	26.64
9.	*H nehereus*	36.00	37.63	1.09	3.19	0.011	2.76	20.24	23.32
10.	*C dussumieri*	23.60	24.84	1.03	2.80	0.014	2.90	13.75	15.12
11.	*T setirostris*	22.00	23.18	1.03	2.74	0.015	2.90	12.89	14.07
12.	*A chacunda*	27.00	28.35	1.05	2.93	0.013	2.86	15.55	17.36
13.	*I megaloptera*	37.00	38.66	1.09	3.21	0.011	2.76	20.75	23.98
14.	*P macracanthus*	49.00	50.97	1.12	3.46	0.009	2.69	26.84	31.99
15.	*A leiogaster*	30.50	31.97	1.06	3.03	0.012	2.83	17.39	19.67

Table 24(b). Growth parameters of commercially important fishes from the BoB, Bangladesh obtained from FiSAT II analysis

Species	L_∞ (cm)	K ($year^{-1}$)	ϕ	Species	L_∞ (cm)	K ($year^{-1}$)	ϕ
L. calcarifer	114.50	0.87	4.06	*H. nehereus*	37.95	0.87	3.10
P.a heterolepis	39.08	0.13	2.30	*C.dussumieri*	24.50	0.80	2.68
P.s chinensis	34.0	0.94	3.04	*T. setirostris*	23.40	0.94	2.71
E. affinis	65.40	0.59	3.40	*A. chacunda*	29.30	0.24	2.31
S. taty	33.00	0.45	2.69	*I. megaloptera*	38.65	0.80	3.08
S. panijus	42.60	0.31	2.75	*P. macracanthus*	43.80	0.38	2.86
P. paradiseus	25.20	1.22	2.89	*A. leiogaster*	32.0	0.45	2.66
M. cordyla	42.50	1.23	3.35				

The previously estimated K and Ø value for *L. calcarifer* was 1.82 & 3.42 from Thailand, 0.296 & 3.35 from Australia, 0.187 & 3.38 from the Papua New Guinea, respectively (Froese and Pauly, 2022). The earlier estimated K and Ø value for *P. chinensis* was 0.670, & 2.99 from the BoB, Bangladesh. L_∞ estimated by Khan (2004) was 81.7 cm for *E. affinis* from India while the K and Ø value was 0.79, 3.72 respectively. From the Hoogly-Mattah estuary (lower Sundarbans) L_∞ estimated 20.5 cm for *S. taty* while the K and Ø value was 0.332, 2.14 respectively (Pauly, 1978). The previously estimated K and Ø value for *S. panijus* was 0.054 & 3.10 respectively (Krishnaya, 1963) from the Hooghly estuary, BoB, India. The earlier estimated K and Ø value for *M. codryla* respectively was 0.380 & 2.76 from Taiwan, 0.360 & 2.88 from India respectively (CIMFRI, 2003).

The L_∞ estimated by Biradar (1989) was 39.0 cm for *H. nehereus* from India while the K and Ø value was 0.530 & 2.91 respectively. The previously estimated K and Ø value was 1.50 & 2.95 from Katubdia channel, Bangladesh, 0.560 & 2.88 in Gujarat, India respectively. Fernandez and Devaraj (1996) estimated L_∞, K & Ø (25.6 cm TL, 1.210 & 2.90) for *C. dussumieri* from the northwest coast of India. Hu et al. (2015) estimated L_∞, K & Ø were (19.1 cm TL, 0.41 & 2.17 respectively) for *T. setirostris* from Taiwan. The previous estimated L_∞, K & Ø (20.8 cm TL, 0.869 & 2.58) for *A. chacunda* from the Godavary estuary, India. The previous estimated L_∞, K & Ø were (32.0 cm TL, 0.70 & 2.86 respectively) for *P. macracanthus* from the South China sea (Lester and Watson, 1985).

We estimated L_∞ higher than our largest specimen might be attributed to von Bertalanffy model being insufficient for determining the growth of fish species because fish do not grow linearly (Vigliola et al., 1998). Fish grow more rapidly at Juvenile stage and growth rate becomes slower at older stage. Consequently, the growth performance index (Ø) is a more consistent method for a fish population to compare the growth performance as it considers L_∞ along with *K* simultaneously (Pauly and Munro, 1984).

11.1.2.6 Recruitment

Recruitment pattern of commercially important marine fishes was assessed from the analysis of the total time series of LFDs and growth parameters using VBGF models that shown in Fig 20. *L. calcarifer* recruits in the stock in August-September. The recruitment of *P. heterolepis* population is more or less continuous throughout the sampling period with a major peak in April–May. *P. chinensis* recruits two times in every year. One is in April-May and the another is in September. *E. affinis*, *S. taty*, *S. panijus*, *M. cordyla*, *C. dussumieri*, *A. chacunda*, *I. megaloptera* and *A. leiogaster* recruits in the stock twice in a year and rest of the species in single in a year.

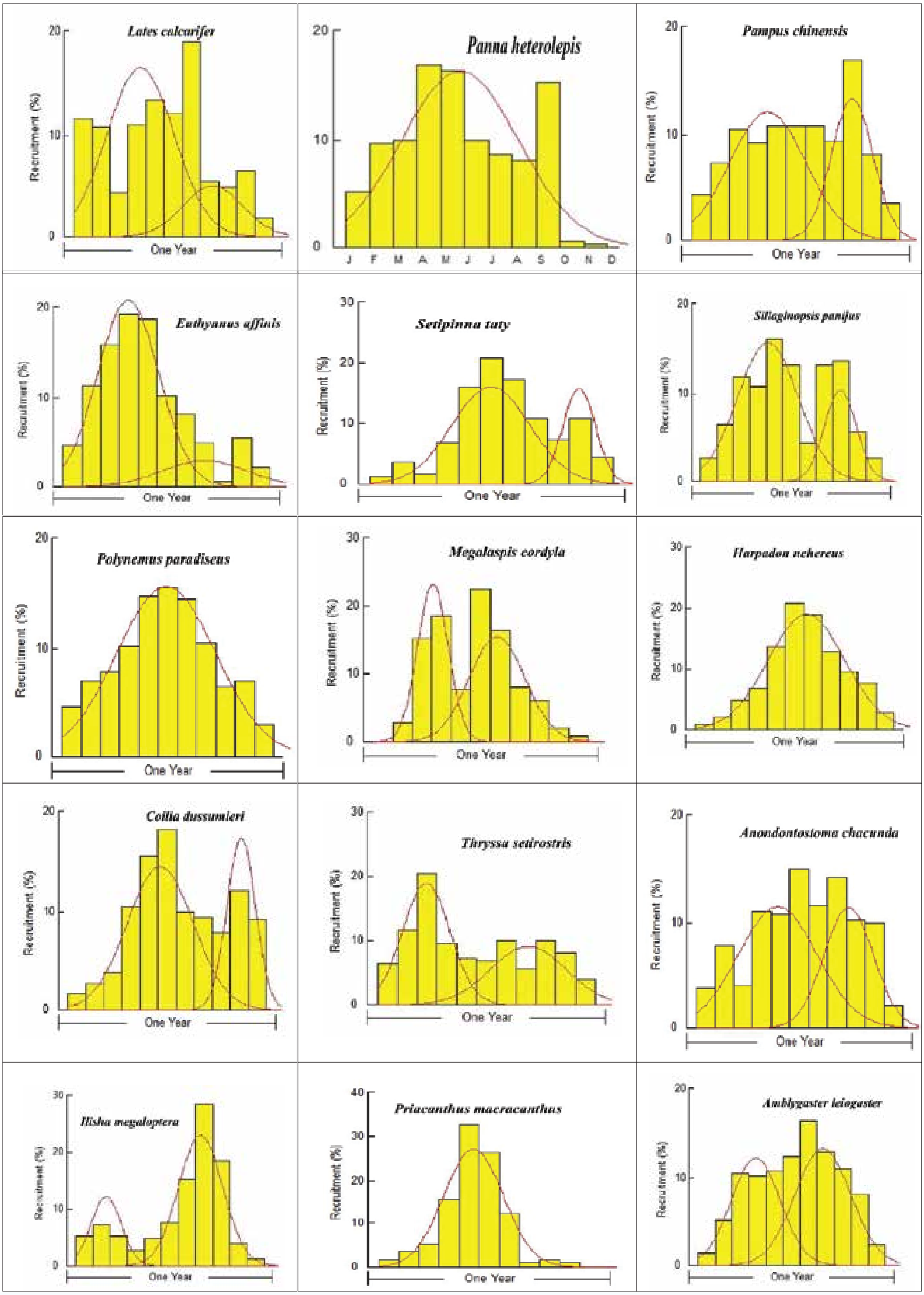


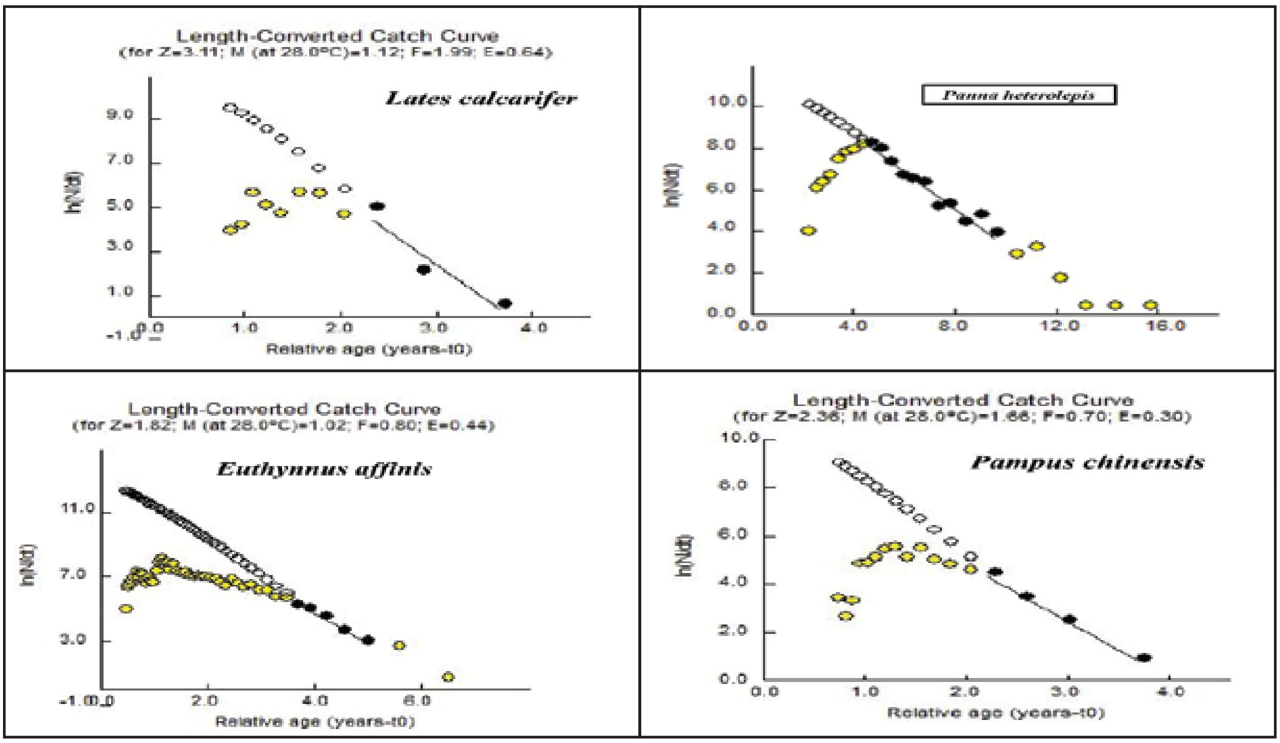
Fig 30. Recruitment pattern of commercially important marine fishes in the BoB, Bangladesh

11.1.2.7 Mortality

Mortality (total-, natural-, & fishing mortality) of commercially important marine fishes is tabulated in Table 25 & 26 and Fig 31.

Table 25. Mortality (Total mortality, Z; Natural mortality, M; Fishing mortality, F; Exploitation rate, E) of commercially important marine fishes in the BoB, Bangladesh

Sl. No.	Species	Z ($year^{-1}$)	M ($year^{-1}$)	F ($year^{-1}$)
01	*L calcarifer*	3.11	1.12	1.99
02	*P heterolepis*	0.87	0.55	0.43
03	*P chinensis*	2.36	1.66	0.70
04	*E affinis*	1.82	1.02	0.80
05	*S taty*	1.42	1.03	0.39
06	*S panijus*	1.47	0.75	0.72
07	*P paradiseus*	5.42	2.14	3.28
08	*M cordyla*	3.26	1.91	1.35
09	*H nehereus*	3.08	1.53	1.55
10	*C dussumieri*	2.88	1.63	1.25
11	*T setirostris*	3.84	1.84	2.00
12	*A chacunda*	1.22	0.71	0.51
13	*I megaloptera*	2.67	1.44	1.23
14	*P macracanthus*	1.31	0.85	0.46
15	*A leiogaster*	2.94	1.04	1.90



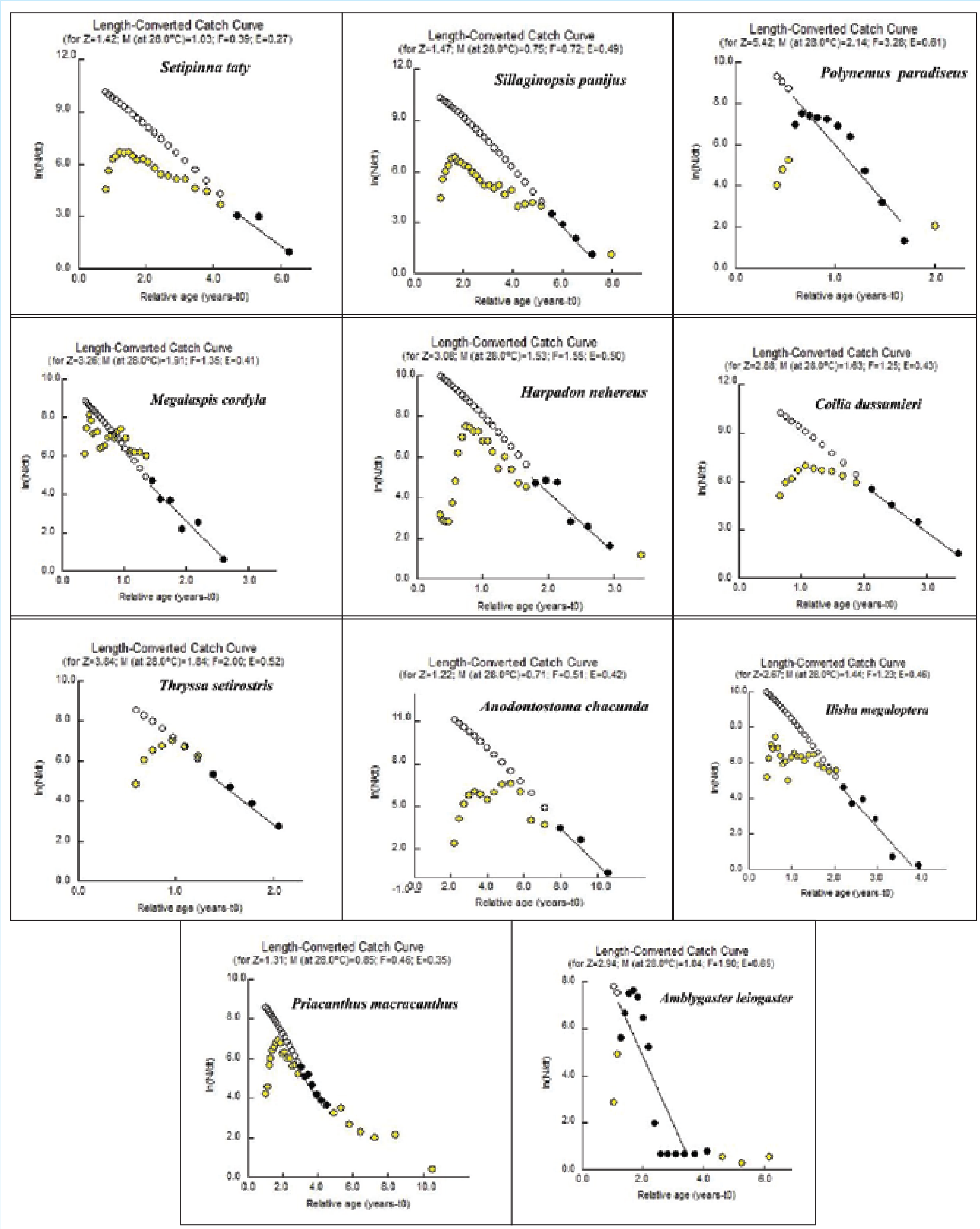


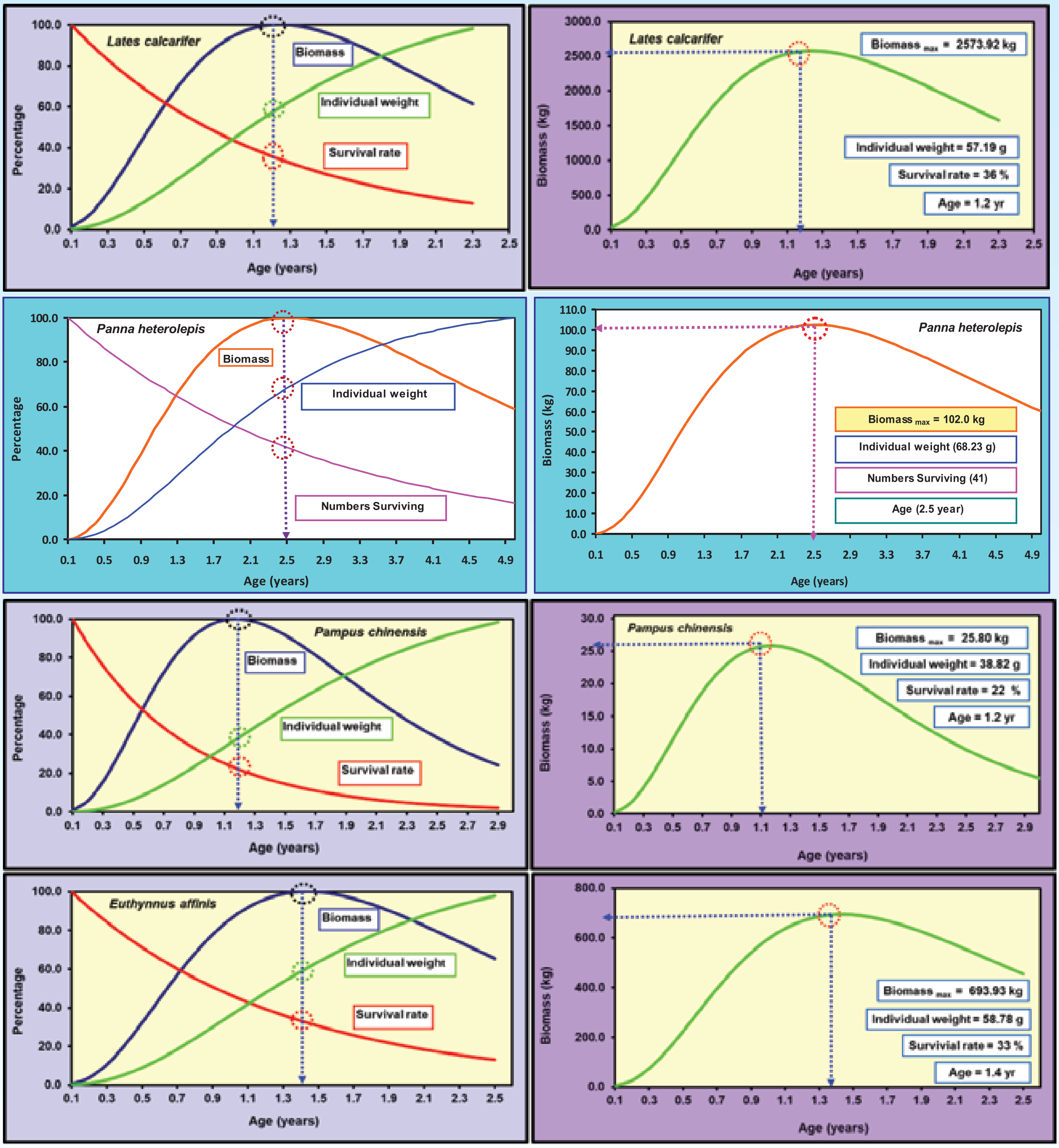
Fig 31. Estimation of mortality rates of commercially important marine fishes in the BoB, Bangladesh

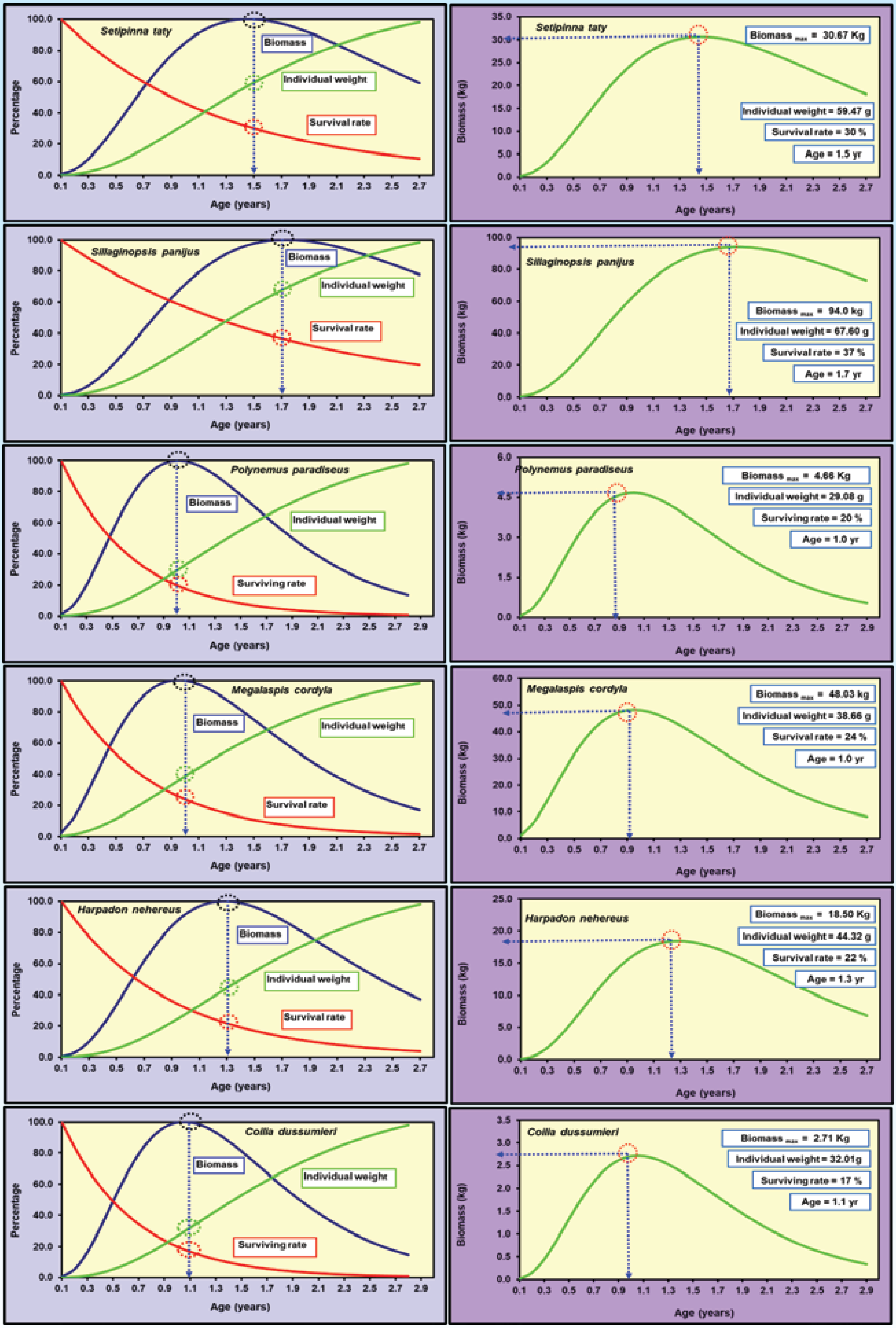
Table 26. Natural mortality (M) of 15 commercially important marine fishes in the BoB Bangladesh through multi-models

Sl. No	Species	Natural mortality (M)													
		Then_ nls	Then_ lm	Hamel_ Amax	ZM_ CA_pel	ZM_ CA_dem	Then_ VBGF	Hamel _k	Jensen _k 1	Jensen _k 2	Pauly_ lt	Roff	Jensen_ Amat	Ri_Ef_ Amat	User input
1	*L. calcarifer*	2.21	2.32	2.27	2.6	1.39	1.04	2.21	1.89	2.02	1.45	2.91	2.5	1.89	1.12
2	*P. heterolepis*	1.91	1.98	1.94	2.23	1.19	1.33	1.89	1.62	1.73	1.78	2.45	2.12	1.66	0.55
3	*P. chinensis*	1.79	1.84	1.8	2.08	1.11	1.22	1.75	1.5	1.6	1.65	2.28	1.96	1.56	1.66
4	*E. affinis*	2.04	2.13	2.08	2.39	1.28	1.13	2.03	1.74	1.86	1.55	2.67	2.29	1.77	1.02
5	*S. taty*	1.91	1.98	1.94	2.23	1.19	1.37	1.89	1.62	1.73	1.82	2.45	2.12	1.66	1.03
6	*S. panijus*	1.95	2.02	1.98	2.28	1.227	1.29	1.93	1.65	1.76	1.74	2.53	2.17	1.69	0.75
7	*P. paradiseus*	1.84	1.9	1.86	2.16	1.16	1.47	1.81	1.54	1.65	1.93	2.37	2.04	1.61	2.14
8	*M. cordyla*	1.87	1.93	1.89	2.18	1.17	1.51	1.84	1.58	1.68	1.98	2.39	2.06	1.62	0.71
9	*H. nehereus*	1.93	2	1.96	2.25	1.21	1.32	1.91	1.64	1.74	1.77	2.49	2.14	1.67	1.53
10	*C. dussumieri*	1.84	1.9	1.86	2.16	1.16	1.45	1.81	1.55	1.65	1.92	2.37	2.04	1.61	1.63
11	*T. setirostris*	1.84	1.9	1.86	2.17	1.16	1.49	1.81	1.55	1.65	1.96	2.37	2.04	1.61	1.84
12	*A. chacunda*	1.87	1.93	1.89	2.18	1.17	1.51	1.84	1.58	1.68	1.98	2.39	2.06	1.62	0.71
13	*I. megaloptera*	1.93	2	1.96	2.25	1.21	1.31	1.91	1.64	1.74	1.76	2.49	2.14	1.67	1.44
14	*P. macracanthus*	1.97	2.05	2.01	2.3	1.23	1.22	1.96	1.68	1.79	1.66	2.55	2.2	1.71	0.85
15	*A. leiogaster*	1.89	1.95	1.91	2.2	1.181	1.37	1.868	1.59	1.7	1.82	2.43	2.09	1.64	1.04

11.1.2.8 Relative biomass

The maximum relative biomass was found when population reached at 1.2 for *L. calcarifer*, 2.5 for *P. heterolepis*, 1.2 for *P. chinensis*, 1.4 for *E. affinis*, 1.5 for *S. taty*, 1.7 for *S. panijus*, 1.0 for *P. paradiseus*, 1.0 for M. cordyla, 1.3 for *H. nehereus*, 1.1 for *C. dussumieri*, 1.0 for *T. setirostris*, 1.8 for *A. chacunda*, 1.2 for *I. megaloptera*, 1. 5 for *P. macranthus* and 1.3 for *A. liogaster*. Maximum relative biomass was 2573.92 for *L. calcarifer*, 102.0 for P. *heterolepis*, 25.80 for *P. chinensis*, 693.93 for *E. affinis*, 30.67 for *S. taty*, 94.0 for *S. panijus*, 46.6 for *P. paradiseus*, 48.03 for *M. cordyla,* 18.50 for *H. nehereus*, 2.71 for *C. dussumieri*, 6.38 for *T. setirostris*, 69.8 for *A. chacunda*, 41.78 for *I. megaloptera*, 268.11 for *P. macranthus* and 52.52 for *A. liogaster* in the Padma River from recruitment of 1000 specimens in the BoB, Bangladeh. The maximum biomass was expressed by kilogram (kg) unit (Fig 32).




Setipinna taty
Biomass
Individual weight
Survival rate
Percentage
Age (years)
Setipinna taty
Biomass max = 30.67 Kg
Individual weight = 59.47 g
Survival rate = 30 %
Age = 1.5 yr
Biomass (kg)
Age (years)
Sillaginopsis panijus
Biomass
Individual weight
Survival rate
Percentage
Age (years)
Sillaginopsis panijus
Biomass max = 94.0 kg
Individual weight = 67.60 g
Survival rate = 37 %
Age = 1.7 yr
Biomass (kg)
Age (years)
Polynemus paradiseus
Biomass
Individual weight
Surviving rate
Percentage
Age (years)
Polynemus paradiseus
Biomass max = 4.66 Kg
Individual weight = 29.08 g
Surviving rate = 20 %
Age = 1.0 yr
Biomass (kg)
Age (years)
Megalaspis cordyla
Biomass
Individual weight
Survival rate
Percentage
Age (years)
Megalaspis cordyla
Biomass max = 48.03 kg
Individual weight = 38.66 g
Survival rate = 24 %
Age = 1.0 yr
Biomass (kg)
Age (years)
Harpadon nehereus
Biomass
Individual weight
Survival rate
Percentage
Age (years)
Harpadon nehereus
Biomass max = 18.50 Kg
Individual weight = 44.32 g
Survival rate = 22 %
Age = 1.3 yr
Biomass (kg)
Age (years)
Coilia dussumieri
Biomass
Individual weight
Surviving rate
Percentage
Age (years)
Coilia dussumieri
Biomass max = 2.71 Kg
Individual weight = 32.01g
Surviving rate = 17 %
Age = 1.1 yr
Biomass (kg)
Age (years)

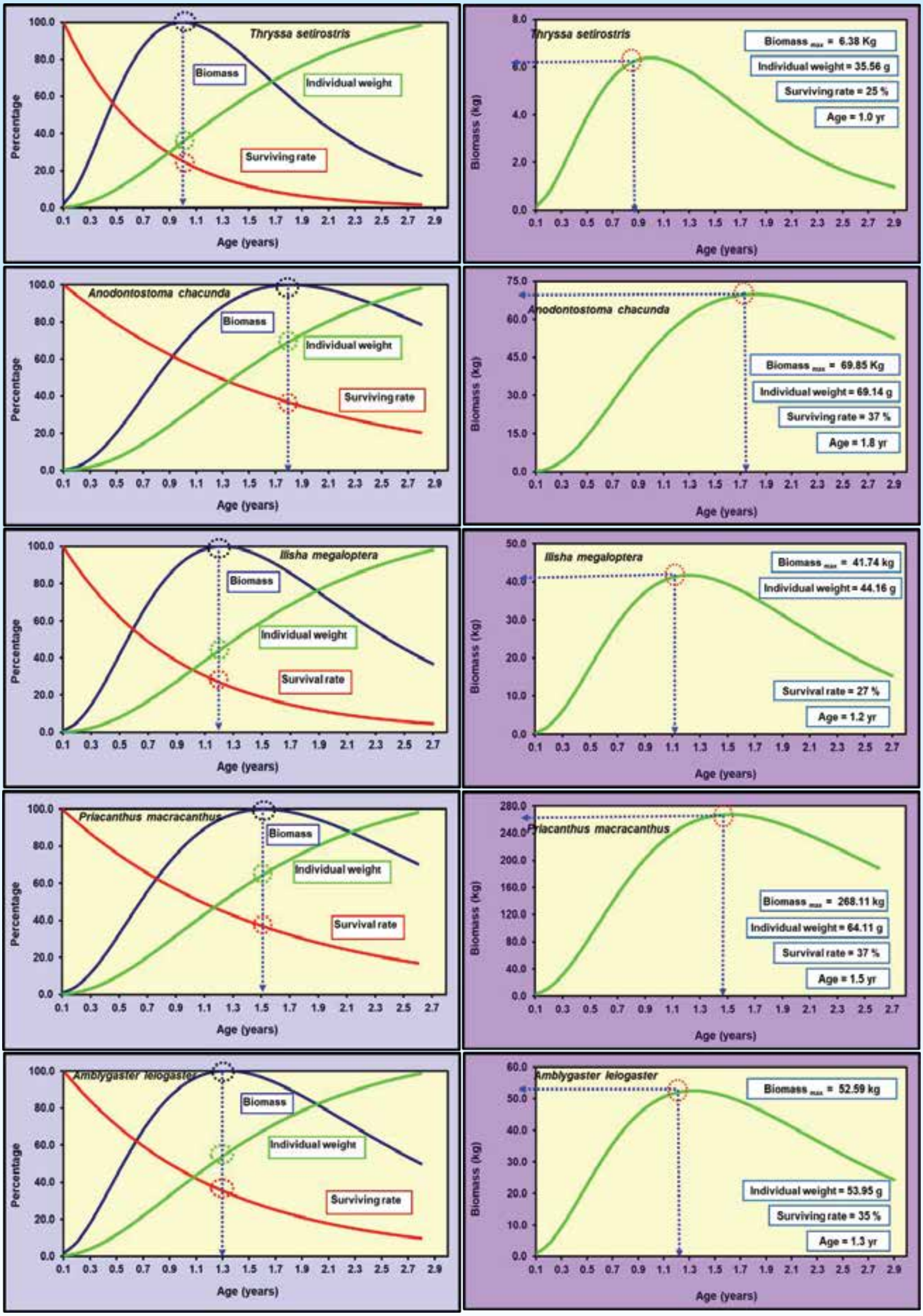


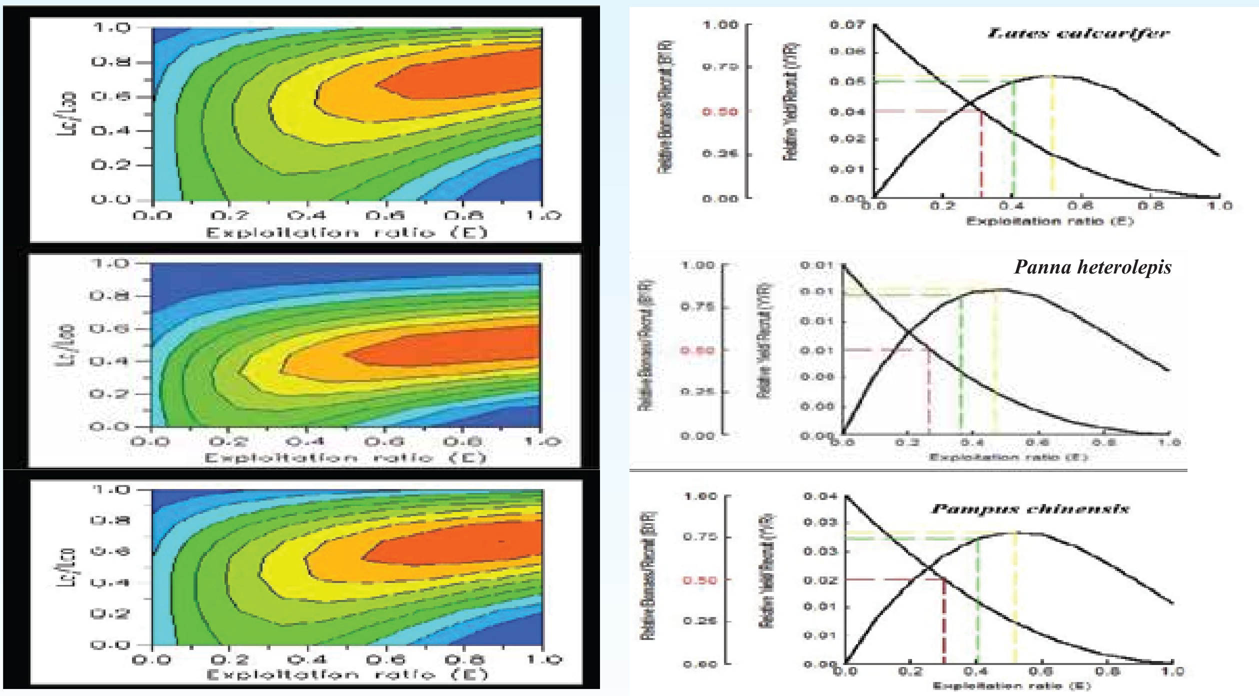
Fig 32. Relative biomass of commercially important marine fishes in the BoB, Bangladesh.

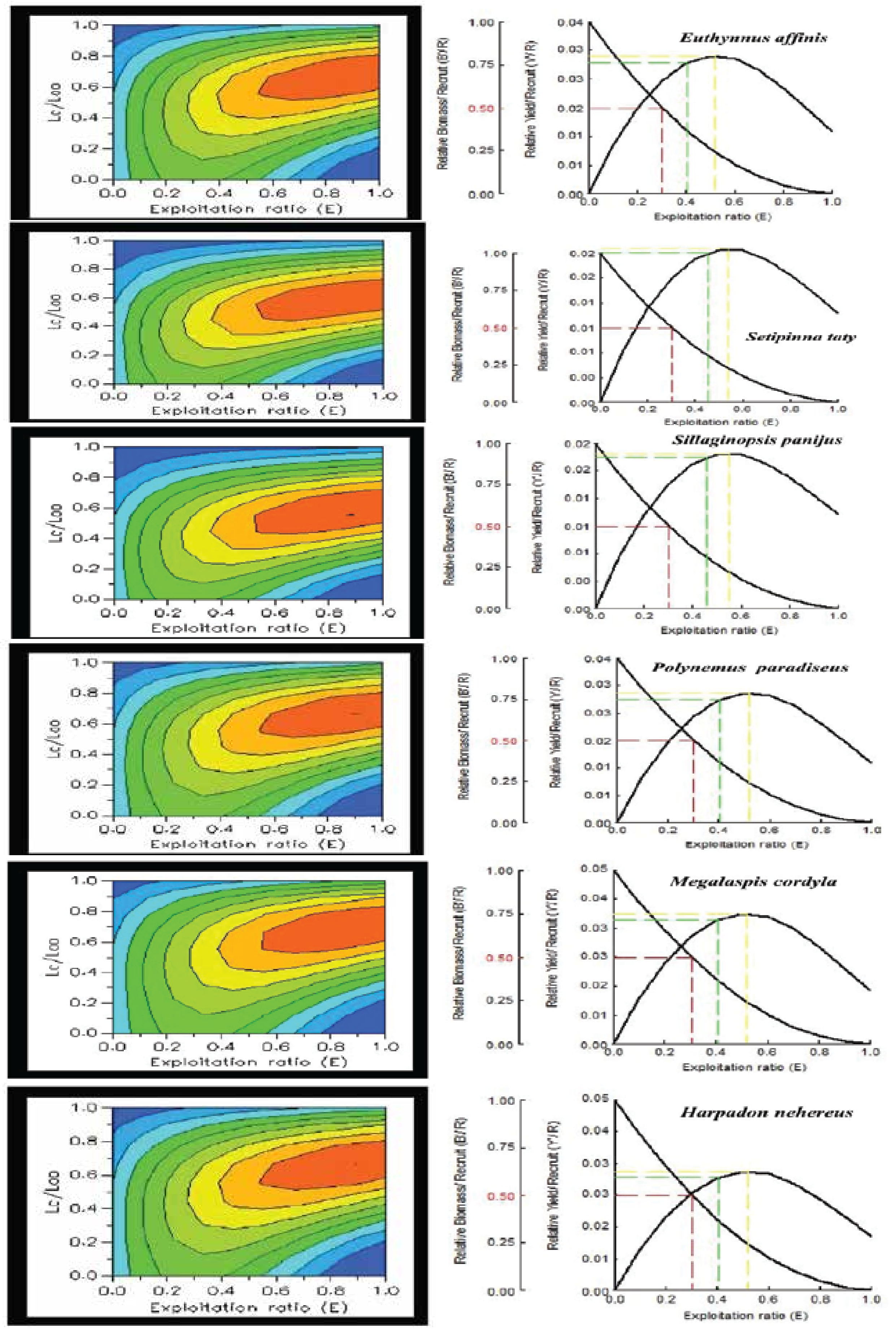
11.1.2.9 Exploitation and maximum sustainable yield (MSY)

The estimated current exploitation rate (E) for *L. calcarifer* (0.64) is higher than the predicted values of E_{max} = 0.52, E_{50} = 0.31 and E_{10} = 0.41. The estimated current exploitation rate *E* (0.49) is higher than the predicted values of E_{max} = 0.47, E_{50} = 0.26 and E_{10} = 0.36 for *P. heterolepis* in the BoB, Bangladesh. The predicted total SSB was 23801.09 metric tons and the MSY of *P. heterolepis* was estimated at 10234.47 mt. The E for *P. chinensis* (0.30) is higher than the predicted values of E_{max} = 0.52, E_{50} = 0.30 and E_{10} = 0.41. The E for *E. affinis* (0.44) is higher than the predicted values of E_{max} = 0.52, E_{50} = 0.30 and E_{10} = 0.41. However, exploitation rate E, E_{50}, E_{max} and MSY for other marine fishes shown in Table 27 and Fig 33.

Table 27. Exploitation rate and maximum sustainable yield (MSY) of commercially important marine fishes in the BoB, Bangladesh.

Sl. No.	Species	*E*	E_{50}	E_{max}	MSY (MT)	Stock status
01	*L calcarifer*	0.564	0.310	0.52	24298.88	4% over exploited
02	*P heterolepis*	0.49	0.260	0.47	10234.47	2% over exploited
03	*P chinensis*	0.30	0.303	0.52	313.65	22% under exploited
04	*E affinis*	0.44	0303	0.52	13077.43	8 % under exploited
05	*S taty*	0.27	0.301	0.54	455.04	27% under exploited
06	*S panijus*	0.49	0.301	0.55	637.96	6% under exploited
07	*P paradiseus*	0.61	0.303	0.52	99.55	9% over exploited
08	*M cordyla*	0.41	0.305	0.52	769.41	11% under exploited
09	*H nehereus*	0.50	0.303	0.52	55708.90	2% under exploited
10	*C dussumieri*	0.43	0.301	0.53	110.74	10% under exploited
11	*T setirostris*	0.52	0.302	0.53	55.31	Balance
12	*A chacunda*	0.42	0.223	0.35	859.92	7% over exploited
13	*I megaloptera*	0.46	0.303	0.52	525.80	6% under exploited
14	*P macracanthus*	0.35	0.301	0.54	6340.75	19% under exploited
15	*A leiogaster*	0.65	0.301	0.54	425.44	11% over exploited




Euthynnus affinis
Setipinna taty
Sillaginopsis panijus
Polynemus paradiseus
Megalaspis cordyla
Harpadon nehereus
Lc/Loo
Exploitation ratio (E)
Relative Biomass/ Recruit (B'/R)
Relative Yield/ Recruit (Y'/R)

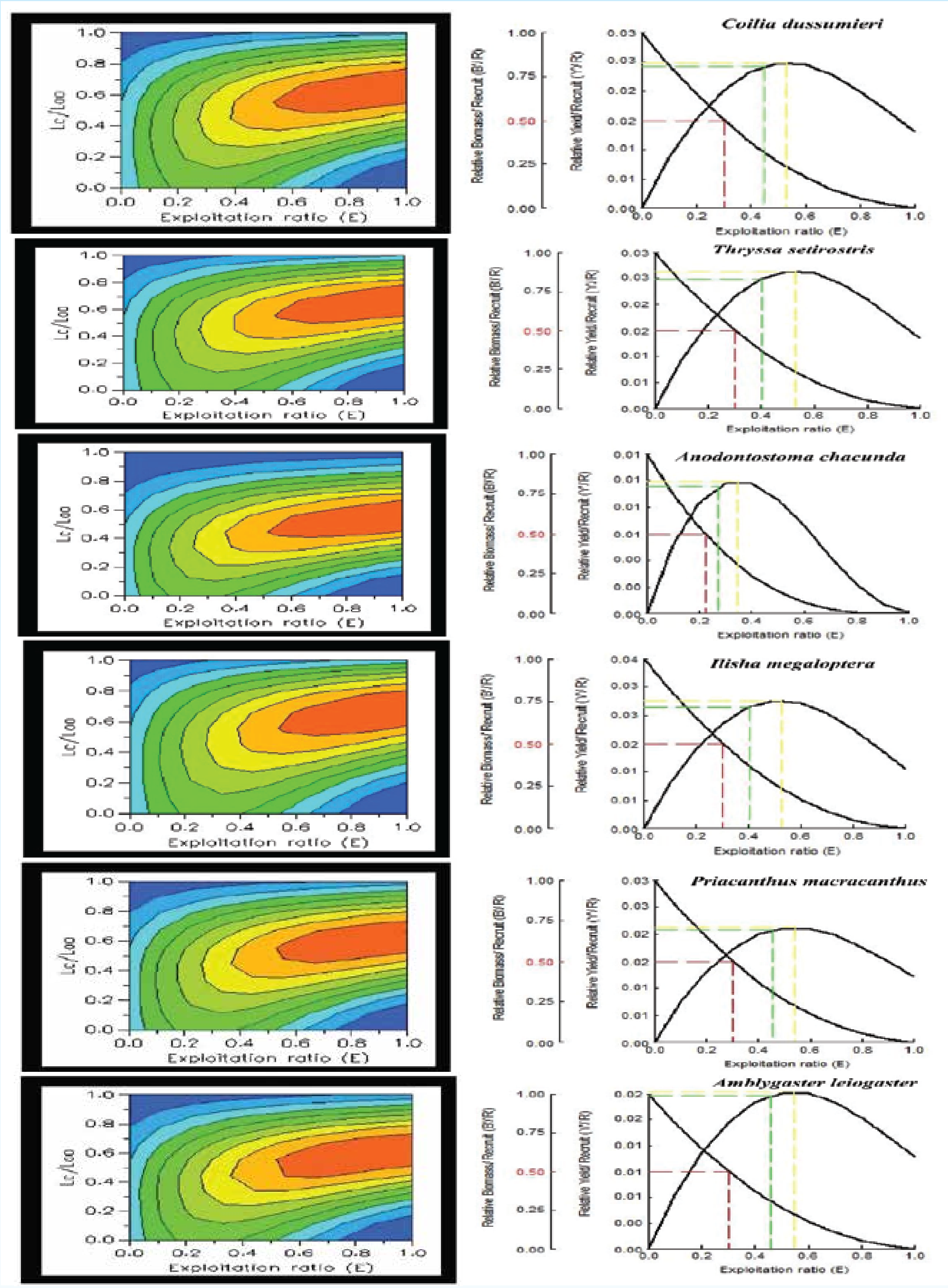


Fig 33. Yield Isopleths, Relative yield-per-recruit (*Y′/R*) and relative biomass-per-recruit (*B′/R*) of commercially important marine fishes in the BoB, Bangladesh

11.1.2.10 Fish catch data

Fish catch data of commercially important marine fishes in the BoB, Bangladesh from BFDC Pathorghata landing center.

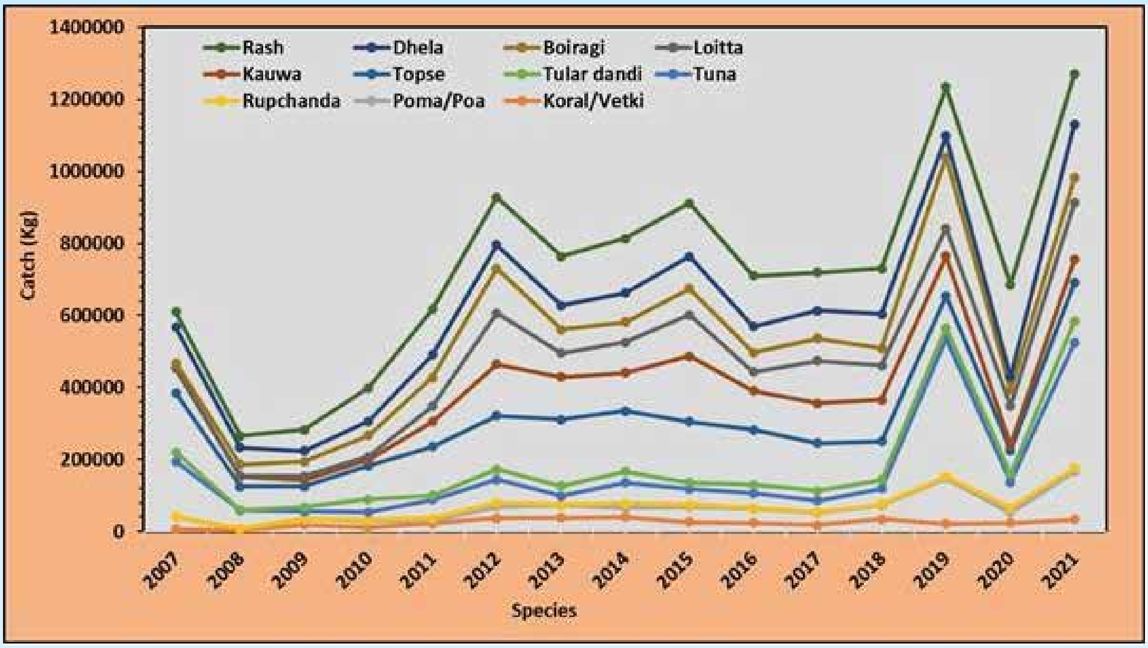


Fig 34. Fish catch data of commercially important marine fishes in the BoB, Bangladesh from BFDC Pathorghata landing center.

11.1.2.11 Stock status of marine fishes in the BoB

According to the outputs of LBB, the biomass of *Bregmaceros mcclellandi* (B/B_0 = 0.11 and B/B_{MSY} = 0.27) and *Escualosa thoracata* (B/B_0 = 0.14 and B/B_{MSY} = 0.37) revealed that these stocks are on the verge of collapse and thereby, classified as grossly overfished. The exploitation ratio for *Escualosa thoracata* was 42 percent higher than the sustainable margin, and for *Bregmaceros mcclellandi,* it was 52 percent higher. The L_{mean}/L_{opt} and L_c/L_{c_opt} ratios were also less than unity (0.90), indicating the dominance of the first-spawner in the catch is the governing feature of these two fisheries.

Based on the fisheries sustainability benchmarks, the biomass information provided by LBB classified *Coilia dussumieri, Johnius belangerii,* and *Ilisha filigera* as overfished stocks (B/B_0 < 0.4 and B/B_{MSY} < 1). These stocks' fishing pressure and exploitation rate appeared to be almost double than the reference points (Table 25). The L_{mean}/L_{opt} and L_c/L_{c_opt} ratios of these three species indicate the presence of a few larger fishes in the stocks. On the other hand, *Megalaspis cordyla* formed the Healthy group with stock biomass greater than the target reference points (B/B_0 > 0.4 and B/B_{MSY} > 1) and low fishing mortality and exploitation (F/M < 1 and F/Z < 0.50) (Table 28). Although the stock biomass appears to be healthy, it seems likely that this species' fishery is still suffering from overfishing, with L_{mean}/L_{opt} and L_c/L_{c_opt} ratios than 0.90. The probability of capture for different length classes was analyzed, and the LBB returned *Lc* values for all six species. To ensure healthy spawning biomass, the fishery's selectivity should exclude immature individuals from the catch, allowing them to mature and reproduce at least once in their lives. However, based on the estimation of L_m (first maturity length, at which 50% of the individuals are mature), it was observed that except *J. belangerii* and *C. dussumieri,* the remaining species were suffering from growth overfishing, with *Lc* values less than assumed L_m (Table 28).

Table 28. Stock status of marine fishes from the BoB, Bangladesh based on LBB (length-based Bayesian biomass) method

Scientific name	L_∞	L_c	L_{opt}	L_m	L_{mean}/L_{opt}	L_c/L_{c-opt}	F/M	F/Z	Z/K	B/B_0	B/B_{MSY}	Stock status
Sardinella fimbriata	22.8	10.6	-	-	0.89	0.85	1.4	-	3.8	0.26	0.7	Overfished
Dussumieria acuta	19.1	14.2	-	-	1.3	1.4	0.59	-	2.8	0.57	1.6	Healthy
Dussumieria elopsoides	18.0	12.6	-	-	1.1	1.3	0.44	-	1.7	0.63	1.7	Healthy
Lepturacanthus savala	111.0	25.5	-	-	0.57	0.40	2.0	-	4.8	0.11	0.3	Grossly overfished
Pampus argenteus	26.5	18.4	-	-	0.95	0.84	2.7	-	2.6	0.18	0.42	Grossly overfished
Nemipterus japonicus	25.0	8.67	-	-	0.81	0.73	0.14	-	1.5	0.79	2.1	Healthy
Nemipterus randalli	22.0	10.2	-	-	0.88	0.91	0.13	-	0.99	0.83	2.1	Healthy
Illisha filigera	36.1	16.3	-	-	0.93	0.87	2.0	-	4.9	0.20	0.54	Overfished
Saurida tumbil	37.0	7.65	-	-	0.63	0.45	0.99	-	2.9	0.25	0.7	Overfished
Upeneus sulphureus	19.2	10.7	-	-	1.0	0.97	2.0	-	4.2	0.22	0.59	Overfished
Bregmaceros mcclellandi	10.5	5.22	8.7	6.89	0.78	0.65	3.1	0.76	2.5	0.11	0.27	Grossly overfished
Escualosa thoracata	12.2	5.97	8.1	7.89	0.74	0.78	2.53	0.71	4.2	0.14	0.37	Grossly overfished
Illisha filligera	36.6	22.38	25.0	24.20	1.0	1.0	1.9	0.67	2.5	0.23	0.61	Overfished
Johnius belangerii	33.0	21.78	25.0	19.28	0.95	0.94	1.6	0.64	2.1	0.29	0.74	Overfished
Coilia dussumieri	17.2	11.35	12.0	10.60	1.1	1.2	1.8	0.64	2.5	0.27	0.76	Overfished
Megalaspis cordyla	45.6	20.52	32.0	25.78	0.85	0.79	0.72	0.41	2.7	0.42	1.1	Healthy

(Source: Al-Mamun et al., 2021; Barman et al., 2021; Alam et al., 2022)

L_∞, Asymptotic length, L_c, length at capture; L_{opt}, optimum catchable length; L_m, length at sexual maturity; L_{mean}, mean length of exploited stock; optimum length at first capture; F, fishing mortality; M, natural mortality; Z, total mortality; K, growth coefficient; B, current biomass; B_0 unfished biomass; B_{MSY}, biomass capable of producing maximum sustainable yield

11.1.3 Identification of the major man-made and climatic threats/ factors to fisheries resources in the BoB, Bangladesh

11.1.3.1 Man-made and climatic threats/ factors to fisheries resources in the BoB, Bangladesh

From the survey and focus group discussion (FGD) reduction among fisherman, fish farmers, traders, researchers, Government and NGO personnel, we found that, fishing with mosquito net in estuaries & mangrove was the major man-made threats (80%) for the fishes in the BoB followed by the fishing through Behundi net (75%), catches of fry, fingerlings, and jatka (70%), Fishing through China net (65%) fishing from Indian and Myanmar's fishers, catches of brood marine fish, use of destructive fishing gears, pollution and other natural calamities (Fig 35 & Table 29). Recently, indiscriminate fishing is increased through an introduced fishing gear namely China net. According to Rahman et al. (2012), the fish biodiversity are declining due to a combination of over exploitation, environmental degradation, pesticides and aquatic pollution, spread of diseases, uncontrolled introduction of exotic fishes, destruction of breeding grounds, excessive water abstraction, siltation, various ecological changes in its natural habit and lack of proper management and subsequent ship breaking industry in the BoB are the key causes for destroying of marine fisheries resources.

Table 29. Major man-made and climatic threats/ factors to fisheries resources in the BoB, Bangladesh from the survey and focus group discussion (FGD) among fisherman, fish farmers, traders, researchers, Government and NGO personnel

Causal factors	**Respondent (%)**
Fishing with mosquito net in estuaries & mangrove	80
Fishing through *Behundi* net	75
Catches of fry, fingerlings & *jatka*	70
Fishing through China net	65
Fishing from Indian & Myanmar's fishers	55
Catches of broodfish in spawning period	50
Destructive fishing gears	35
Fishing through poison	35
Pollution	25
Climate change	20
Natural disaster	10
Others	5

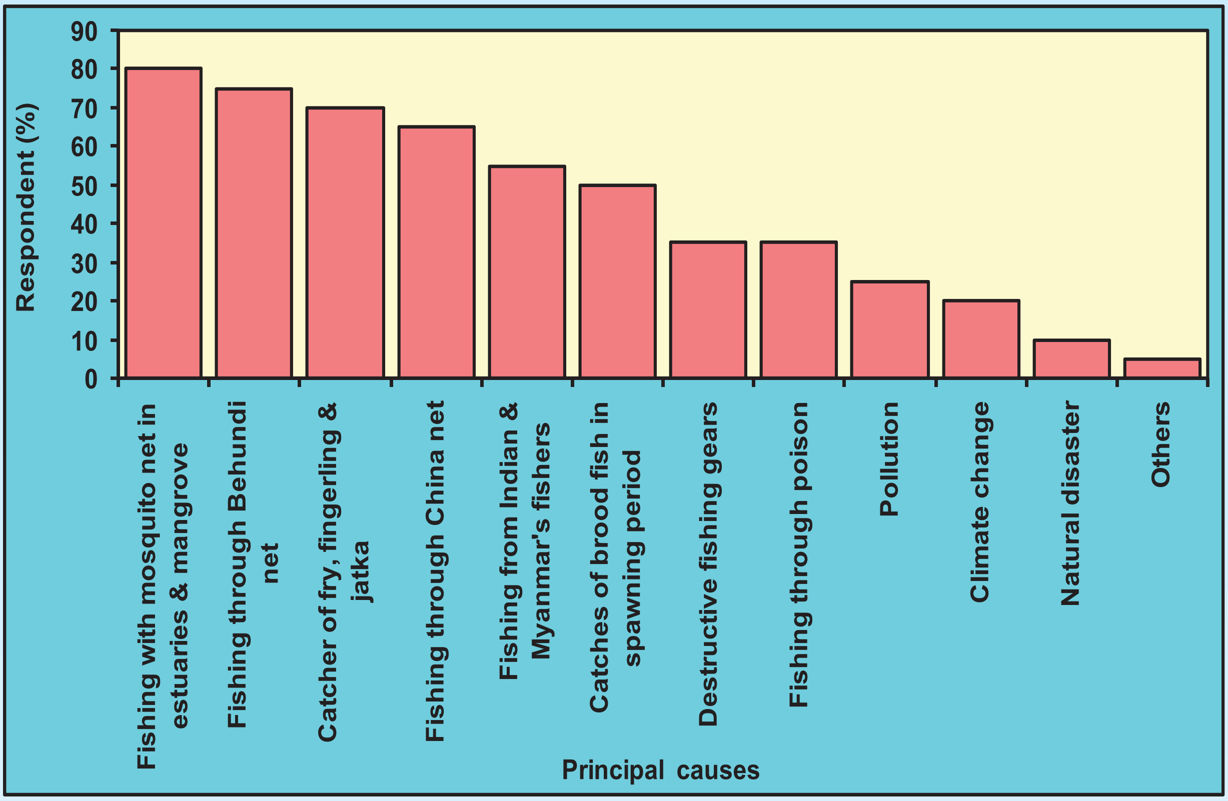


Fig 35. Principle causal threats/ factors to fisheries resources in the BoB, Bangladesh

11.2 Component 2 (SAU)

11.2.1 Determination of the genetic stocks (single or discrete) of commercial marine fish with variation of habitats in BD and to assess the intra and inter population genetic diversity and divergence of commercial fish in the BoB, Bangladesh and other neighbouring seas.

11.2.1.1 Genetic stock assessment and diversity of *P chinensis* in BoB, BD & other sea area

i. **Genetic diversity**

A total of 369 nucleotide long sequences of the mtDNA control (d-loop) region were obtained from 92 individuals of KP and CC population after removing the ambiguous sequences near the primer ends. The d-loop region sequences of KP population comprised 5 haplotypes with 4 polymorphic sites and the d-loop region sequences of CC population comprised 8 haplotypes with 10 polymorphic sites. The nucleotide composition of the sequences of KP population are C= 17.09%, T= 30.50%, A= 38.08%, G= 14.34%. On the other hand, these values are C= 17.16%, T= 30.35%, A= 37.91%, G= 14.58% for CC population. Most of the nucleotide substitutions were transitional (Table 31) and no indel was detected in the sequences of two populations. Four transitions and single transversion occurred the nucleotide sequence for both populations (Table 31). The nucleotide diversities (π) were very low in each population as 0.003 and 0.007 nucleotide differences per site while the gene (haplotype) diversities (h) were relatively high, 0.632 and 0.855 for KP and CC populations, respectively.

Table 31. Genetic diversity for BoB population of *P. chinensis*

Sea	Pop. / Stock	Sb (ti+tv)	Nid	Nh	h	Π	S
BoB	KP	4(3+1)	0	5	0.632	0.003	4
	CC	10(9+1)	0	8	0.855	0.007	10
[Number of substitution (Sb), Transition (ti), transversion (tv), number of indels (N_{id}), number of haplotype (N_h), haplotype diversity (*h*), nucleotide diversity (π), number of polymorphic site (S)							

ii. Population differentiation

Estimates of F_{ST} between KP and CC populations of Bangladesh was 0.126 showing no significant deviation from the random mixing (P>0.05). This result indicates that there is no population genetic structure within the marine water of Bangladesh. However, estimates of F_{ST} between Bangladeshi populations (KP and CC of BoB) and each of the compared populations from other seas (ARS, SCS) ranged from 0.132 to 0.269 with significant difference ($P\leq0.01$) (Table 32). This result indicates a unique population genetic structure was established in the BoB region compared to other seas. Exact test of population differentiation showed that the fish populations are panmixic within its area of each sea (random mating) but they belong to separate breeding unit in different seas (Table 32).

Table 32. Pairwise F_{ST} values (below diagonal) and exact P values (above diagonal) among populations of *P. chinensis* for d-loop region

Population	Son	Om	Xia	Bei	KP	CC
Son	-	0.10	0.00	0.00	0.00	0.00
Om	0.026	-	0.00	0.00	0.00	0.00
Xia	0.143**	0.169**	-	0.37	0.00	0.00
Bei	0.172**	0.197**	-0.013	-	0.00	0.00
KP	0.258**	0.248**	0.240**	0.269**	-	0.08
CC	0.148**	0.175**	0.132**	0.159**	0.040	-

**P<0.01; *P<0.05

iii. Haplotype network

All sequences defined 35 haplotypes among 184 specimens where ten haplotypes found in the BoB population. Among ten of the BoB haplotypes, nine haplotypes (BH1, BH2, BH3, BH4, BH5, BH6, BH7 from CC, and BH8, Bh9 from KP region) were unique and novel for the BoB that are not present in other seas. Rest one (Hap1) of the BoB was shared with Sonmiani and Ormara of the Arabian Sea population. A lineage of BoB containing 06 unique haplotypes of BoB population indicates an evidence and support the result of *F*st i.e., BoB as a distinct population (Fig 36).

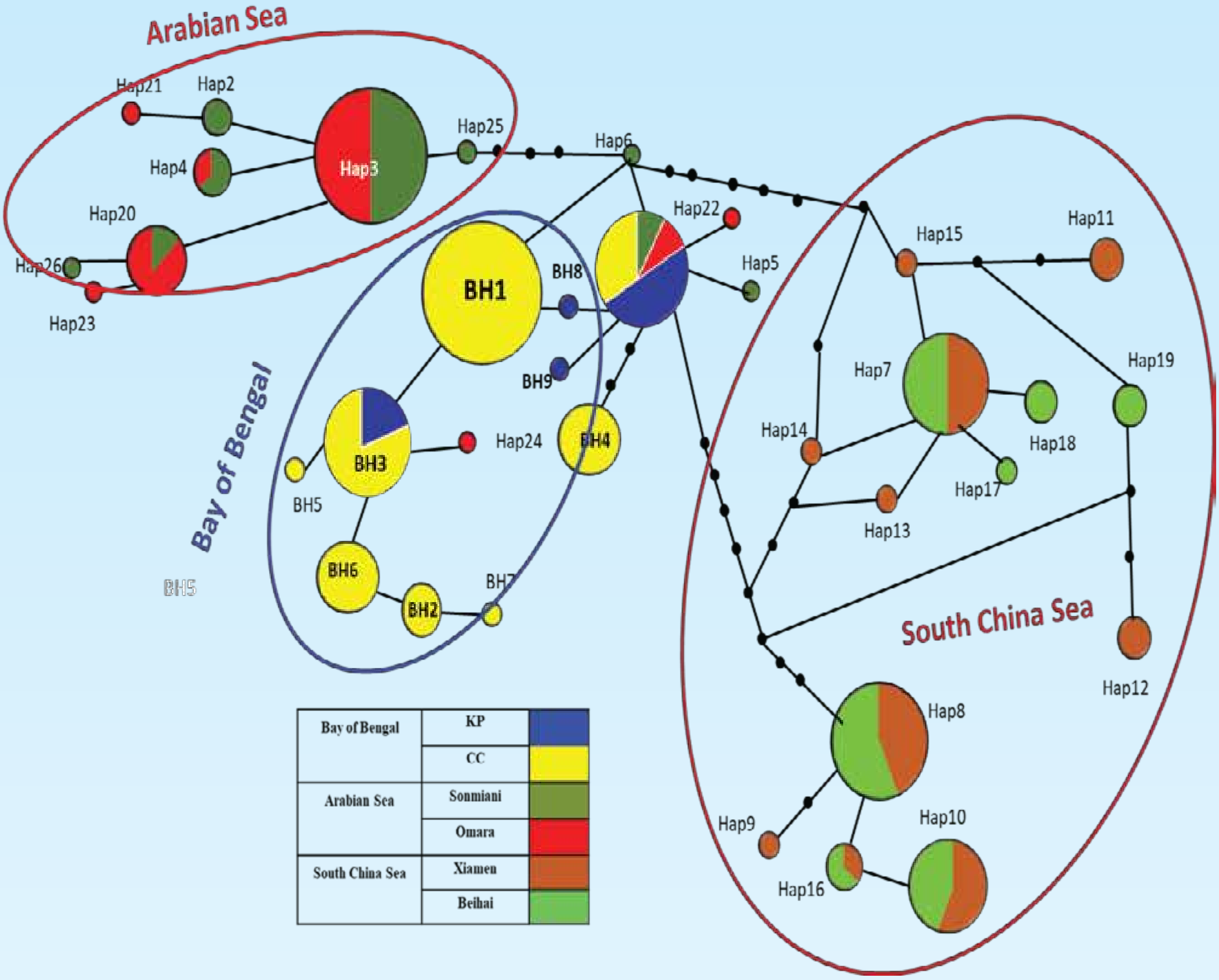


Fig 36. Haplotype network of control region observed in *P. chinensis* samples. Each connecting line represents a single mutation and small blanked circles represent an intermediate hypothesized missing ancestor between observed haplotypes. The sizes of circles are proportional to haplotype frequency.

iv. Phylogenetic analysis

Phylogenetic reconstruction of total 35 mitochondrial D-loop haplotypes using Neighbor Joining Method with the Kimura 2-parameter model resulted 3 (three) separate clades (Fig. 37). Clade-A represents the lineage of Arabian Sea (Sonmiani and Omara). Clade-B consists of the populations of the BoB (KP and CC) and Arabian Sea (Sonmiani and Omara). Clade-C clearly represent the lineage of South China Sea (Beihai and Xiamen populations).

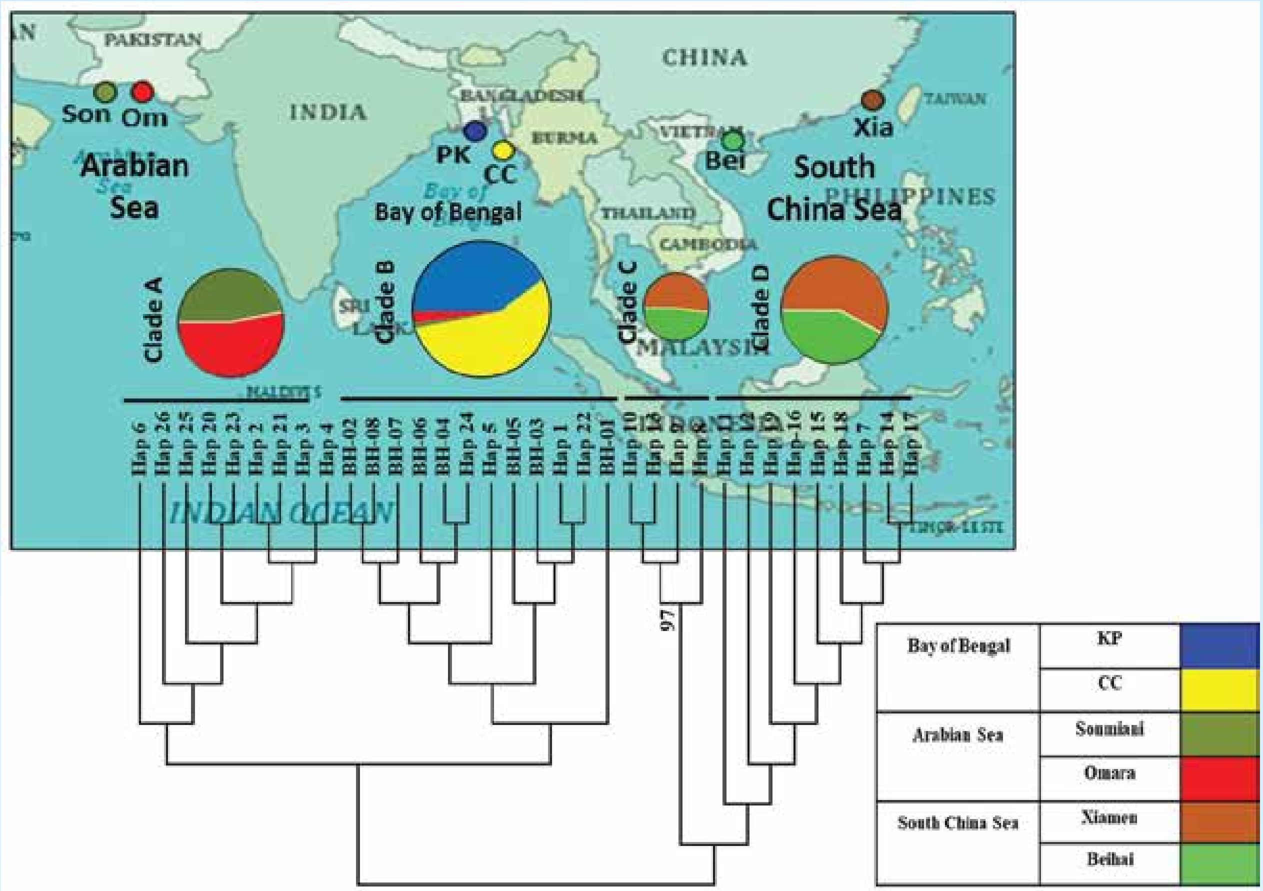


Fig 37. Neighbor-joining tree constructed using the Kimura-2 model for mitochondrial D-loop haplotypes of *P. chinensis*. Bootstrap support of >70% are shown above branches. Coloured circle in front of a clade represent the percentage of samples of different locations for that respective clade.

v. Pattern of historic demography

The neutrality tests (i.e. Tajima's *D* tests) exhibits positive values (*D* = 0.257) and Fu's *F*s value (F_S = – 0.594) were negative and non-significant in KP populations implying a demographic equilibrium in that region (Table 33). For CC population, Tajima's *D* test was also positive (*D* = 0.182) and non-significant whereas, the Fu's *F*s value was negative (F_S = – 0.495) and non-significant which also imply a demographic equilibrium for this population.

Table 33. Tajimas's *D* and Fu's F_S statistics for KP and CC populations of *P. chinensis* of Bangladesh.

Population	Tajima's *D*		Fu's F_S	
	D	*P*	F_S	*P*
KP	0.254	0.666	-0.594	0.347
CC	0.182	0.636	-0.495	0.391

11.2.1.2. Genetic stock assessment and diversity of *P argenteus* in BoB, BD & other sea areas

i. Genetic diversity

A total of 433 nucleotide long sequences of mtDNA control region (d-loop) were obtained from the two Bangladeshi populations, KP and CC after removing the ambiguous sequences near the primer ends. The d-loop region sequences of KP population comprised 5 haplotypes where 4 polymorphic sites were identified. Nucleotide composition of the sequences of KP population are C= 17.28%, T=31.17%, A= 38.81%, G= 12.73%, and the nucleotide composition of the sequences of CC population are C= 17.20%, T= 31.23%, A= 39.03%, G= 12.54%. No indels were detected in the sequences of the two populations. Five transitions were occurred in the nucleotide sequence of KP population. On the other hand, nine transitions with 1 transversion were found in CC population (Table 34). The nucleotide diversities (π) were very low in each population showing 0.004 and 0.006 nucleotide differences per site while the haplotype (gene) diversities (h) were relatively high i.e. 0.933 and 0.923 for KP and CC populations, respectively. High level of haplotype diversities in contrast with low nucleotide diversity among the BoB population indicates that Bangladeshi populations have experienced expansion after a period of low effective population size (Grant and Bowen 1998).

Table 34. Genetic diversity of *P argenteus* for BoB population.

Sea	**Population**	**Sb (ti+tv)**	Nid	Nh	h	π	S
BoB	KP	4 (2+2)	0	5	0.933	0.004	4
	CC	10 (9+1)	0	9	0.923	0.006	10
[Number of substitution (Sb), Transition (ti), transversion (tv), number of indels (N_{id}), number of haplotype (N_h), haplotype diversity (h), nucleotide diversity (π), number of polymorphic site (S).							

ii. Population differentiation

Table 35. Pairwise F_{ST} values (below diagonal) and non-differentiation exact P values (above diagonal) among populations of *P. argenteus* for d-loop region

Population	KP	CC	CH	TH	MM	IN	PK	KT
KP	-	0.19	0.00	0.00	0.00	0.01	0.05	0.01
CC	0.035	-	0.00	0.00	0.00	0.00	0.00	0.00
CH	0.101**	0.103**	-	0.00	0.00	0.00	0.00	0.00
TH	0.208**	0.197**	0.212**	-	0.53	0.00	0.00	0.00
MM	0.281**	0.259**	0.268**	-0.004	-	0.00	0.00	0.00
IN	0.075**	0.079**	0.102**	0.186**	0.239**	-	0.07	0.00
KP	0.057**	0.063**	0.087**	0.171**	0.224**	0.012	-	0.00
KT	0.143**	0.139**	0.159**	0.245**	0.301**	0.091**	0.091**	-

**P<0.01; * P<0.05

The F_{ST} value between KP and CC population of Bangladesh was estimated as 0.035 with no significant deviation (*P*>0.01) from random mixing which suggests no population differentiation found within the BoB, Bangladesh. Estimates of F_{ST} between Bangladeshi populations (KP and CC) and each of the populations of other seas were ranged from 0.057 to 0.281 with significant difference (*P*=0.01) (Table 35). This result indicates a unique population genetic structure (i.e. a single genetic stock) was established in the BoB region compared to other seas. Exact test of population differentiation also showed significant differentiation between BoB and each of other populations investigated suggesting a non-panmictic population (a separate breeding unit) in the BoB compared to other seas. (Table 35).

iii. Haplotype Network

All sequences defined 78 haplotypes where 13 haplotypes were found in the BoB population. All of these 13 haplotypes were unique and novel for the BoB that are not present in other populations. Among these haplotypes of the BoB, 10 haplotypes (BH1, BH2, BH3, BH4, BH5, BH6, BH7, BH8, BH10) were unique for the CC population and four haplotypes (BH9, BH11, BH12, BH13) were unique for KP population (Fig 38).

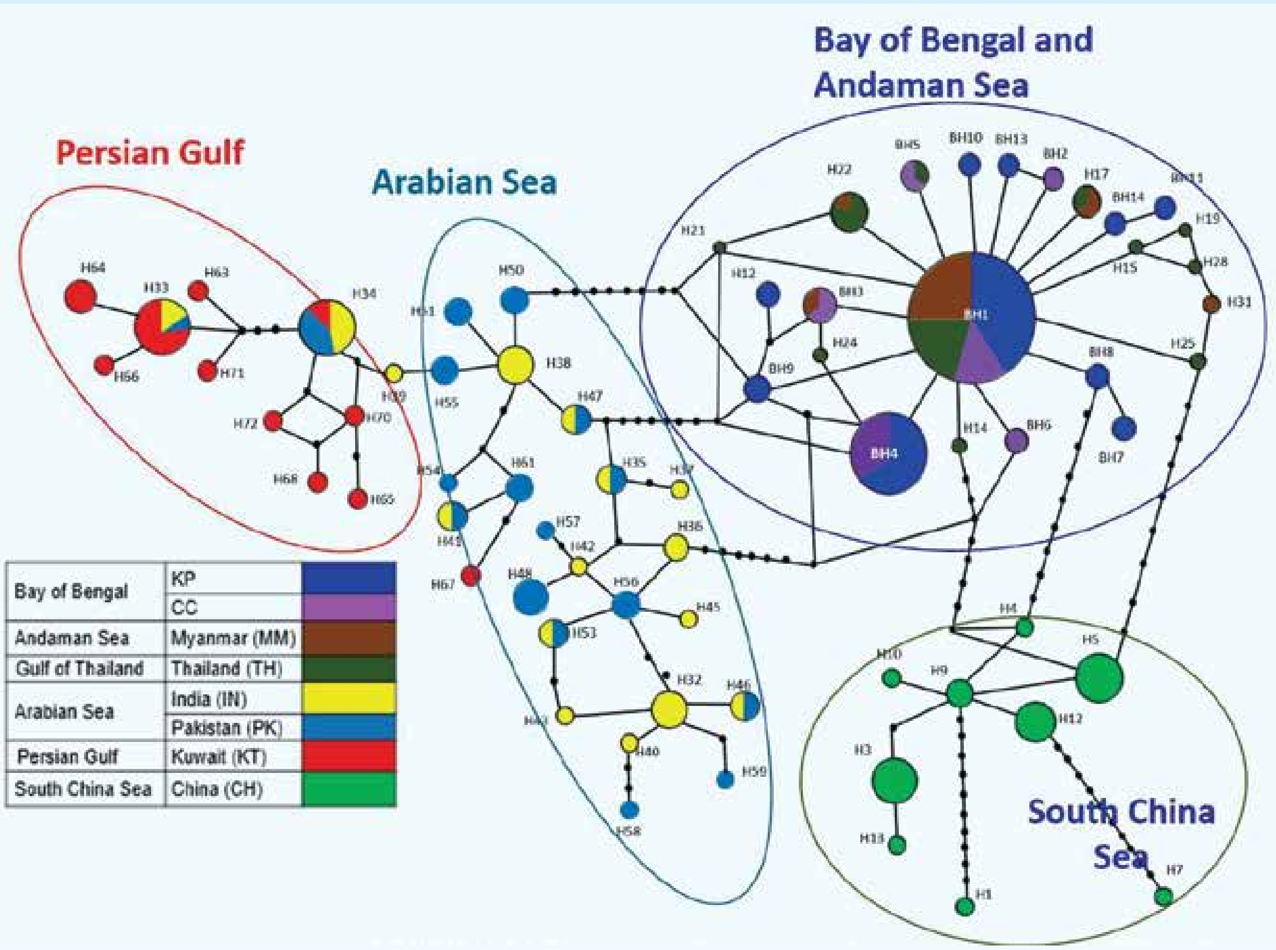


Fig 38. Haplotype network of control region observed in *P. chinensis* samples. Each connecting line represents a single mutation and small blanked circles represent an intermediate hypothesized missing ancestor between observed haplotypes. The sizes of circles are proportional to haplotype frequency.

iv. Phylogenetic analysis

Phylogenetic reconstruction of total 78 mitochondrial D-loop haplotypes using Neighbor Joining Method with the Kimura 2-parameter are shown in the Fig 39. The phylogeny showed two distinct clades (Clade-1 & Clade-2) with higher bootstrap value (>90). Clade-1 consists of the samples of Arabian Sea and Persian Gulf. On the other hand, Clade-2 contains the samples of BoB, Andaman Sea, Gulf of Thailand and South China Sea.

Fig 39. Neighbor-joining tree constructed using the Kimura-2 model for mitochondrial D-loop haplotypes of *P. argenteus*. Bootstrap support of >70% are shown above branches. Scale represents the genetic distance in mutations/site.

v. Pattern of demographic history

In the neutrality tests i.e., Tajima's *D* values of both KP and CC populations are negative but not significant whereas, Fu's *F*s value were significantly negative for both of these populations implying a demographic expansion of *P. argenteus* in this region (Table 36).

Table 36. Tajimas's *D* and Fu's F_S statistics for BoB populations of *P. argenteus*

Population	**Tajima's *D***		**Fu's F_S**	
	D	*P*	F_S	*P*
KP	-0.470	0.354	-2.612	0.011
CC	-0.594	0.329	-3.888	0.006

11.2.1.3. Genetic stock assessment of *E affinis* in BoB, BD & other sea areas

i. Genetic diversity

A total of 450 nucleotide long sequences of mtDNA d-loop region (control region) were obtained from 106 individuals of two Bangladeshi populations (KP and CC) after removing the ambiguous sequences near the primer ends. The d-loop region sequences of KP population comprised 20 haplotypes with 22 polymorphic sites, and the CC population covered 14 haplotypes with 15 polymorphic sites. Nucleotide composition of the sequences of KP population are C= 20.21%, T= 27.91%, A= 37.08%, G= 14.80%, and the sequences of CC population are C= 20.12%, T= 27.98%, A= 37.04%, G= 14.86%. Most of the nucleotide substitutions were transitional (Table 37). The nucleotide diversities (π) were low i.e. 0.004 and 0.008 nucleotide differences per site while the haplotype diversities (h) were very high, 0.928 and 0.949 for KP and CC populations, respectively. High level of haplotype diversities in contrast with low nucleotide diversity among the BoB population indicates that this fish has experienced population expansion after a period of low effective population size.

Table 37. Genetic diversity of *E affinis* for BoB population.

Sea	**Population**	**Sb (ti+tv)**	Nid	Nh	h	π	S
BoB	KP	13(13+0)	0	13	0.928	0.004	13
	CC	22(19+3)	0	20	0.949	0.008	22
[Number of substitution (Sb), Transition (ti), transversion (tv), number of indels (N_{id}), number of haplotype (N_h), haplotype diversity (h), nucleotide diversity (π), number of polymorphic site (S).							

ii. Population differentiation

Estimates of pairwise F_{ST} value between KP and CC populations of Bangladesh was 0.019 with no significant difference from random mixing indicating that no population genetic structure was established within Bangladeshi marine water. Further, estimates of pair wise F_{ST} between Bangladeshi populations and each of the 8 populations of other seas investigated varied from 0.037 to 0.103 with significant difference ($P<0.05$) (Table 38). This result indicates a unique population genetic structure that was established in the northern BoB region compared to other seas.

Table 38. Pairwise F_{ST} values among populations of *E affinis*

Population	**KP**	**CC**	**VE**	**RA**	**KO**	**KA**	**PB**	**TU**	**PO**
KP	-								
CC	0.019	-							
VE	0.078**	0.067**	-						
RA	0.103**	0.090**	-0.004	-					
KO	0.083**	0.070**	-0.005	-0.006	-				
KA	0.068**	0.055**	-0.006	-0.002	0.006	-			
PB	0.075**	0.065**	-0.002	-0.001	0.007	-0.005	-		

Popul ation	KP	CC	VE	RA	KO	KA	PB	TU	PO
TU	0.048**	0.037**	0.004	0.014	0.004	-0.002	0.0007	-	
PO	0.059**	0.047**	018**	0.026**	0.012	0.011	0.009	-0.0004	-
VI	0.059**	0.051**	-0.001	0.005	0.004	-0.006	-0.004	-0.005	0.002

** (P<0.01) and * (P<0.05)

iii. Phylogenetic analysis

Phylogenetic reconstruction of 194 mitochondrial D-loop haplotypes using the neighbor-joining method with the Kimura 2-parameter model resulted in a shallow tree with short branches (Fig. 40). Haplotypes from individuals of a population were scattered throughout the tree, being well mixed with those from other samples. There were no significant genealogical clusters or clades associated with any particular sampling localities.

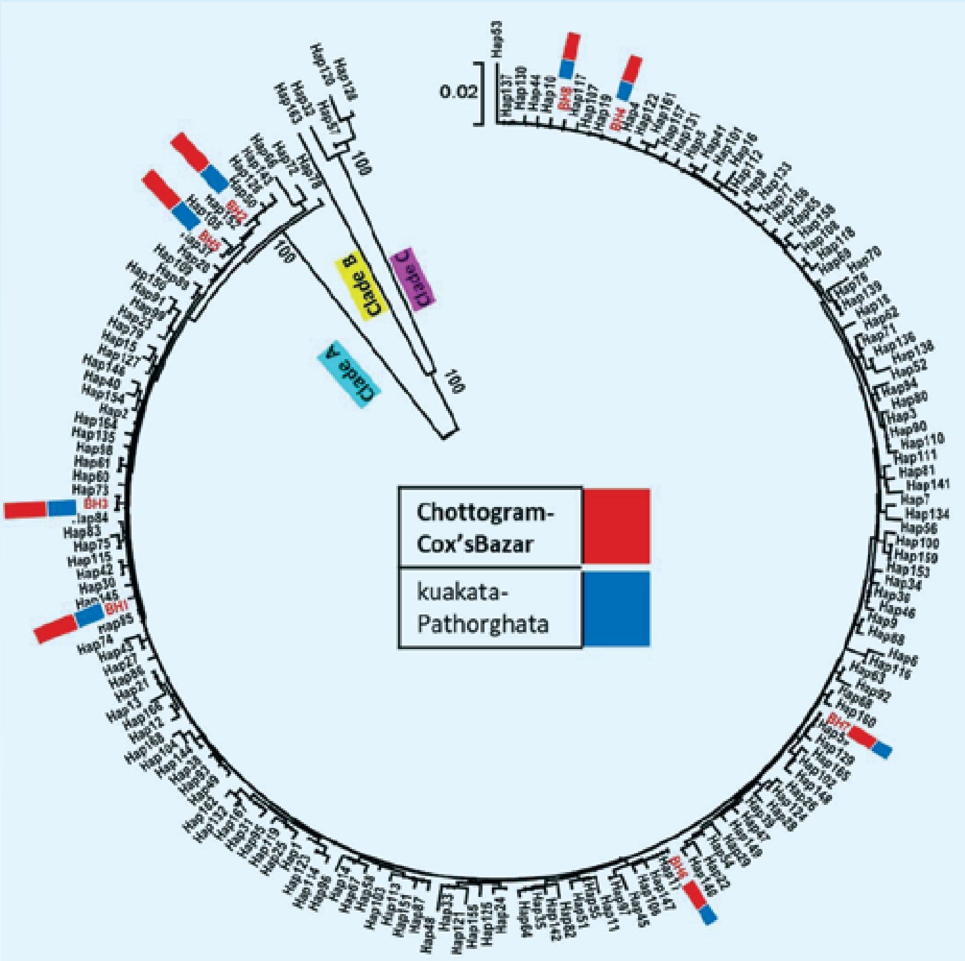


Fig 40. Neighbor-joining tree constructed using the Kimura-2 model for mitochondrial D-loop haplotypes of *E affinis*. Bootstrap support of >90% are shown above branches. Scale represents the genetic distance in mutations/site.

iv. Pattern of historic demography

In the neutrality tests, both Tajima's D and Fu's F_S statistics with the d-loop sequences showed significantly negative values (D = –1.92 & –1.69, $P < 0.05$; $F_S = –11.41$ & –66.67, $P < 0.05$) for the KP and CC populations (Table 39)., indicating a history of demographic expansion of Bangladeshi population.

Table 39. Tajimas's *D* and Fu's F_S statistics of *E affinis* for BoB populations.

Population	Tajima's *D*		Fu's F_S	
	D	*P*	F_S	*P*
KP	–1.92	0.013	–11.41	0.000
CC	–1.69	0.029	–16.67	0.000

11.2.1.4. Genetic stock assessment of *A thazard* in BoB, BD & other sea areas

i. Genetic diversity

A total of 451 nucleotide long sequences of mtDNA d-loop region (control region) were obtained from 120 individuals of two Bangladeshi populations (CB and PG) after removing the ambiguous sequences near the primer ends. The d-loop region sequences of CC population comprised 24 haplotypes with 142 polymorphic sites. And the d-loop region sequences of KP population comprised 23 haplotypes with 158 polymorphic sites. Nucleotide composition of CC population are C= 19.59%, T= 29.32%, A= 37.53%, G= 13.55% and the nucleotide composition of KP population are C= 19.54%, T= 29.14%, A= 37.87%, G= 13.45%. Most of the nucleotide substitutions were transitional (100 transitions for CC and 82 transitions for CC population) (Table 40). The nucleotide diversities (π) were low in each population of the BoB, 0.09 nucleotide differences per site while the haplotype diversities (*h*) were relatively high, 1.00 for PG and CB populations. High level of haplotype diversities in contrast with low nucleotide diversity among the BoB population indicates that this fish has experience population expansion after a period of low effective population size (Grant and Bowen 1998).

Table 40. Genetic diversity of *A thazard* for BoB population.

Population	Sb (ti+tv)	N_{id}	N_h	h	π	S
Coxs Bazar (CB)	108 (87+21)	54	24	1.00	0.09	142
Pathorghata (PG)	90 (71+19)	85	23	1.00	0.09	158
Verava (VE)	108(93+15)	36	49	0.99	0.05	130
Ratnagiri (RA)	100 (85+15)	47	46	0.99	0.05	133
Kochi (KO)	131 (100+31)	40	45	1.00	0.06	141
Kavaratti (KA)	114 (91+23)	37	50	1.00	0.05	129
Port-Blair (PB)	39(31+8)	28	8	1.00	0.05	61
Tuticorin (TU)	104 (188+16)	40	50	1.00	0.05	127
Pondicherry (PO)	138 (101+37)	34	49	1.00	0.05	142
Vizag (VI)	131 (97+34)	39	48	0.99	0.05	139

Number of substitution (Sb), Transition (ti), transversion (tv), number of indels (N_{id}), number of haplotype (N_h), haplotype diversity (h), nucleotide diversity (π), number of polymorphic site (S).

ii. Population differentiation

Pairwise estimates of the conventional F_{ST} among the populations were nearly zero or even negative with no significant deviation from the random mixing indicating that no population genetic structure is established over the range of investigation. The negative F_{ST} values implied more variations present within the samples of same population than those between the populations (Table 41).

Table 41. Pairwise F_{ST} values among populations of *A. thazard* for the d-loop region

Sl No.	Populn.	1	2	3	4	5	6	7	8	9	10
1	VE	-									
2	RA	0.00	-								
3	KO	-0.00	0.00	-							
4	KA	0.00	0.00	0.00	-						
5	PB	0.00	-0.00	-0.00	0.00	-					
6	TU	0.00	0.00	0.00	-0.00	0.00	-				
7	PO	0.00	-0.00	-0.00	-0.00	0.00	0.00	-			
8	VI	0.00	0.00	0.00	0.00	-0.00	0.00	0.00	-		
9	CB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	
10	PG	0.00	-0.00	0.00	0.00	-0.00	-0.00	0.00	0.00	0.00	-

** (P<0.01) and * (P<0.05)

iii. Demographic history

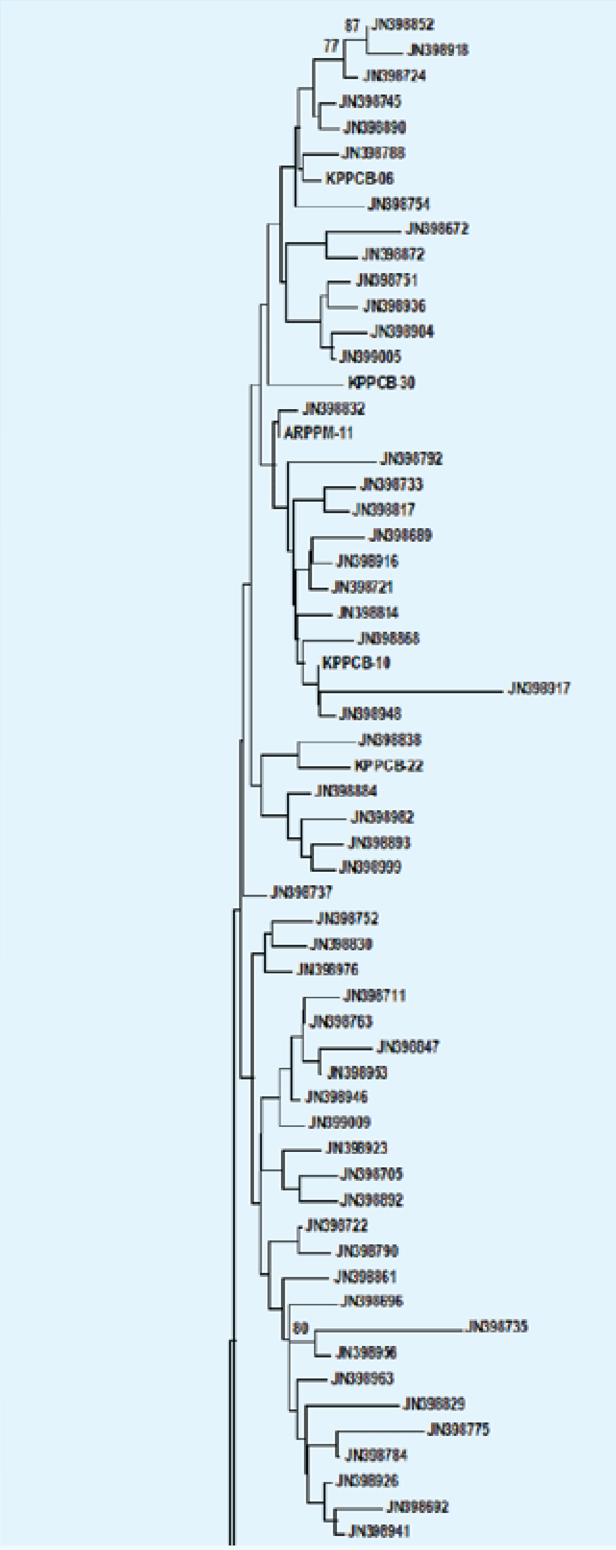
In the neutrality tests i.e. Tajima's *D* values were 0.165 and – 0.093 for CB and PG population, respectively and these values were not significant ($P>0.05$), but the Fu's *F*s values (-5.75 and -5.28) were very significant (P = 0.01 or near zero) indicating that this Bangladeshi populations has undergone population (Table 42).

Table 42. Tajimas's *D* and Fu's F_S statistics parameter estimates for BoB population of *A. thazard*.

Population	Tajima's *D*		Fu's F_S	
	D	*P*	F_S	*P*
Cox's Bazar (CB)	0.165	0.64	-5.75	0.01
Pathorghata (PG)	-0.093	0.191	-5.28	0.02

iv. Phylogenetic analysis

Phylogenetic reconstruction of total 374 mitochondrial D-loop haplotypes using Neighbor Joining method with the Kimura 2-parameter model resulted two separate clades, Clade-A and Clade-B (Fig 40). Clade- A consists the samples of the Arabian Sea (VE, RA, KO, KA and TU), Andaman Sea (PB) and the samples of the BoB, Bangladesh (PG, CB, VZ & PO). Clade-B consists of only the haplotypes of the BoB KP, CC, VI and PO. (Fig 39).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JN398936
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JN399005
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JN398792
JN398733
JN398817
JN398689
JN398916
JN398721
JN398814
JN398868
KPPCB-10
JN398917
JN398948
JN398838
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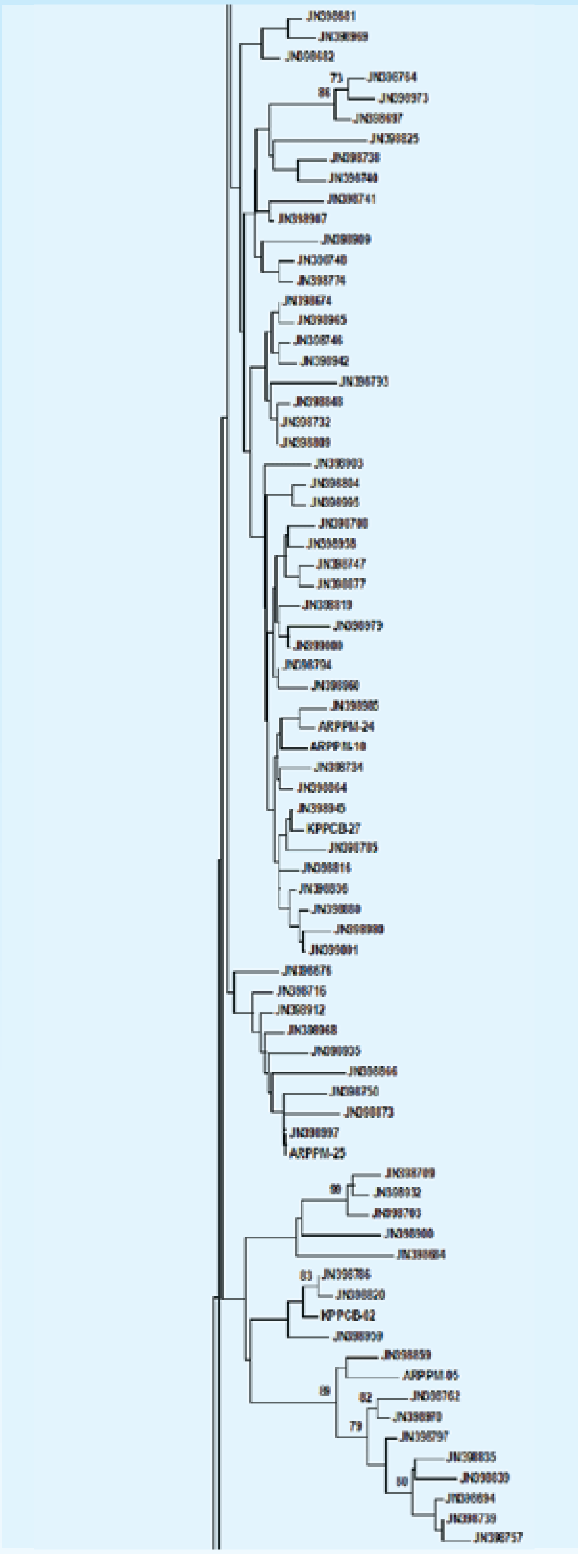

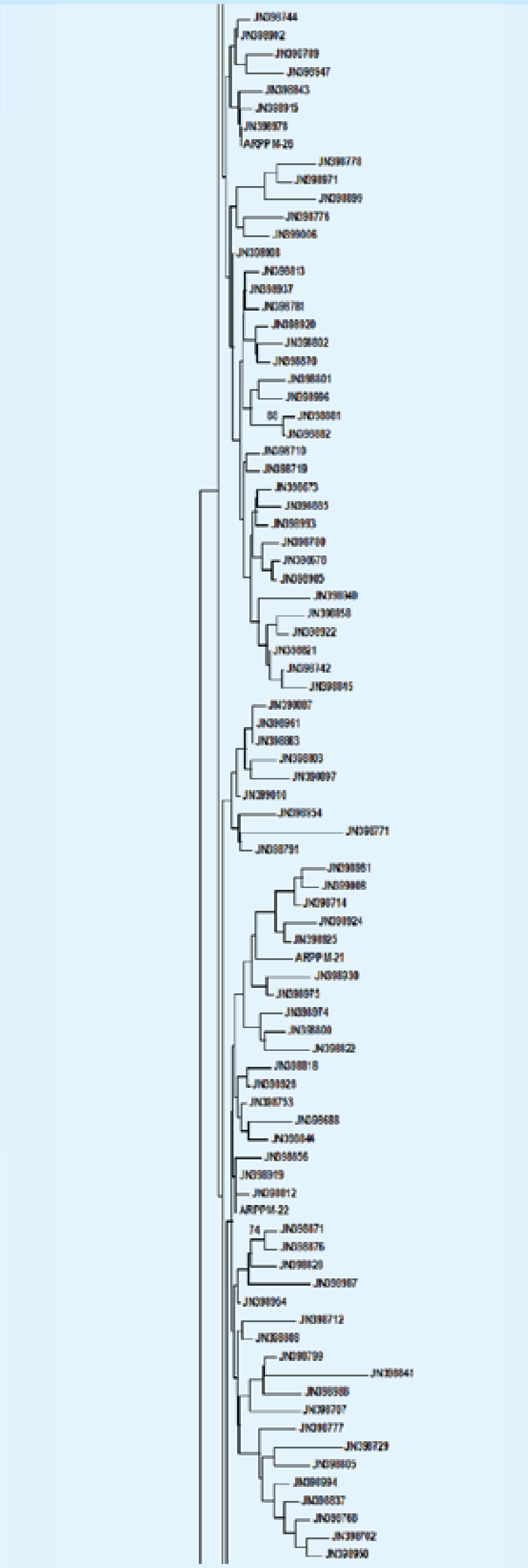

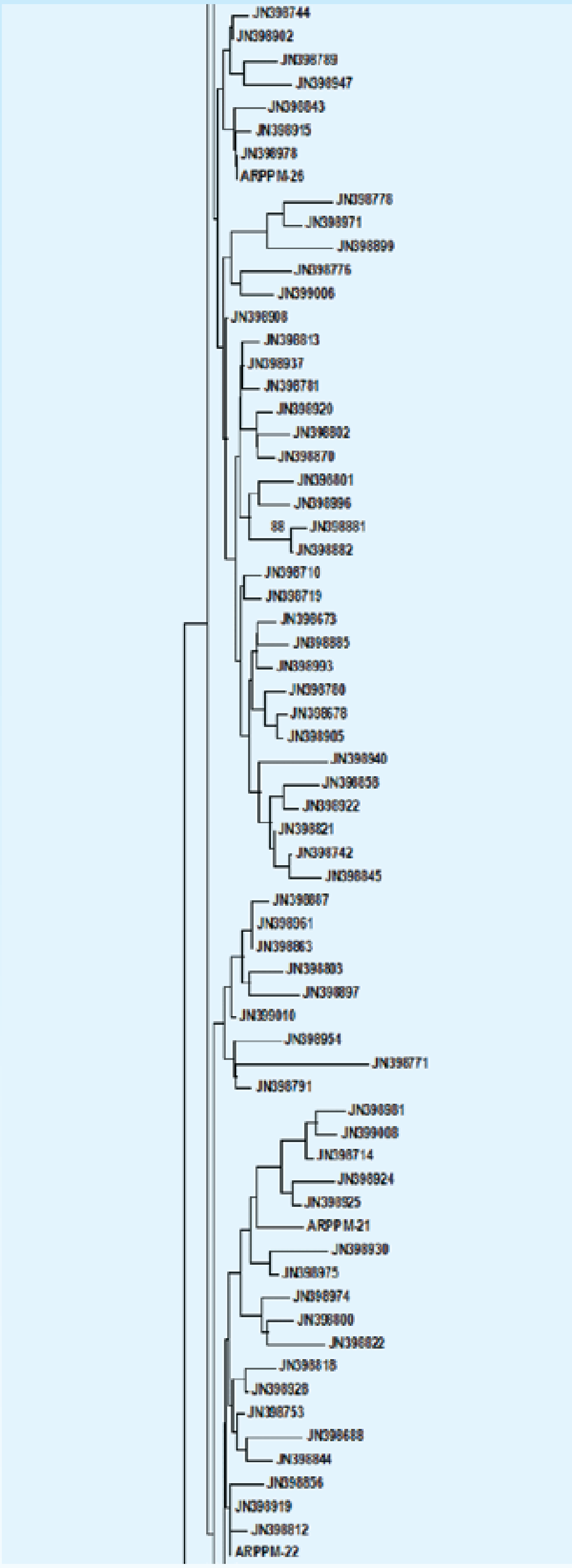
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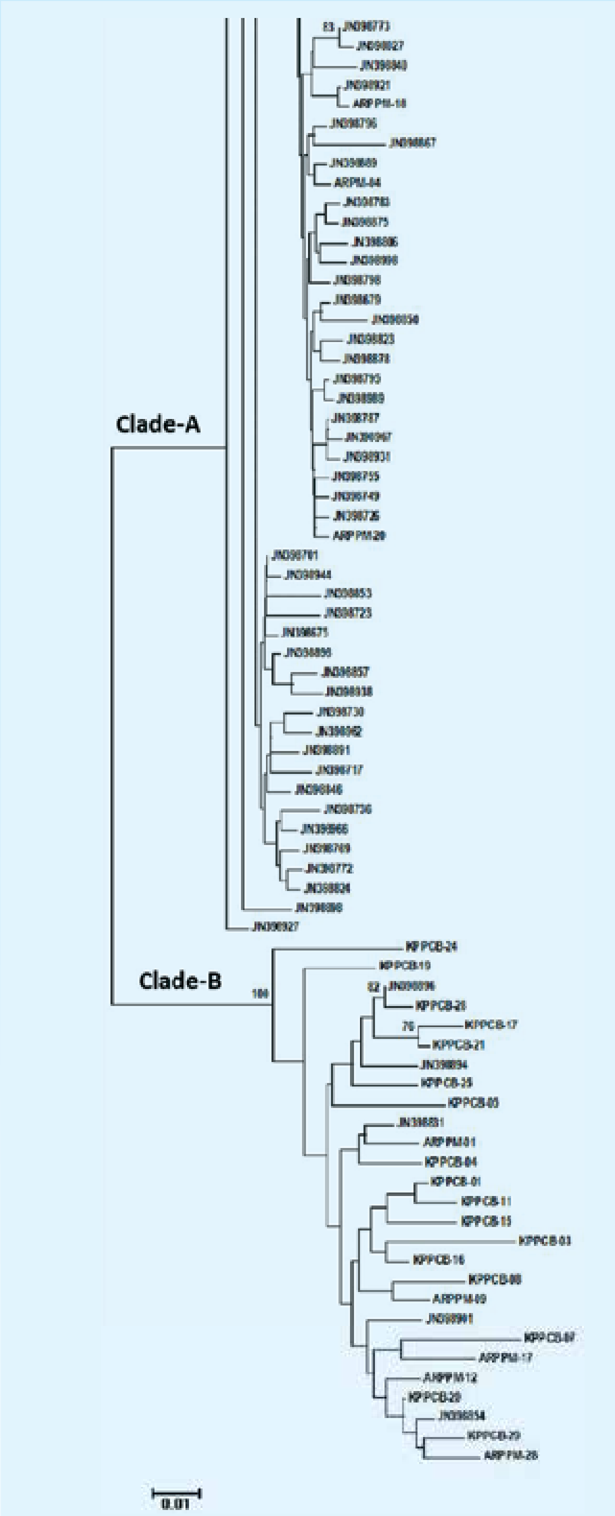

Fig 41. Neighbor-joining tree constructed using the Kimura-2 model for mitochondrial D-loop haplotypes of *A. thazard*. Bootstrap support of >70% are shown above branches. Scale represents the genetic distance in mutations/site.

11.2.1.5. Genetic stock assessment of *M cordyla* in BoB, BD & other sea areas

i. Genetic diversity

A total of 607 nucleotide long sequences of mtDNA COI gene region were obtained from two Bangladeshi populations (KK and CB) after removing the ambiguous sequences near the primer ends. The COI sequences of KK population comprised 2 haplotypes where 1 polymorphic site was identified. On the other hand, CB population contained 3 haplotypes with two polymorphic sites. Nucleotide composition of 61 sequences of KP population are C: 27.36%, T: 30.31%, A: 24.54%, G: 17.79% and the nucleotide composition of 39 sequences of CB population are C: 27.35%, T: 30.31%, A: 24.54%, G: 17.80%. No indels were detected in the sequences of both populations. No transition and transversion was found in KK population; whereas, only one transitions was occurred in CB population but no transversion was found in this population (Table 43). The nucleotide diversities (π) were very low in each population; 0.00 and 0.002 nucleotide differences per site and the haplotype diversities (h) were also relatively low, 0.31 and 0.58 for KP and CC populations, respectively. Low nucleotide diversity in contrast with low haplotype diversity within these two populations of the BoB indicates that this fish has experienced a recent bottleneck or founder event by single or a few lineages (Grant and Bowen 1998).

Table 43. Genetic diversity of *M. cordyla* for BoB population.

Population	Ni	Sb (ti+tv)	N_{id}	N_h	h	π	S
KK	61	00	01	2	0.226	0.0004	1
CB	39	1 (1+0)	01	3	0.14	0.0002	2
[Number of individuals (Ni), number of substitution (Sb), Transition (ti), transversion (tv), number of indels (N_{id}), number of haplotype (N_h), haplotype diversity (h), nucleotide diversity (π), number of polymorphic site (S)							

ii. Population differentiation

Table 44. Pairwise F_{ST} and P values between the BoB and other populations of *M. cordyla* for mtDNA COI region.

Population	KK	CB	SCS	SS	AS	PG	WIO
KK	-	0.257	0.00	0.00	1.00	1.00	0.00
CB	-0.000	-	0.00	0.00	1.00	1.00	0.00
SCS	0.487**	0.518**	-	0.03	0.019	0.046	0.00
SS	0.719**	0.771**	0.062	-	0.000	0.000	0.000
AS	-0.038	-0.094	0.461**	0.726**	-	-1.00	0.003
PG	-0.069	-0.126	0.440**	0.711**	0.000	-	0.005
WIO	0.817**	0.886**	0.594**	0.739**	1.000**	1.000**	-
**p<0.01, *p<0.05							

Estimates of F_{ST} between KK and CB populations of Bangladesh, -0.00 (P>0.05) with no significant deviation from the random mixing (i.e. single genetic stock in Bangladesh). Pairwise estimates of conventional F_{ST} among the populations ranged from zero to 1.0 and some of the values were significant (e.g. KK and CB vs. SCS and SS) and non-significant (e.g. KK and CB vs. AS and PG). These values were even negative with no significant deviation from the random mixing (e.g. KK vs. CB; KK and CB vs. AS and PG) indicating that no population genetic structure was established over the Arabian Sea and BoB. The negative F_{ST} values implied more variations present within the same population than those between the populations. Exact test of population differentiation also showed similar result. However, KK, CB, AS and PG populations of *M. cordyla* showed population panmixia between them which means no mating restrictions, neither genetic nor behavioural, between the populations and that therefore, all recombination is possible (Table 44).

iii. Haplotype network

All sequences defined nine haplotypes among 173 specimens where 3 haplotypes found in the BoB population. Among 3 of the BoB haplotypes, 2 haplotypes were unique for the BoB that is not present in other population. In the BoB, one haplotype is unique for CB population, and one haplotype was shared between KP and CC population (Fig. 42). The haplotype BH1 was the most dominant haplotype and it was shared by the BoB, South China Sea, Arabian Sea, and Persian Gulf. This dominant haplotype contained 113 individuals of the BoB.

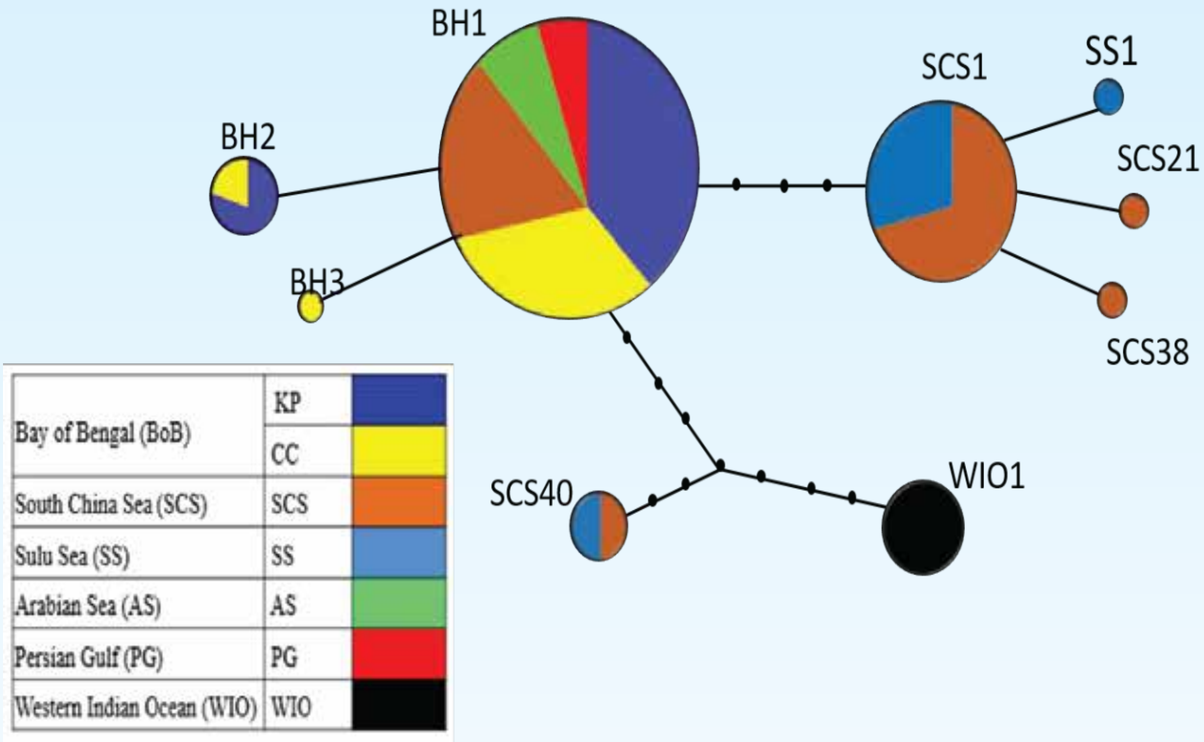

Fig 42. Haplotype network of mtDNA COI gene region observed in *M. cordyla* samples. Each connecting line represents a single mutation and small blanked circles represent an intermediate hypothesized missing ancestor between observed haplotypes. The sizes of circles are proportional to haplotype frequency.

iv. Phylogenetic analysis

Phylogenetic reconstruction of total 9 mitochondrial COI haplotypes using Neighbor Joining Method with the Kimura 2-parameter model resulted three clades (Fig 43). Clade- A consists the haplotypes of Soth China Sea (SCS) and Sulu Sea (SC). Clade-B consists of haplotypes of KK and CB population of the BoB, South China Sea (SCS), Arabian Sea (AS), and Persian Gulf (PG). Clade-3 belongs to the haplotypes of South China Sea and Western Indian Ocean.

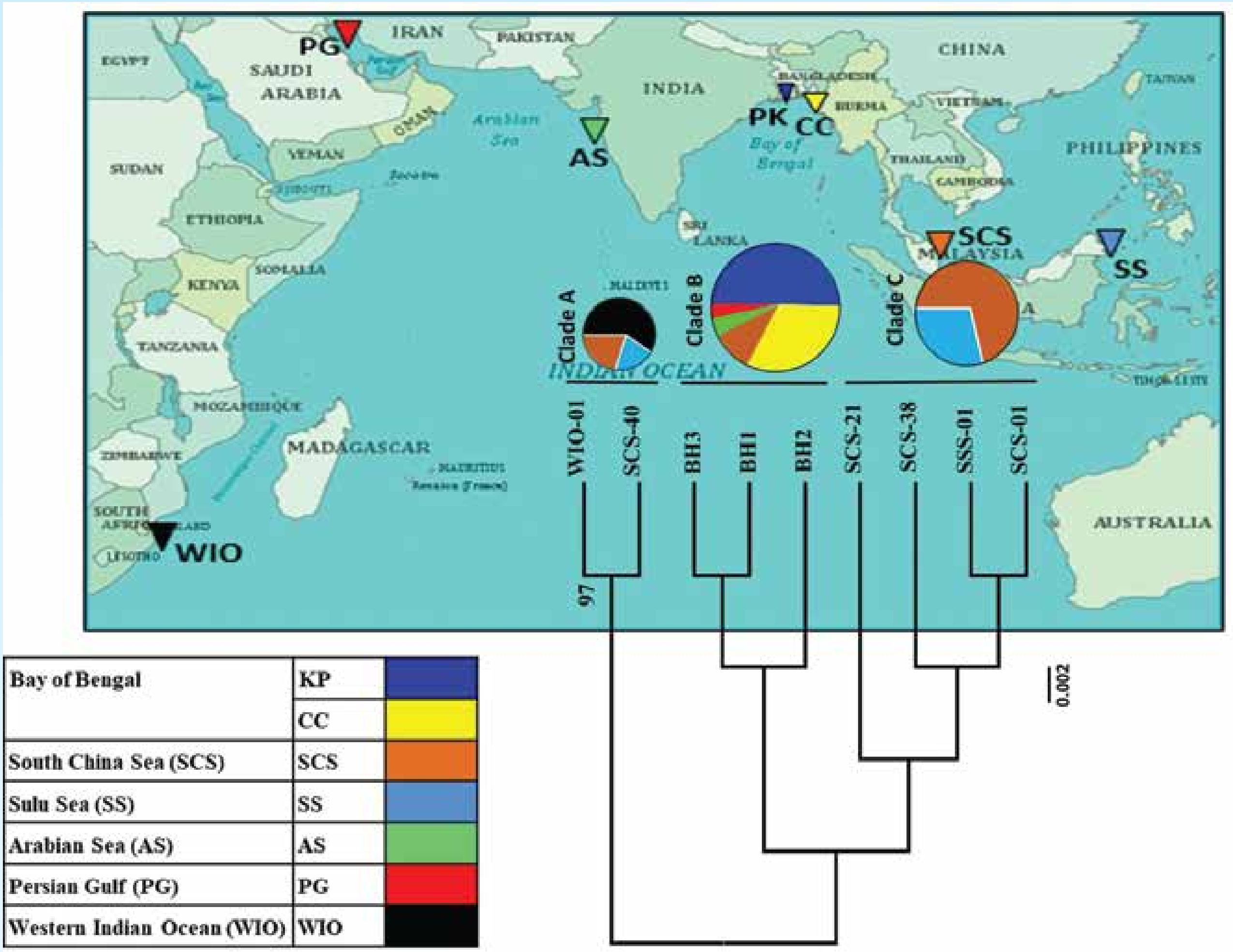

Fig 43. Neighbor-joining tree constructed using the Kimura-2 model for mitochondrial COI haplotypes of *M. cordyla*. Bootstrap support of >90% are shown above branches. Scale represents genetic distance between species.

v. Demographic history

In the neutrality test, Tajima's D tests (KP: D= 0.000, P=1; Ch-Cox: D= -1.15, P=0.13) results for KK and CB populations of the BoB were not statistically significant. The Fu's Fs test are positive (F_S=0.33, $P < 0.42$) and not statistically significant for KK population. On the other hand, Fu's Fs test are negative (F_S=-2.26, $P < 0.01$) and statistically significant for CC population (Table 45).

Table 45. Tajimas's *D* and Fu's F_S statistics, and mismatch distribution parameter estimates (τ, Θ_0, Θ_1) for BoB population.

Population	Tajima's *D*		Fu's F_S	
	D	*P*	F_S	*P*
KK	0.00	1.0	0.33	0.34
CB	-1.15	0.13	-2.26	0.01

11.2.1.6. Genetic stock assessment of *L calcarifer* in BoB, BD & other seas areas

i. Genetic diversity

A total of 279 nucleotide long sequences of mtDNA cytb region (control region) were obtained from two Bangladeshi populations (SK) after removing the ambiguous sequences near the primer ends. The Cytb region sequences of SK population comprised only 2 haplotypes with 34 polymorphic sites. The nucleotide composition of the sequences of SK population are C= 27.00%, T= 32.01%, A= 25.09%, G= 15.90%. And nucleotide composition of the sequences of the Malay peninsula population are C= 27.61%, T= 31.72%, A= 25.17%, G= 15.50%. The nucleotide diversities (π) were low (0.008) and the haplotype diversities (*h*) were also relatively high (0.263) in the BoB population which indicates that BoB population of this fish has experienced recent bottleneck or founder events by a single or a few lineages (Grant and Bowen 1998) (Table 46).

Table 46. Genetic diversity of *L. calcarifer* for BoB population.

Sea	Population ID	Sb (ti+tv)	Nid	Nh	*h*	π	S
BoB	Satkhira (SK)	00	0	1	1	0.000	0
	Cox'sBazar (CB)	00	0	1	1		0
Straits of Malacca	MS	30 (263+4)	0	8	0.91	0.05	0
South China Sea	SCS	59(41+25)	1	12	0.90	0.06	59
[Number of substitution (Sb), Transition (ti), transversion (tv), number of indels (N_{id}), number of haplotype (N_h), haplotype diversity (*h*), nucleotide diversity (π), number of polymorphic site (S).							

ii. Population differentiation

Estimates of F_{ST} between SK population of Bangladesh and compared population of Malay peninsula were varied from 0.0363 with significant difference (P=0.00) (Table 47). This result indicating a unique population genetic structure (i.e., a single genetic stock) was established in the BoB region compared to other seas. Exact test of population differentiation also showed significant differentiation between BoB and other populations investigated suggesting a non-panmictic population between BoB and other sea.

Table 47. Pairwise F_{ST} values among populations of *L. calcarifer* for cytb region.

Population	SK	CB	MS	SCS
Satkhira (SK)	-			
Cox'sBazar (CB)	-	-		
Straits of Malacca (MS)	0.508**	0.564**	-	
South China Sea (SCS)	0.518**	0.585**	0.036	-
** p<0.01, * p<0.05				

iii. Haplotype network

All sequences defined 15 haplotypes where only one (BH-01) haplotypes found in the BoB population. The BoB haplotype was shared among two BoB populations Satkhira (SK) and Cox's Bazar (CB) and between Malacca straight population (Fig 44). The haplotype BH-1 was the most dominant haplotype

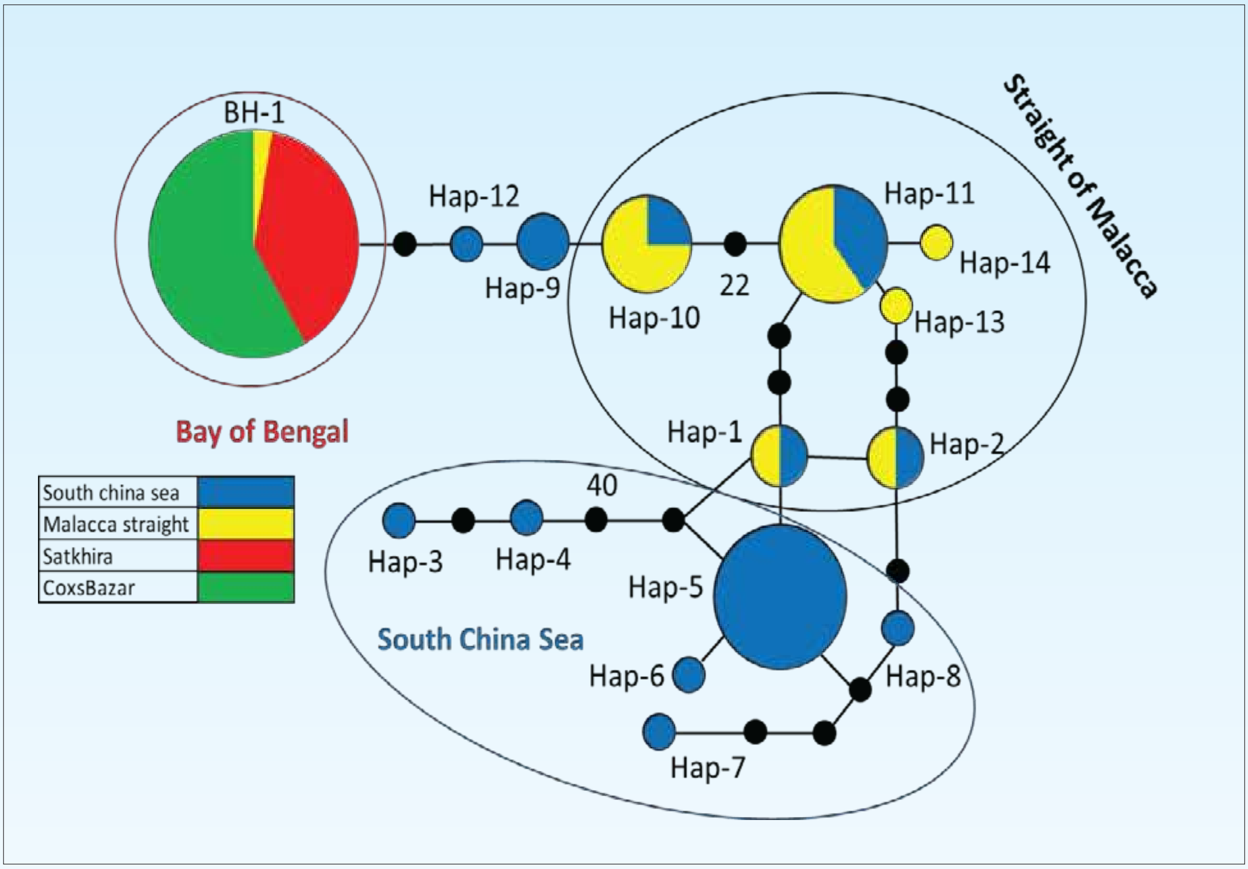

Fig 44. Haplotype network of mtDNA Cytb gene region observed in *L. calcarifer* samples. Each connecting line represents a single mutation and small blanked circles represent an intermediate hypothesized missing ancestor between observed haplotypes. The sizes of circles are proportional to haplotype frequency.

iv. Phylogenetic analysis

Phylogenetic reconstruction of total 15 mitochondrial Cytb haplotypes using Neighbor Joining Method with the Kimura 2-parameter model resulted three separate clades (Fig 45).

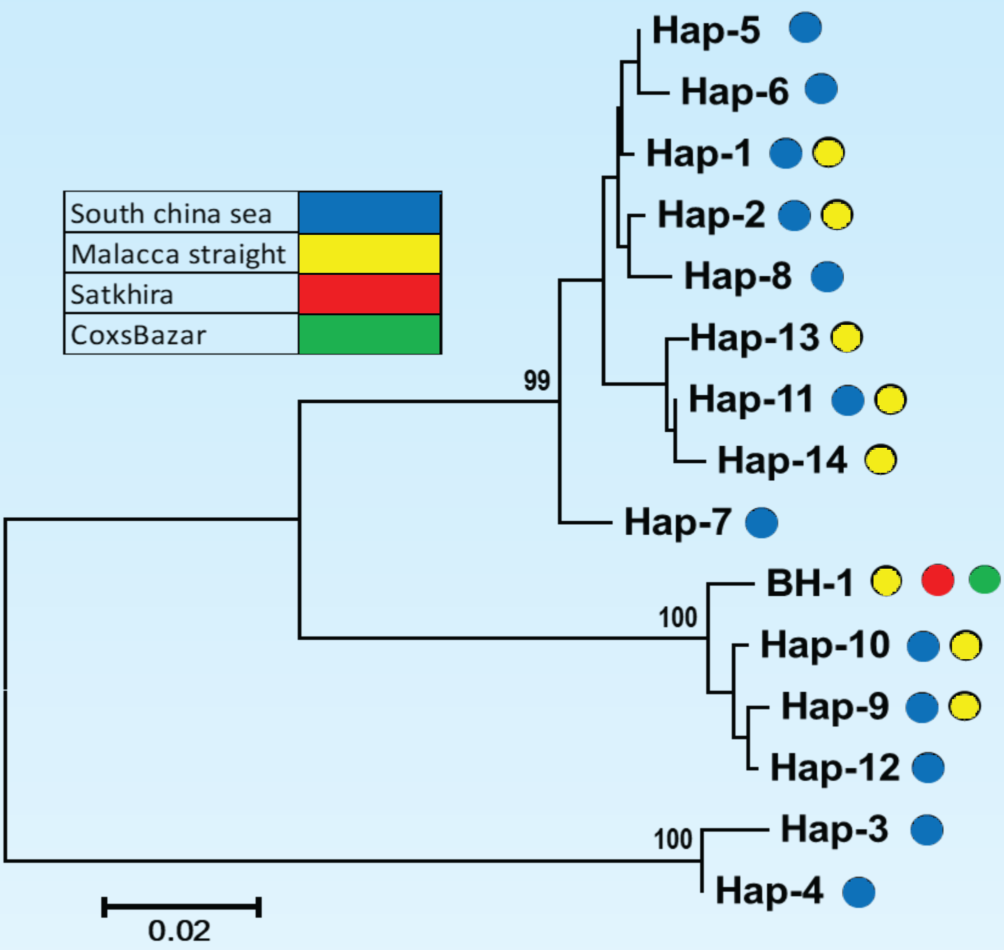

Fig 45. Neighbor-joining tree constructed using the Kimura-2 model for mitochondrial Cytb haplotypes of *L. calcarifer*. Bootstrap support of >70% are shown above branches. Scale represents the genetic distance in mutations/site.

v. Demographic history

The neutrality tests i.e., Tajima's *D* tests value and Fu's *F*s value both have positive values are not significant in SK and CB populations implying a demographic equilibrium of this species in this region (Table 48).

Table 48. Tajimas's *D* and Fu's F_S statistics for the BoB population of *L. calcarifer*.

Population	Tajima's *D*		Fu's F_S	
	D	*P*	F_S	*P*
Satkhira (SK)	0.00	1.00	0.00	-
Cox'sBazar (CB)	0.00	1.00	0.00	-
Straits of Malacca (MS)	2.36	0.99	2.24	0.845
South China Sea (SCS)	0.279	0.68	1.527	0.769

11.2.1.7. Genetic stock assessment of *S tenuifilis* in BoB, BD

i. Genetic diversity

A total of 429 nucleotide long sequences of mtDNA d-loop region (control region) were obtained from two Bangladeshi populations (BK and MR) after removing the ambiguous sequences near the primer ends. The d-loop region sequences of Matamuhuri river (MR) population comprised 7 haplotypes with 7 polymorphic sites. And the d-loop region sequences of Bishkhali river (BK) population comprised 7 haplotypes with 8 polymorphic sites. The nucleotide diversities (π) were low in both populations, 0.004 and 0.003 nucleotide differences per site on both, while the haplotype diversities (*h*) were relatively high, 0.731 and 0.724 for MR and BK populations, respectively (Table 49). High level of haplotype diversities in contrast with low nucleotide diversity among the BoB population indicates that this fish has experienced population expansion after a period of low effective population size (Grant and Bowen 1998).

Table 49. Genetic diversity of *S. tenuifilis* for BoB population.

Sea	**Population**	**Sb (ti+tv)**	Nid	Nh	*h*	π	S
BoB	MR	7 (1+6)	0	7	0.731	0.004	7
	BK	8 (7+1)	0	7	0.724	0.003	8
	[Number of substitution (Sb), Transition (ti), transversion (tv), number of indels (N_{id}), number of haplotype (N_h), haplotype diversity (*h*), nucleotide diversity (π), number of polymorphic site (S).						

ii. Population differentiation

Estimates of F_{ST} between KP and CC populations of Bangladesh 0.047 with significant deviation (P=0.048) from the random mixing (Table 50).

Table 50. Pairwise F_{ST} values (below diagonal) between populations of *S tenuifilis* for d-loop

Population	MR	BK
Matamuhuri river (MR)	-	
Bishkhali river (BK)	0.047*	-
** (P<0.01) and * (P<0.05)		

iii. Haplotype Network

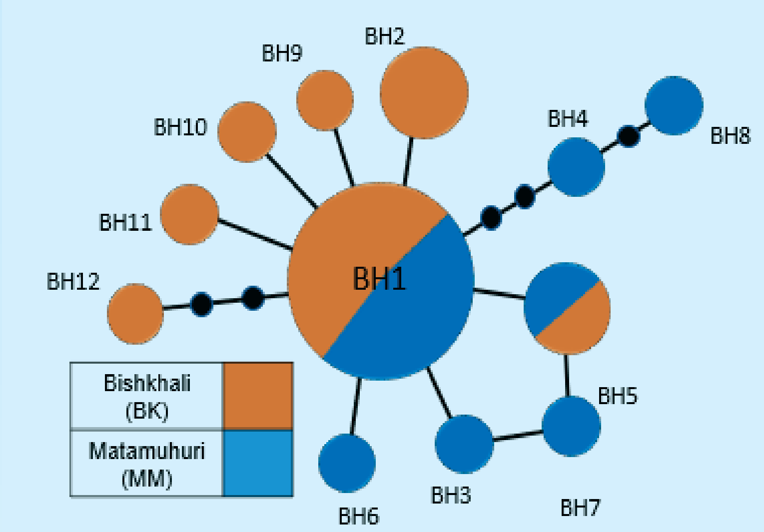

Fig 46. Haplotype network of mtDNA control gene region observed in *S. tenuifilis* samples. Each connecting line represents a single mutation and small blanked circles represent an intermediate hypothesized missing ancestor between observed haplotypes. The sizes of circles are proportional to haplotype frequency.

All sequences defined a total of 12 haplotypes, where 07 haplotypes (BH-01, BH-3 to BH-08) were found in Matamuhuri river (MR) river and 07 haplotypes (BH-01, BH-02, BH-05, BH-09 to BH-12) were found in Bishkhali river (BK). Among all haplotypes, five haplotypes (BH-03, BH-04, Bh-06, BH-07, BH-08) were unique in the Matamuhuri river (MR) river population and five (BH-02, Bh-09, BH-10, BH-11 and BH-12) were unique for the BK population. Two haplotypes (BH-01, BH-05) were shared by both populations (Fig 46).

iv. Phylogenetic analysis

Phylogenetic reconstruction of the mitochondrial D-loop haplotypes using Neighbor Joining Method with the Kimura 2-parameter model are shown in the figure Fig 47.

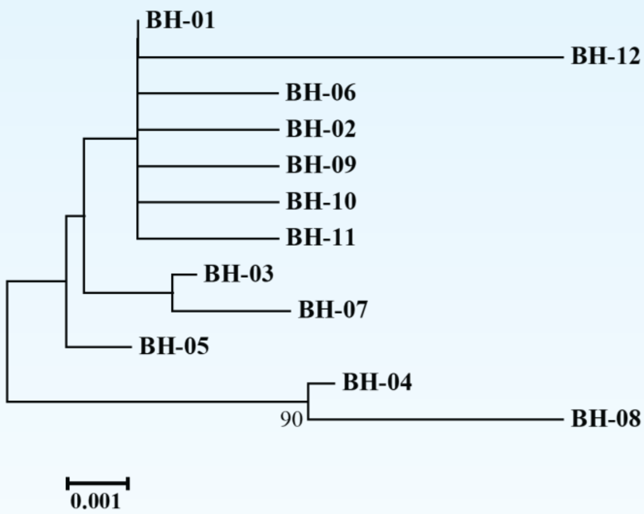

Fig 47. Neighbor-joining tree constructed using the Kimura-2 model for mitochondrial D-loop haplotypes of *S. tenuifilis*. Bootstrap support of >70% are shown above branches. Scale represents the genetic distance in mutations/site.

v. Demographic history

The neutrality tests i.e. Tajima's *D* tests values and Fu's *F* values of both populations were significantly negative implying a demographic expansion of this fish in the BoB region (Table 51).

Table 51. Tajimas's *D* and Fu's F_S statistics of *S. tenuifilis* for BoB population.

Population	Tajima's *D*		Fu's F_S	
	D	*P*	F_S	*P*
MR	-0.73	0.26	-2.59	0.03
BK	-1.91	0.01	-3.66	0.001

11.2.1.8. Genetic stock assessment of *S panijus* in BoB, BD

i. Genetic diversity

A total of 730 nucleotide long sequences of mtDNA Cytochrome b (Cytb) region were obtained from two Bangladeshi populations, Bishkhali river (BK) and Baleshwar river (BR) after removing the ambiguous sequences near the primer ends. The sequences of BK population comprised 6 haplotypes with 5 polymorphic sites. And the sequences of BR population comprised 6 haplotypes with 4 polymorphic sites. The sequences of MR population comprised 8 haplotypes with 7 polymorphic sites. Nucleotide composition of BK population are C= 30.41%, T= 3041%, A= 22.93%, G= 16.25%; the nucleotide composition of BR population sequences is C= 30.38%, T= 30.44%, A= 22.99%, G= 16.19% and the nucleotide composition of BR population sequences are C= 30.41%, T= 30.41%, A= 22.87%, G= 16.31%. Most of the nucleotide substitutions were transitional (Table 52). The nucleotide diversities (π) were low in both BoB populations, 0.001 nucleotide differences per site while the haplotype (gene) diversities (*h*) were relatively high which are 0.647, 0.552, and 0.339 for BK, BR and MR populations, respectively. High level of haplotype diversities in contrast with low nucleotide diversity among the BoB population indicates that this fish has experienced population expansion after a period of low effective population size (Grant and Bowen 1998).

Table 52. Genetic diversity of *S. panijus* for BoB population.

Sea	Population	Sb (ti+tv)	Nid	Nh	*h*	π	S
BoB	BK	5 (5+0)	0	6	0.647	0.001	5
	BR	4 (4+0)	0	6	0.552	0.001	4
	MR	7 (7+0)	0	8	0.339	0.001	7
	[Number of substitution (Sb), Transition (ti), transversion (tv), number of indels (N_{id}), number of haplotype (N_h), haplotype diversity (*h*), nucleotide diversity (π), number of polymorphic site (S).						

ii. Population differentiation

The F_{ST} value between KR, BR and MR populations are 0.155-0.516 with significant deviation (P<0.01) from the random mixing (Table 32). This result indicates that two different populations are present in the BoB, Bangladesh. Exact test of population differentiation also showed significant differentiation between two BoB populations suggesting non-panmictic populations within Bangladeshi marine waters.

Table 53. Pairwise F_{ST} values (below diagonal) and non-differentiation exact P values (above diagonal) among populations of *S. panijus*

Population	BKR	BR	MR
Bishkhali river (BK)	-	0.01	0.01
Baleshwar river (BR)	0.155**	-	0.00
Meghna river (MR)	0.156**	0.516**	-
**P<0.01 *P<0.05			

iii. Haplotype

All sequences of cytb defined 16 haplotypes where 3 haplotypes (BH-1, BH-5, BH-6) were unique for in the Bishkhali river (BK) population, 3 haplotypes (BH-7, BH-8, BH-9) were unique in Baleshwar River (BR) and 7 haplotypes (BH-10 to BH-16) are unique for ther Meghna River (MR) population (Fig). BH-2 haplotype shared aamong three population and two haplotypes (BH-3 and BH-4) were shared by BK and BR populations.

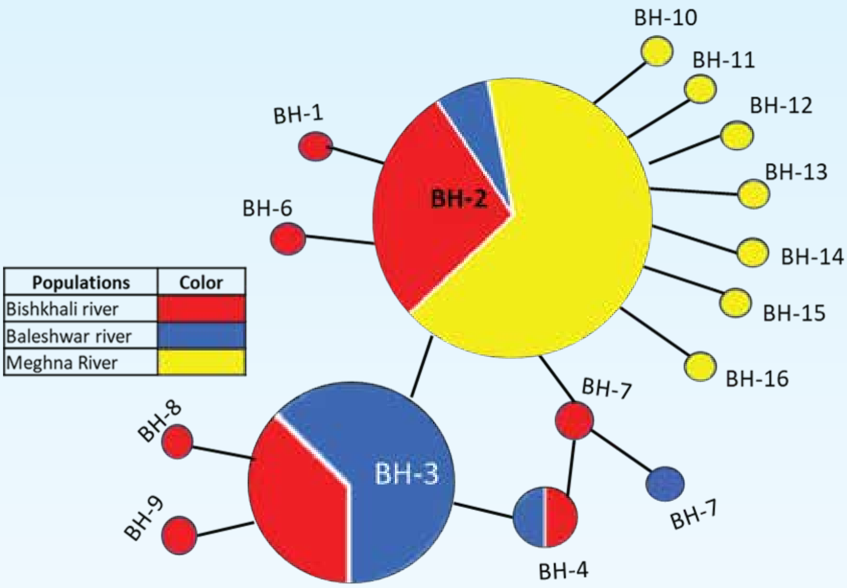

Fig 48. Haplotype network of mtDNA cytb gene region observed in *S. panijus* samples. Each connecting line represents a single mutation and small blanked circles represent an intermediate hypothesized missing ancestor between observed haplotypes. The sizes of circles are proportional to haplotype frequency.

iv. Phylogenetic analysis

Phylogenetic reconstruction of the total 16 mitochondrial Cytb haplotypes using Neighbor Joining Method with the Kimura 2-parameter model resulted two separate clades (Clade A & Clade B; Fig 49).

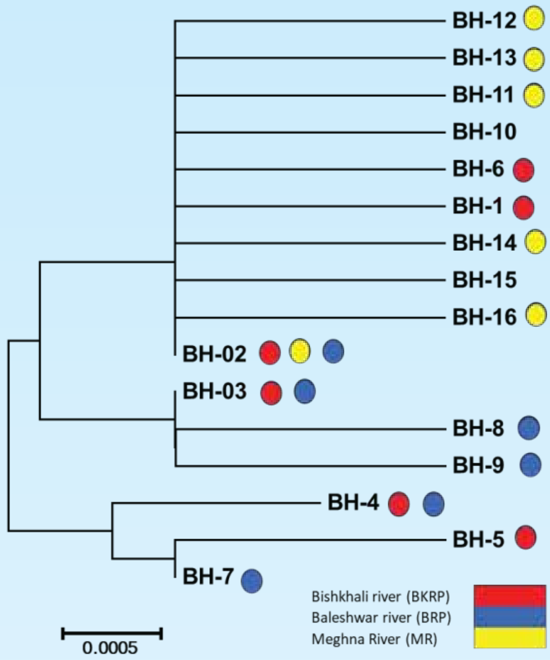

Fig 49. Neighbor-joining tree constructed using the Kimura-2 model for mitochondrial D-loop haplotypes of *S. panijus* Bootstrap support of >80% are shown above branches. Scale represents the genetic distance in mutations/site.

v. Demographic history

The neutrality tests i.e. Tajima's *D* tests for BK, BR, and MR populations of the BoB revealed nonsignificant negative values (Table 54). On the other hand, the Fu's F_s values are negative but significant (Table 54) implying a demographic expansion of *S. panijus* in the BoB region.

Table 54. Tajimas's *D* and Fu's F_S statistics of *S. panijus* for thr BoB population.

Population	Tajima's *D*		Fu's F_S	
	D	*P*	F_S	*P*
Bishkhali river (BK)	-0.97	0.17	-2.32	0.04
Baleshwar river BR)	-1.07	0.16	-3.35	0.001
Meghna river (MR)	-2.18	0.11	-8.545	0.000

11.2.1.9. Genetic stock assessment of *P paradiseus* in BoB, BD

i. Genetic diversity

A total of 563 nucleotide long sequences of mtDNA d-loop region (control region) were obtained from 174 individuals of four Bangladeshi populations (KF, KK, BK and BR) after removing the ambiguous sequences near the primer ends. The sequences of KR population comprised 18 haplotypes with 27 polymorphic sites. The sequences of KK population comprised 12 haplotypes with 35 polymorphic sites, and BK and BR both comprises 17 haplotypes with 43 and 37 polymorphic sites, respectively. The nucleotide diversities (π) were low in each population ranged between 0.009 to 0.012 nucleotide differences per site. However, the haplotype diversities (*h*) were relatively high ranging between 0.959 and 0.994 (Table 55). High level of haplotype diversities in contrast with low nucleotide diversity among the BoB population indicates that this fish has experienced population expansion after a period of low effective population size.

Table 55. Genetic diversity of *P. paradiseus* for BoB population.

Population	**Sb (ti+tv)**	Nid	N_h	*h*	π	S
Karnofuli river (KF)	25 (20+5)	2	18	0.984	0.009	27
Kirtonkhola river (KK)	30 (26 + 4)	6	22	0.959	0.008	35
Bishkhali river (BK)	22 (19+3)	21	17	0.988	0.012	43
Baleshwar river (BS)	34 (27 + 7)	3	17	0.994	0.012	37

Number of substitution (Sb), Transition (ti), transversion (tv), number of indels (N_{id}), number of haplotype (N_h), haplotype diversity (*h*), nucleotide diversity (π), number of polymorphic site (S).

ii. Population differentiation

Pairwise values of fixation index (F_{ST}) showed that Kirtonkhola river population (KK) has significant variation with Karnafuli (KF) and Baleshwar river (BS) populations. However, the rest of pairwise F_{ST} between other populations did not show significant differences (Table 56). Exact test of population differentiation also showed significant differentiation i.e. non-panmixic population for KK population as compared to KF and BS river populations.

Table 56. Pairwise F_{ST} values among populations of *P. paradiseus* for d-loop region

Population	**KF**	**KK**	**BK**	**BS**
Karnofuli river (KF)	-	0.01	0.55	0.57
Kirtonkhola river (KK)	0.019**	-	0.15	0.01
Bishkhali river (BK)	0.003	0.002	-	0.11
Baleshwar river (BR)	0.0001	0.123**	0.009	-

**$P<0.01$; * $P<0.05$

iii. Haplotype network

All of d-loop sequences defined 74 haplotypes where 18 haplotypes (BH-1 to BH-18) were found in Karnofuli river (KR) and 22 haplotypes (BH-19 to BH-39 and BH-12) were found in Kirtonkhola river (KK) river. Further, 17 haplotypes (BH-40 to BH-53 and BH-12, 14, 32) were found in Bishkhali river (BK) and 17 haplotypes (BH-54 to BH-67 and BH-6, 11, 24) found in Baleshwar River (BR). Two haplotypes (BH-6,11) were shared between KR and BR. A single haplotype was shared for each of the pair KK & BK; KK & BR; KK & BK. Another haplotype was shared by KR, KK & BK (Fig 50).

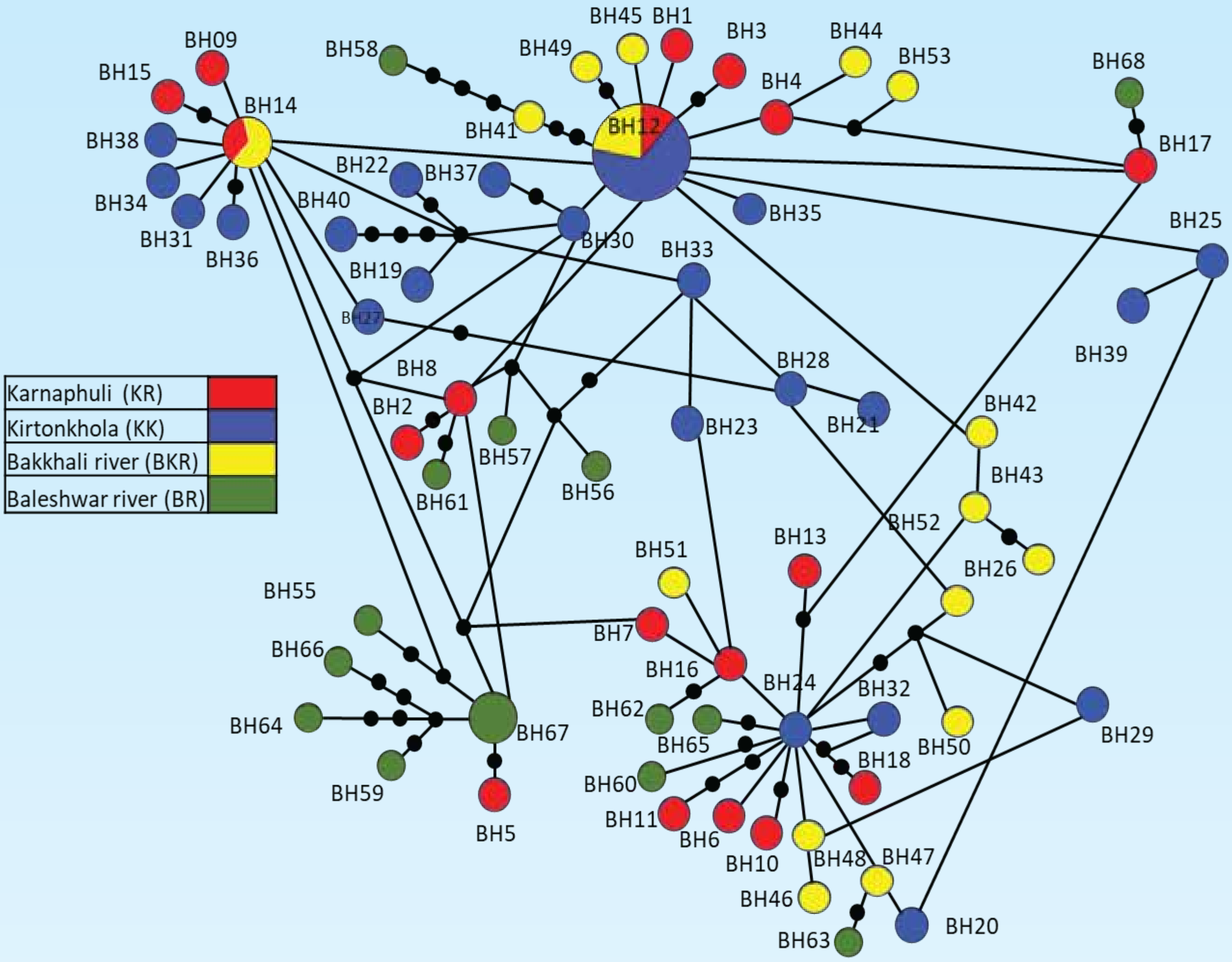

Fig 50. Haplotype network of mtDNA control gene region observed in *P. paradiseus* samples. Each connecting line represents a single mutation and small blanked circles represent an intermediate hypothesized missing ancestor between observed haplotypes. The sizes of circles are proportional to haplotype frequency.

iv. Phylogenetic analysis

Phylogenetic reconstruction of the total 67 mitochondrial haplotypes using Neighbor Joining Method with the Kimura 2-parameter model are shown in the Fig 51. There is no clade with high bootstrap value that present a particular sampling location in the phylogeny.

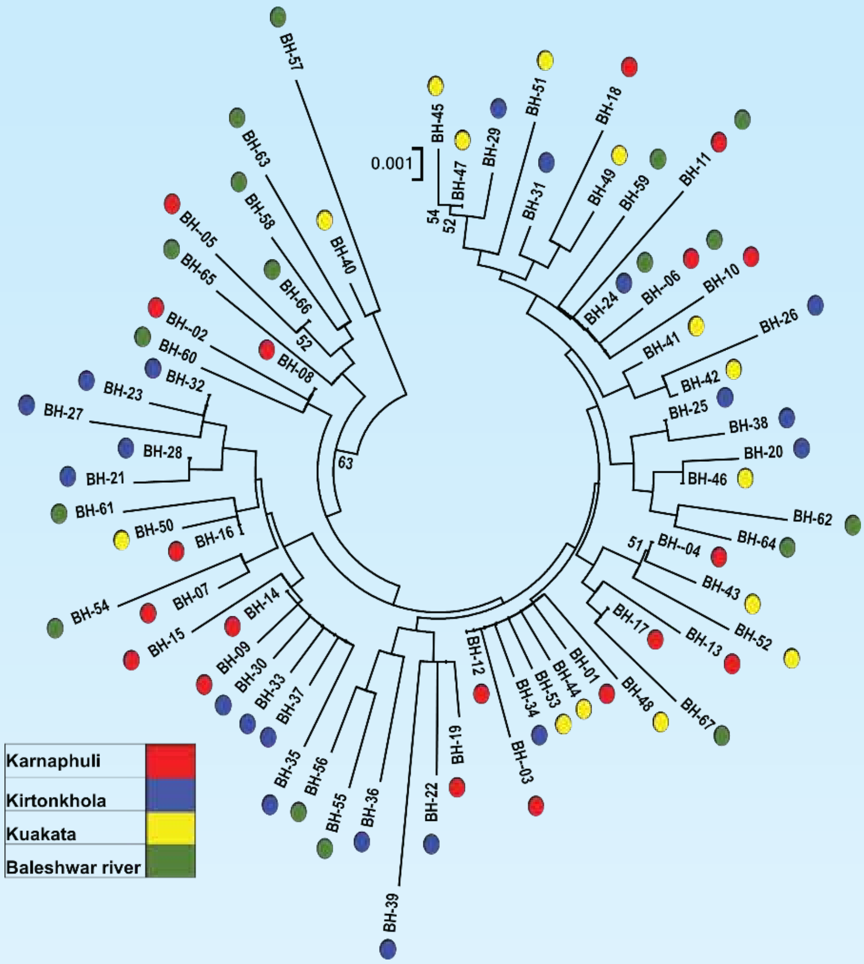

Fig 51. Neighbor-joining tree constructed using the Kimura-2 model for mitochondrial D-loop haplotypes of *P. paradiseus*. Bootstrap support of >90% are shown above branches. Scale represents the genetic distance in mutations/site.

v. Demographic history

The neutrality tests i.e. Tajima's *D* tests and Fu's F_s values of all four populations are negative but significant (P<0.05), implying a demographic expansion of this fish in the BoB region (Table 57).

Table 57. Tajimas's *D* and Fu's F_S statistics of *P. paradiseus* for BoB population.

Population	Tajima's *D*		Fu's F_S	
	D	*P*	F_S	*P*
KR	-1.584	0.039	-12.942	0.000
KK	-1.936	0.010	-15.062	0.000
KU	-1.781	0.024	-9.032	0.000
BR	-1.670	0.028	-10.543	0.000

11.2.1.10. Genetic stock assessment of *C dussumieri* in BoB, BD & other seas

i. Genetic diversity *C dussumieri* in BoB, BD & other seas

A total of 790 nucleotide long sequences of mtDNA ATPase 6/8 gene region were obtained from 108 individuals of two Bangladeshi populations (PR and NR) after removing the ambiguous sequences near the primer ends. The amplified sequences of Pashur river estuary (PRE) population comprised 10 haplotypes with 13 polymorphic sites and the sequences of Naf River (NR) population consists of 9 haplotypes with 12 polymorphic sites. Most of the nucleotide substitutions were transitional. The nucleotide diversities (π) were low in each population i.e. 0.001 nucleotide differences per site for both populations while the haplotype (gene) diversities (h) were relatively high which are 0.687 and 0.571 for PR and NR populations, respectively (Table 58). High level of haplotype diversities in contrast with low nucleotide diversity among the BoB population indicates that this fish has experienced population expansion after a period of low effective population size (Grant and Bowen 1998).

Table 58. Genetic diversity of *C dussumieri* for BoB population.

Region	Population	Sb (ti+tv)	Nid	Nh	h	π	S
Bangladesh (BoB)	Pasur river estuary (PR)	13 (10+3)	0	10	0.687	0.001	13
	Naf river (NR)	12 (6+6)	0	9	0.571	0.001	12
	[Number of substitution (Sb), Transition (ti), transversion (tv), number of indels (N_{id}), number of haplotype (N_h), haplotype diversity (h), nucleotide diversity (π), number of polymorphic site (S).						

ii. Population differentiation *C dussumieri* in BoB, BD & other seas

Pairwise F_{ST} value between PRE and NR populations of Bangladesh is 0.03 with significant deviation from the random mixing. Besides, these two Bangladeshi populations (PR and NR) showed significant population genetic structure (i.e. significant F_{ST} value) with other populations (i.e. WB, AP, GUJ and MAH) analysed in the present study (F_{ST} = 0.03 to 0.757; P>0.05) except between PRE and AP (Table 59). This result suggests a unique population genetic structure (i.e., a single genetic stock) was established in the Northern BoB region compared to other regions. Exact test of population differentiation also showed similar result suggesting a non-panmictic population for northern BoB, Bangladesh.

Table 59. Pairwise F_{ST} values among populations of *C. dussumieri* for comtrol region (below diagonal) and the exact *P* values (above diagonal).

Population	WB	AP	GUJ	MAH	DC	NR
West Bengal (WB)	-	0.081	0.00	0.00	0.00	0.00
Andhra Pradesh (AP)	0.951	-	0.00	0.00	0.09	0.045
Gujarat (GUJ)	0.714**	0.743**	-	0.00	0.00	0.00
Maharashtr (MAH)	0.683**	0.666**	0.100**	-	0.00	0.00

Population	WB	AP	GUJ	MAH	DC	NR
Pasur river estuary (PRE)	0.117**	0.063	0.757**	0.729**	-	0.00
Naf river (NR)	0.082**	0.073*	0.757**	0.737**	0.03**	-
** (P<0.01) and * (P<0.05)						

iii. Haplotype network

All sequences defined 49 haplotypes where 18 haplotypes were found in the BoB population. Among 18 BoB haplotypes, 16 haplotypes were unique for the BoB i.e. not present in other populations (Fig 52).

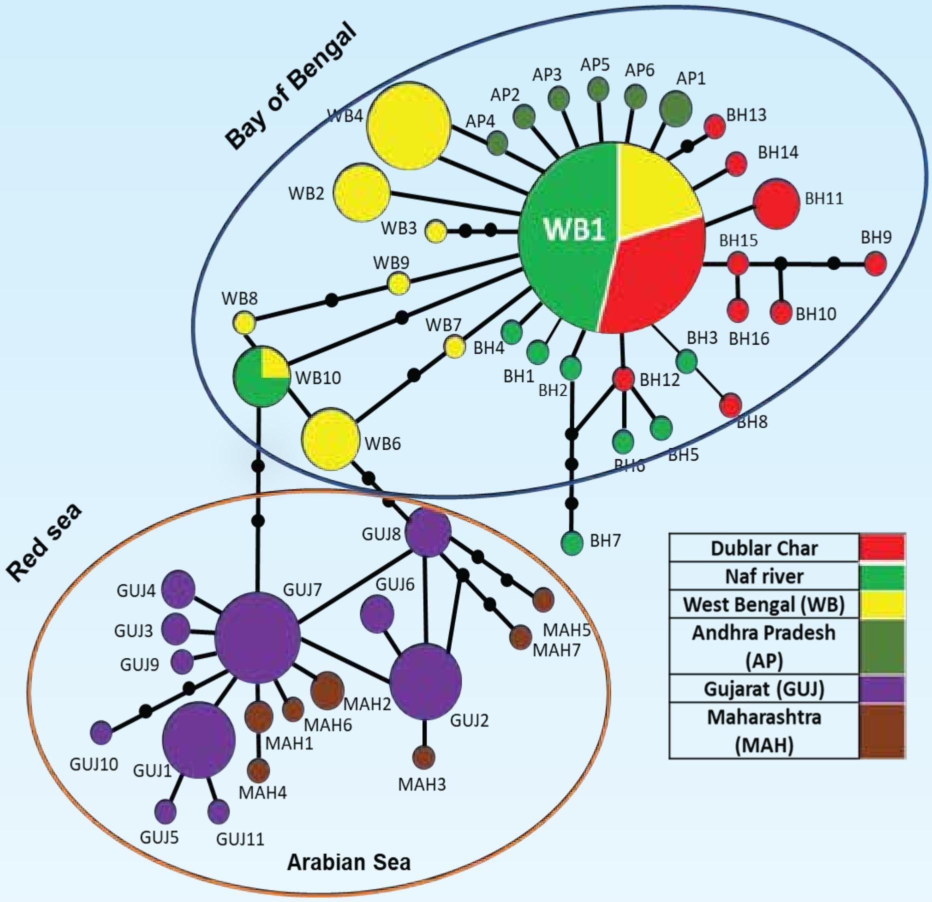

Fig 52. Haplotype network of mtDNA ATPase 6/8 gene region observed in *C. dussumieri* samples. Each connecting line represents a single mutation and small blanked circles represent an intermediate hypothesized missing ancestor between observed haplotypes. The sizes of circles are proportional to haplotype frequency.

iv. Phylogenetic analysis

Phylogenetic reconstruction of 49 haplotypes using Neighbor Joining Method with the Kimura 2-parameter model resulted three separate clades (Fig 53). Clade- A and B contain the haplotypes of the BoB (CC, KP, WB and AP). Clade-C belongs to the haplotypes of Arabian Sea (AP and GUJ).

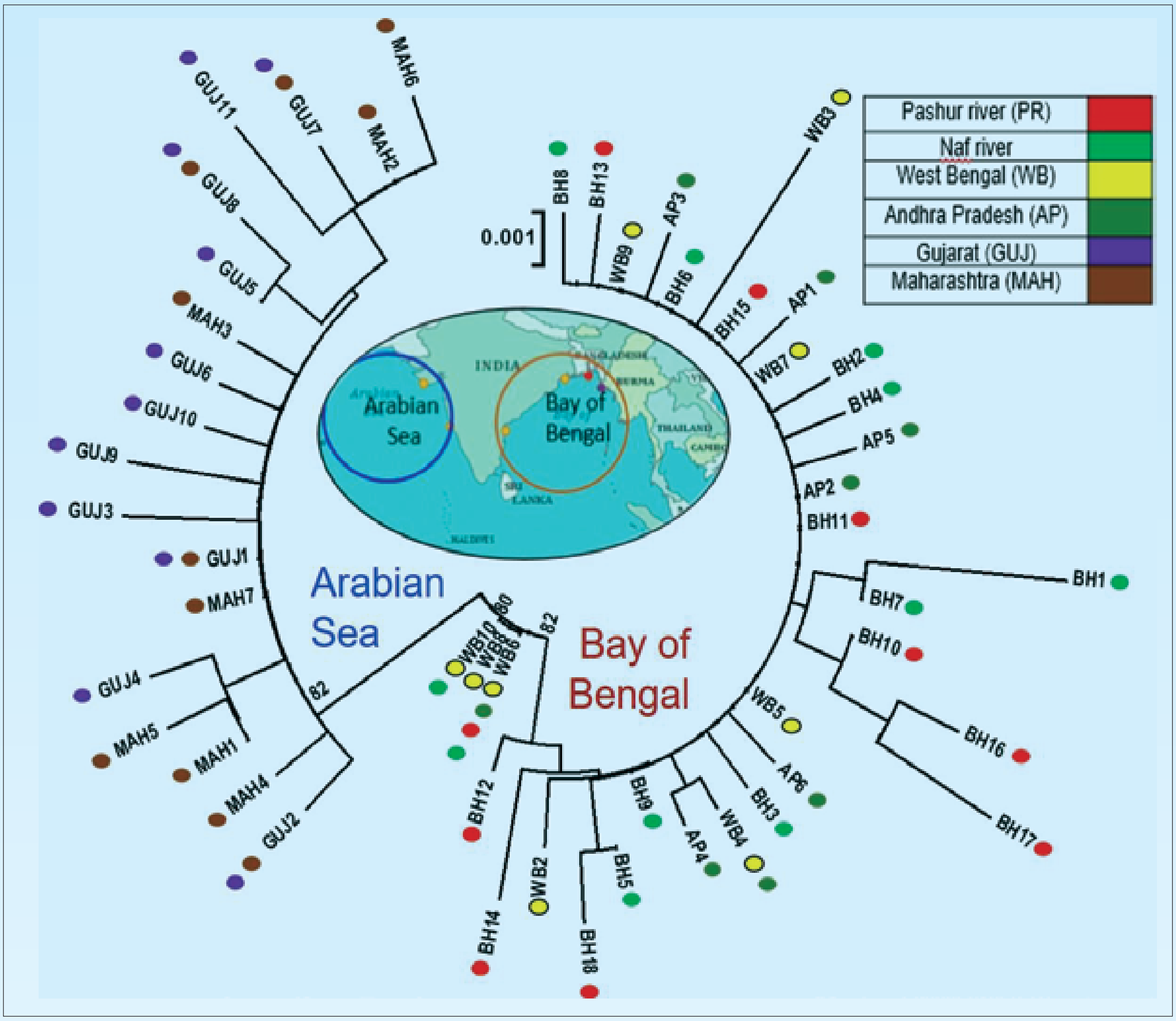

Fig 53. Neighbor-joining tree constructed using the Kimura-2 model for mitochondrial D-loop haplotypes of *C dussumieri*. Bootstrap support of >70% are shown above branches. Scale represents the genetic distance in mutations/site.

v. Demographic history

The neutrality tests i.e. Tajima's *D* and Fu's *F*s values were negative but significant ($D = -1.96$ & -1.25, and $F_S = -3.69$ & -4.27; $P < 0.05$) implying a demographic expansion of this species of Bangladeshi populations (Table 60).

Table 60. Tajimas's *D* and Fu's F_S statistics, parameter estimates of *C dussumieri* for BoB population.

Population	Tajima's *D*		Fu's F_S	
	D	*P*	F_S	*P*
Pasur river estuary (PR)	– 1.96	0.00	–4.27	0.00
Naf river (NR)	–1.25	0.15	–3.69	0.04

12. Research highlights

Title of the sub project

Stock Assessment of Commercially Important Fishes in the BoB through Multi-model Inferences and Molecular Markers: Management Policy Implications Considering the Emerging Climate Change

Component-1 (RU)

Background

BoB, Bangladesh has a large area (EEZ: 140860 km^2) but the production of marine fishes is very lower in amount (659911 MT in 2018-19; 15.05% of total production). On the other hand, there is no reliable data on the total fish species list as well as lack of knowledge of the species-wise current stock, location of the spawning ground and the grow out areas for each genetic stock (i.e., unit stock). Moreover, the exact reason for declining in relation to life history straits, i.e., populations parameters and stock status was not identified. Thus, the sub project was implemented to assess the stock of commercially important marine fishes in the BoB considering the emerging climate change.

Objectives

The objectives of the sub-project were to estimate the sexual maturity (size & age), spawning- and peak-spawning season of fishes through multiple functions for the justification of fishing-ban period in the BoB and to assess the stock's status of commercially important fishes in the BoB using growth parameters through multi-models. The study also identified the major man-made and climatic threats/ factors to fisheries resources in the BoB, Bangladesh.

Methodology

The study was conducted in the BoB, Bangladesh (covering Khulna, Barishal, Chattogram and Cox's Bazar regions). Monthly samples of 15 selected commercially important fishes were collected using hired commercial fishing boat/fishers and were immediately placed in ice followed by fixing in 10% formalin and 10% formalin/alcohol on arrival in the laboratory. Catches data of marine commercial fishes was collected from BFDC landing center, Pathorghata, Barguna. Interview was conducted with the local fishers, boatmen & owners, aged group, business men, exporters over the major fish landing centers of Bangladesh through pre-tested structured questionnaire for gathering local knowledge of commercially important marine fish their fishing, nursery, spawning grounds and spawning season, catch trends etc. The landing sites were visited daily in all seasons considering lunar cycle and species availability. In addition, water quality parameters were monitored using Multi-Meter Digital Meter. Climate data (rainfall (mm), water & air temperature (˚C)) were collected from the Bangladesh Meteorological Department. Analysis on different biological aspects including fish category, relative growth, condition factor, growth pattern and form factor, sexual maturity, spawning- and peak-spawning season, growth parameters, performance and life span, recruitment pattern and length-, and age-at first recruitment, stock assessment (exploitation rate and maximum sustainable yield, MSY) etc. were done.

Key findings

- ✓ A total of 740 marine fish species, as so far, the highest number enlisted from the BoB, Bangladesh;
- ✓ Based on the value of '*b*', isometric growth found for 4 species, positive allometric growth found for 5 species, and negative allometric for 6 species from 15 commercially important marine fishes;

- ✓ Growth Parameters (L_∞, K, t_0, ϕ, t_{max}), size at sexual maturity (L_m) and optimum catchable length (L_{opt}) of 15 commercially important marine fishes were estimated that are essential to calculate the biomass and maximum sustainable yield (MSY) and estimated to select the mesh size of fishing gear;
- ✓ Information generated on the spawning and peak spawning season of commercially important marine fishes of the BoB indicating requirement of amendment of current fishing banning period from "20th May to 23th July" to a newly proposed period of "mid-April to June (15th April to 30th June) each year";
- ✓ Exploitation rate of 15 commercially important marine fishes indicated that *P. heterolepis*, *S. panijus*, *H. nehereus* and *T. setirostris* was balanced exploitation; *L. calcarifer*, *P. paradiseus*, *A. leiogaster* was over-exploited; and the rest are under-exploited;
- ✓ Information on MSY for *L. calcarifer*, *P. heterolepis*, *P. chinensis*, *E. affinis*, *S. taty*, *S. panijus*, *P. paradiseus*, *M. cordyla*, *H. nehereus*, *C. dussumieri*, *T. setirostris*, *A. chacunda*, *I. megaloptera*, *P. macracanthus* and *A. leigaster was* generated
- ✓ Fishing with mosquito net in estuaries and other coastal mangroves, Behundi nets (for catches of fry, fingerlings, and jatka) and use of destructive fishing gears (like China net) for capturing marine brood fish were identified as major causal factors for declining marine fishes.

Keywords: BoB, Stock status, Fishing ban period, Molecular marker, Fisheries management, commercially important fish.

Component-2 (SAU)

Background

Stock identification through population genetic structure analysis establishes a basis for the management of fisheries resources. Generally, a single panmictic population could be recovered through increased recruitment by propagation or short-term conservation initiative. On the other hand, different populations with unique genetic structures should be managed as distinct units, and such units require separate monitoring and management. Fisheries management should therefore attempt to address each stock separately ensuring sustainable use of each stock, and not the population as a whole. Further, it is also important to know the genetic diversity of each of the existing population of a fish. Genetic variability influences both the health and long-term survival of population because decreased genetic diversity has been associated with reduced fitness, such as high juvenile mortality, diminished population growth, reduced immunity and ultimately the higher extinction risk.

Objectives

To determine whether there are single or multiple genetic stocks of commercial marine fishes in Bangladesh, and to assess the intra and inter population genetic diversity and divergence of these commercial fish in the BoB, Bangladesh and other neighboring seas. The research will also find out the major anthropogenic factors/threats for the marine fish stock in the BoB, Bangladesh.

Methodology

For the study, about one hundred samples of each species of ten marine fishes namely, *P chinensis, P argenteus, E affinis, A thazard, M cordyla, L calcarifer, S tenuifilis, S panijus, P paradiseus* and *C dussumieri* were collected between October 2020 and April 2022, mainly from rivers and coasts of two distinct ecological regions of Bangladesh coast of the South-west (Borguna-Khulna-Patuakhali, KP) and the South-east (Chattogram-Cox's Bazar, CC) coastal zones. KP is high brackish water area with dense clayed particle in river and estuaries; and CC is sandy area with more clear saline water river and estuaries. For amphidromous or anadromous fish, we collected samples from coastal rivers. Fish samples of other seas of the Indian Ocean region (e.g. Southern BoB, Arabian Sea, Persian Gulf etc.) and South-west Pacific or their DNA sequence data were also collected from different researchers and scientific studies. A survey and focus group discussions (FGD) were also conducted to identify the major threats for marine fisheries of Bangladesh especially caused by human interference beside climate change. For genetic diversity and stock study, sequence variations in different mtDNA gene regions such as COI, Cytb, and noncoding control (d-loop) region were examined. Polymerase chain reaction (PCR) was used to amplify the target mtDNA regions and sequenced. Lastly, the variation in the obtained DNA sequence data of different geographic locations were analyzed using different bioinformatic softwares such as Geneous, ARLEQUIN, MEGA-6; TCS etc.

Key findings

i. For all the genes in every sampling location of Bangladesh, the nucleotide diversities (π) were very low (0.0001 ~ 0.05) but the haplotype or gene diversities (h) were relatively high, 0.5 ~ 1.0 (i.e. h>0.5) which indicated that the studied fishes have experienced population expansion after a period of low effective population size, except two species, *M. cordyla* and *L. calcarifer* for which the gene diversities were also low (0.14 ~ 0.263). This result implies that these two fish species of Bangladesh has experienced recent bottleneck. Immediate conservation measures should be taken for these two species.

ii. The population statistic F_{ST}, and exact test of population differentiation revealed two different scenarios for two groups of fishes. The first group contains six fish species namely *P. chinensis, P. argenteus, E. affinis, A. thazard, M. cordyla, L. calcarifer* which are mostly oceandromous, pelagic and highly migratory having wide distribution throughout the Indian Ocean and South-West Pacific (or, Indo-west Pacific). This group showed no significant population genetic differentiation within the country indicating that these six species have single genetic stock and these are panmictic (random mating among populations) throughout Bangladeshi marine water. Further, these six oceanodrmous and high migratory fishes showed their own genetic structure (F_{ST} $P \leq 0.05$) within the BoB (BoB) when compared with other neighboring seas such as Arabian Sea, Andaman Sea, Gulf of Thailand, South China Sea etc. Haplotype network and phylogeny showed clear genealogical divisions of fish populations varying with different seas

iii. The second group consists of four species S *tenuifilis, S panijus, P paradiseus* and C *dussumieri* is relatively distributed to the narrow or localized geographic area mostly in the BoB and Andaman Sea. This group is mostly off-shore or coast dwelling and amphidromous (i.e. migrate between fresh and marine water but not to breeding purpose). For these species, pairwise F_{ST} values of mtDNA markers between fish samples of different sampling rivers showed significant differences ($P \leq 0.05$) in most of the cases. These fishes showed their own genetic stock for different rivers such as Bishkhali, Kirtankhola and Boleshwar river for *P. paradeseus* and *S. panjius*; Naf and Pashur rivers for *C. dussumieri*; Matamuhuri and Bishkhali river for *S. tenuifilis* etc

iv. Fishing with mosquito net in estuaries & mangrove and fishing through Behundi net in seas was found in the questionnaire survey and FGD, as the major man-made causes or threats for declining of commercially important marine fishes in the BoB. Besides, catches of fry, fingerlings and jatka, poison fishing in mangroves, illegal fishing by Indian and Myanmar's fishers, and use of destructive fishing gears (e.g. China net, behundi nets in rivers/channels' mouth) are also accountable causes.

Keywords: BoB, Genetic stock, Marine fish, Mitochondrial DNA Marker, Fish conservation

B. Implementation status

1. Procurement (component wise)

Coordination component (BARC)

Description of equipment and capital items	PP Target		Achievement		Remarks
	Physical (No.)	Financial (Tk.)	Financial (Tk.)	Physical (No.)	
(a) Office equipment: Procurement of DSLR Camera	01	149500	01	149500.00	**Completed 100%**
(b)Lab & field equipment					**NA**
(c) Other capital items					**NA**

Component-1 (RU)

Description of equipment and capital items	PP Target		Achievement		Remarks
	Physical (No.)	Financial (TK.)	Physical (No.)	Financial (TK.)	
(a) Office equipment					
Laptop	01	60000.00		59800.000	Completed as per target
(b) Lab & field equipment					
1. Microscope with High Speed Camera	01	480000.00	01	410000.00	Completed as per target
2. Laboratory Freezer	05	400000.00	05	398500.00	
3. Chargeable Digital Balance	02	20000.00	02	19000.00	
4. Portable Eclectic Balance	02	16000.00	02	15600.00	
5. Ice Box	04	60000.00	04	60000.00	
(c) Office Furniture					
1. Fish Egg Cabinet	01	65000.00	01	64500.00	Completed as per target
2. Steel Almira	02	60000.00	02	59800.00	
3. Executive Table with Side Drawer	02	40000.00	02	39400.00	
4. Junior Executive Chair (Side Office)	02	20000.00	02	20000.00	
5. PVC Chair	12	16800.00	12	16800.00	
6. Ceiling Fan	2	8000.00	2	8000.00	

Component 2 (SAU)

Description of equipment and capital items	PP Target		Achievement		Remarks
	Physical (No.)	Financial (Tk.)	Physical (No.)	Financial (Tk.)	
(a) Office equipment					
1. Executive Table	02	27400.00	02	27400.00	Completed as per target
2. Side Drawer	02	12000.00	02	12000.00	
3. Junior Executive Chair	02	20000.00	02	20000.00	
4. Steel Almira	02	59800.00	02	59800.00	
5. PVC Chair	12	16800.00	12	16800.00	
6. Ceiling Fan	02	8000.00	02	8000.00	
7. Desktop computer	01	52000.00	01	52000.00	
8. UPS	01	7000.00	01	7000.00	
9. DSLR Camera	01	85000.00	01	85000.00	
10. Refregeratore	01	50000.00	01	50000.00	
(b) Lab &field equipment					
1. PCR Machine	01	498000.00	01	498000.00	Completed as per target
2. Gel Electrophoresis Machine	01	345000.00	01	345000.00	

2. Establishment/renovation facilities

Not applicable

3. Training/study tour/ seminar/workshop/conference organized
Coordination component (BARC)

Description	Number of participants			Duration (Days)	Remarks
	Male	Female	Total		
Inception Workshop (1 no)	56	7	63	1 day	All workshops held at the Conference room of BARC as per schedule of activity of the Coordination component
Half yearly Research Prog. Review Workshop (3 no.)	65+ 62+72	9+8+10	226	1+1+1 = 2 days	
Annual Research Prog. Review Workshop (2 no.)	65+63	9+8	1145	1+2 =3 days	
Project Completion Report Review Workshop (1 no)	52	6	58	1 day	
Orientation on PCR preparatory guideline	12	05	17	01 Day	All Principal Investigators of the sub project components attended the program

(Not Applicable for RU and SAU components)

C. Financial and physical progress (combined & component wise)

Combined progress

Fig in Taka

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
a. Contractual staff salary	6890006	6796917	6796917	0	100	Not applicable
b. Field research/lab expenses and supplies	19113543	19079803	19079803	0	100	
c. Operating expenses	1919252	1777931	1777931	0	100	
d. Vehicle hire and fuel, oil & maintenance	2682147	2615333	2615333	0	100	
e. Training/workshop/ seminar etc.	310500	304700	304700	0	100	
f. Publications and printing	400000	396000	396000	0	100	
g. Miscellaneous	482652	2513243	2513243	0	100	
h. Capital expenses	2501900	13044500	13044500	0	100	
Total	**34300000**	**33951044**	**33951044**	**0**	**100**	

Coordination component (BARC)

Fig in Taka

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
a. Contractual staff salary	265613	189385	189385	0	100	Not applicable
b. Field research/lab expenses and supplies	0	0	0	0	100	
c. Operating expenses	321256	184494	184494	0	100	
d. Vehicle hire and fuel, oil & maintenance	229969	165476	165476	0	100	
e. Training/workshop /seminar etc.	310500	304700	304700	0	100	
f. Publications and printing	400000	396000	396000	0	100	
g. Miscellaneous	103162	102475	102475	0	100	
h. Capital expenses	149500	149500	149500	0	100	
Total	**1780000**	**1492030**	**1492030**	0	**100**	

Component-1 (RU)

Fig in Taka

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
a. Contractual staff salary	3222463	3222463	3222463	0	100	Not applicable
b. Field research/lab expenses and supplies	11372850	11351510	11351510	0	100	
c. Operating expenses	1115584	1113544	1113544	0	100	
d. Vehicle hire and fuel, oil & maintenance	1669315	1667157	1667157	0	100	
e. Training/workshop /seminar etc.	0	0	0	0	100	
f. Publications and printing	0	0	0	0	100	
g. Miscellaneous	228388	2260870	2260870	0	100	
h. Capital expenses	1171400	11714000	11714000	0	100	
Total	**18780000**	**18752161**	**18752161**	0	**100**	

Component 2 (SAU)

Fig in Taka

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
a. Contractual staff salary	3401930	3385069	3385069	0	100.00	Not applicable
b. Field research/lab expenses and supplies	7740693	7728293	7728293	0	100.00	
c. Operating expenses	482412	479893	479893	0	100.00	
d. Vehicle hire and fuel, oil & maintenance	782863	782700	782700	0	100.00	
e. Training/workshop/ seminar etc.	0	0	0	0	0	
f. Publications and printing	0	0	0	0	0	
g. Miscellaneous	151102	149898	149898	0	100.00	
h. Capital expenses	1181000	1181000	1181000	0	100.00	
Total	**13740000**	**13706853**	**13706853**	**0**	**100.00**	

D. Achievement of sub-project by objectives (Tangible form): Technology generated/ developed

Not applicable

E: Information/knowledge generated/policy generated

Component-1 (RU)

General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output (i.e., product obtained, visible, measurable)	Outcome (short term effect of the research)
To find out the fish stocks through morphometric and meristic then to estimate the size at sexual maturity, age at sexual maturity, spawning- and peak-spawning season of fishes through multiple functions for the justification of fishing-ban period in the BoB	Collected samples using hired commercial fishing boat and fishers and were immediately preserved. Required data collected from the preserved fish samples in the laboratory of Department of Fisheries, RU	Enlist 740 fish from the BoB. Estimate the size and age at sexual maturity of 15 commercially important marine fishes. Adjusted fishing ban period should be from mid-April to June based on the spawning and peak spawning season of commercially important marine fishes in the BoB, Bangladesh	The mesh size of fishing gear can be defined/determined by the size at sexual maturity Adjusted ban period allows fishes to spawn and new recruitments increases the fish production
To calculate the growth parameters through multi-models using length-frequency analysis and then to assess the stock's status of commercially important fishes in the BoB	Collected samples using hired commercial fishing boat and fishers and were immediately preserved. Required data collected from the preserved fish samples in the laboratory of Department of Fisheries, RU	Growth pattern & other parameters of 15 marine fishes were estimated Relative biomass, mortality (total, natural, fishing), optimum catchable length, and MSY were estimated for 15 marine fishes	Set catch limits for marine fishes for sustainable stock year after year
To identify the major man-made and climatic threats/ factors to fisheries resources in the BoB, Bangladesh.	Survey, personal interview, FGD, Literature review	Identified the major man-made and climatic threats to fisheries resources in the BoB, Bangladesh	Man-made threats can be reduced by taking proper actions

Component-2 (SAU)

General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output	Outcome (policy recommendation)
1. To determine whether there are single or discrete genetic stocks of commercial	Collection of fishes from: i. different ecological locations of Bangladesh such	Species were identified through morphology and DNA Barcoding.	• Some river populations of coast deweller amphidromous fishes will require

General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output	Outcome (policy recommendation)
marine fish with variation in habitat within Bangladesh using mitochondrial DNA markers;	as rivers, coast etc. (obj.-1) ii. other areas of BoB (obj.-2) iii. different neighboring seas of BoB such as Arabian sea, South-west Pacific etc. (obj.-2)		separate monitoring and management strategies for conservation because the fish population of some rivers is genetically distinct. Overfishing in any of these rivers may cause extinction of its fish stock. • The highly migratory oceanodromous fishes showed its own genetic structure within the BoB compared to other neighbouring seas. Therefore, the BoB adjacent countries should manage and conserve these vital and shared marine fish species through cooperation with each other. Haplotype network and phylogeny for migratory oceanodromous fish showed clear genealogical divisions of fish populations varying with geographical distribution i.e. genealogical differences occurred among BoB, Arabian Sea,
2. To assess intra and inter population genetic diversity and divergence of commercial fish in the BoB, Bangladesh and other neighbouring seas.	Genomic DNA extraction from fish tissue.	Genomic DNA were extracted.	
	Design, synthesis and testing of PCR primers	The primers were designed for the first time for fishes *P. paradesius* and *S. panijus* and PCR was possible for the target fishes.	
	PCR amplification of target genes of fish mtDNA	Amplified gene regions were sequenced.	
	DNA sequencing of amplified gene regions	DNA sequence data were ready for bioinformatical analysis.	
	• Bioinformatical analysis of DNA sequence data: 1. <u>Genetic diversity</u>: Haplotype diversity (h), nucleotide diversity (π). 2. <u>Population differentiation</u>: Fixation index (F_{ST}), Non-Exact P value. 3. <u>Inter and tra-population genealogical relationship</u>: haplotype network and phylogeny construction. 4. <u>Pattern of demographic history</u>: Neutrality	1. Nucleotide diversities (π) were very low (0.0001 ~ 0.05) but the haplotype or gene diversities (h) were relatively high, 0.5 ~ 1.0 except two species, *M. cordyla* and *L. calcarifer* for which the gene diversities were also low (0.14 ~ 0.263). 2. Population statistic F_{ST}, and exact test of population differentiation revealed two different results for two group of fishes.: Oceandromous and highly migratory fishes showed no population subdivision within Bangladesh water. But these fishes have their own genetic structure in the BoB compared to other neighboring seas. On the other hand, coast dwelling and amphidromous fishes showed population sub-division inside Bangladesh based on the river ecosystem.	

General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output	Outcome (policy recommendation)
	test (Tajima's *D* and Fu's F_S value)	3. Haplotype networks and phylogenies for first group of fish showed clear genealogical divisions of fish populations varying with geographical distribution i.e. genealogical differences occurred among BoB, Arabian Sea, South-west Pacific etc. 4. Neutrality tests such as Tajima's D and Fu's FS statistics also suggested that most of the studied fish species of Bangladeshi populations have undergone the demographic history of population expansion.	South-west Pacific etc. Neutrality tests such as Tajima's *D* and Fu's F_S statistics also suggested that most of the studied fish species of Bangladeshi populations have undergone the demographic history of population expansion.
3. To identify major anthropogenic factors that are the threats for the marine fish stock in the BoB, Bangladesh beside climatic factors and detect the priority areas where management actions are needed.	1. Questionnaire survey 2. Focus group discussion	Fishing with mosquito net in estuaries & mangrove and fishing through Behundi net was found as the major man-made causes or threats for declining of commercially important marine fishes in the BoB followed by catches of fry, fingerlings, & jatka, poison fishing in mangroves, illegal fishing by Indian and Myanmar's fishers, catches of brood fish and use of destructive fishing gears (e.g. China net, behundi nets in rivers/channels' mouth). The climatic changes are also a common factor like other parts of the world.	Government should take immediate actions for removing these obstacles.

F. Materials development/publication made under the sub-project
Component-1 (RU)

Publication	Number of publications		Remarks (e.g., paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Journal publication	10	16	1. Sabbir, W., Hossain, M. Y., Rahman, M. A., Hasan, M. R., Mawa, Z., Tanjin, S., & Ohtomi, J. (2021). First report on reproductive features of the Hooghly croaker *Panna heterolepis* Trewavas, 1977 from the BoB in relation to environmental

Publication	Number of publications		Remarks (e.g., paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
			factors. *Environmental Science and Pollution Research 28*(18), 23152-23159. (Q1; IF: 5.190) 2. Mawa, Z., Hossain, M. Y., Hasan, M. R., Tanjin, S., Rahman, M. A., Sarmin, M. S. & Habib, K. A. (2021). First record on size at sexual maturity and optimum catchable length of 10 marine fishes from the BoB (Bangladesh) through multi-models approach: a key for sound fisheries management. *Environmental Science and Pollution Research*, *28*, 38117-38127. (Q1; IF: 5.190) 3. Rahman, M. A., Hossain, M.Y., Hasan, M.R., Mawa, Z., Tanjin, S., Sarker, B.K. & Islam, M.A. (2021). Length weight relationships and form factor of 8 marine fishes from the BoB. *Thalassas: An International Journal of Marine Sciences*, *37*, 891–895. (Q3; IF: 0.951) 4. Rahman, M. A., Hossain, M. Y., Tanjin, S., Mawa, Z., Hasan, M. R. & Ohtomi J. (2021). Length weight relationship of 5 marine fishes from the BoB. *Journal of Applied Ichthyology*, *37*(02), 364-366. (Q2; IF: 1.222) 5. Sabbir, W., Rahman, M. A., Hossain, M. Y., Hasan, M. R., Mawa, Z., Rahman, O., Tanjin, S. & Sarmin, M. S. (2021). Stock assessment of Hooghly Croaker *Panna heterolepis* in the BoB (Southern Bangladesh): implications for sustainable management. *Heliyon 7*, e07711. (Q1; IF: 3.776) 6. Sabbir, W., Hossain, M.Y., Rahman, M. A., Rahman, M. A., Islam, M. A., Khan, M. N., Chowdhury, A. A., Hasan, M. R. & Mawa, Z. (2021). The Hooghly Croaker, *Panna heterolepis* Trewavas, 1977: Identification through Morphometric and Meristic Characteristics. *Indian Journal of*

Publication	Number of publications		Remarks (e.g., paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
			Geo-Marine Sciences, *50*(06), 502-506. (Q4; IF: 0.553) 7. Rahman, O., Hossain, M.Y., Rahman, M.A., Islam M.A., Rahman, M.A., Parvin, M.F., Sarmin, M.S., Sarker, B.K., Sabbir, W. and Habib, K.A. (2021). Temporal variations of condition factor and relative weight for *Mystus gulio* (hamilton, 1822) from the coastal water in Bangladesh. *Journal of Bio-Science*, 29(1), 111-122. 8. Sabbir, W., Rima, F. A., Hossain, M.Y., Rahman, M. A., Tanjin, S., Hasan, M. R., Mawa, Z., Islam, M. A., & Khan, M. N. (2021). Estimation of Morphometric relationships for flathead sillago, *Sillaginopsis panijus* (Hamilton, 1822) in the BoB (Bangladesh) using multi-linear dimensions. *Indian Journal of Geo-Marine Sciences*, *50*(03), 253-257. (Q4; IF: 0.553) 9. Tanjin, S., Sabbir, W., Hossain, M. Y., Rahman, M. A., Mawa, Z., Hasan, M. R., Rima, F. A., Rahman, O., Sarmin, M. S., Sarker B. K. & Habib, K. A. (2021). Morphometric and Meristic Features of Gangetic hairfin anchovy, *Setipinna phasa* (Hamilton, 1822) in the BoB (Bangladesh). *Journal of King Abdulaziz University - Marine Sciences*, *30* (02), 71-83. (Q4, SJR: 0.11) 10. Sabbir, W., Hossain, M. Y., Rahman, M. A., Hasan, M. R., Mawa, Z., Tanjin, S., Hassan, H. U. & Ohtomi, J. (2020). First Report on Condition Factor of *Panna heterolepis* (Trewavas, 1977) in the BoB (Southwestern Bangladesh) in Relation to Eco-Climatic Factors. *Egyptian Journal of Aquatic Biology and Fisheries*, *24*(2), 591-608. (Q3, SJR: 0.29) 11. Sabbir, W., Hossain, M. Y., Rahman, M. A., Hasan, M. R, Khan, M. N.,

Publication	Number of publications		Remarks (e.g., paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
			Mawa, Z., Tanjin, S., Sarmin, M. S., Rahman, O., Nima, A. & Habib, K. A. (2020). Growth pattern of the Hooghly Croaker *Panna heterolepis* Trewavas, 1977 in the BoB (Bangladesh) in relation to eco-climatic factors. *Egyptian Journal of Aquatic Biology and Fisheries*, *24*(7-Special issue), 847-862. (Q3, SJR: 0.29) 12. Sabbir, W., Hossain, M. Y., Khan, M. N., Rima, F. A., Sarmin, M. S., & Rahman, M. A. (2022). Biometric Indices of Flathead Sillago, *Sillaginopsis panijus* (Hamilton, 1822) from the BoB (Southern Bangladesh). *Thalassas: An International Journal of Marine Sciences*. (Q3; IF: 0.951) 13. Sabbir, W., Hossain, M. Y., Mawa, Z., Hasan, M. R., Rahman, M. A., Islam, M. A., Tanjin, S., Rahman, M. A., Sarker, B. K. and Khan, M. N. (2020). New maximum size record, length–weight relationships and form factor of Hooghly Croaker *Panna heterolepis* Trewavas, 1977 from the BoB (Bangladesh). *Lakes & Reservoirs: Research & Management*, *25*(3), 346-349. (Q3, SJR: 0.33) 14. Rahman, O., Hossain, M.Y., Islam, M.A., Rahman, M.A., Khatun, D., Parvin, M.F., Sarmin, M.S., Tanjin, S., Rahman, M.A., Mawa, Z. and Hasan, M.R. (2020). Life-history traits of long whisker catfish *Mystus gulio* (Siluriformes: Bagridae) in the coastal water (Maloncho river) of southern Bangladesh. *Pakistan Journal of Marine Science*, *29*(2), 99-114. 15. Sarmin, M. S., Tanjin, S., Rahman, M. A., Hasan, M. R., Sabbir, W., Asadujjaman, M., Mondol, M. R. K., Habib, K. A., & Hossain, M. Y. (2021). Estimation of growth pattern and form factor of torpedo scad *Megalaspis cordyla* (linnaeus, 1758)

Publication	Number of publications		Remarks (e.g., paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
			in the BoB, Bangladesh. *Pakistan Journal of Marine Sciences*, *30*(2), 109–117. 16. Tanjin, S., Rahman, M. A., Uddin, M., Sarker, B. K., Sarmin, M. S., Mawa, Z., Rahman, M. A., Rahman, O., Samad, M. A., Habib, K. A., & Hossain, M. Y. (2021). Estimation of condition factor of Bengal tongue sole (*Cynoglossus cynoglossus*) in the Bay of Bengal, Bangladesh. *Pakistan Journal of Marine Sciences*, *30*(2), 127–133.
Video clip/ TV program		1	Channel 24 on 22 September 2020
News Paper/Popular Article		5	Bangla news, Daily Sunshine, Jago news on 08-09.09.2020
Conference/ Seminar papers		6	1. Hasan, M. R., Mawa, Z., & Hossain, M. Y. (2021). Reproductive biology of *Anodontostoma chacunda* in the BoB: Confirm to sustainable management and conservation. 2nd Biennial Fisheries Conference by Fisheries Society of Bangladesh in Bangladesh Agricultural University, Mymensingh, Bangladesh, 25-26 December, 2021. 2. Rima, F, A., Hossain, M. Y., Sabbir, W., & Hasan, M. R. (2021). Population structure, Length-weight relationship, Condition and Form factor of the *Sillaginopsis panijus* in the BoB. 2nd Biennial Fisheries Conference by Fisheries Society of Bangladesh in Bangladesh Agricultural University, Mymensingh, Bangladesh, 25-26 December, 2021. 3. Saabir, W., Hossain, M. Y., Mawa, Z., Sarker, B. K., & Sarmin, M. S. (2021). Assessment of stock and maximum sustainable yield of the Hooghly Croaker *Panna heterolepis* from the BoB (Southern Bangladesh): Implications for sustainable management. 2nd Biennial Fisheries Conference by Fisheries Society of Bangladesh in Bangladesh

Publication	Number of publications		Remarks (e.g., paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
			Agricultural University, Mymensingh, Bangladesh, 25-26 December, 2021. 4. Sabbir, W., Hossain, M. Y., Rahman, M. A., Hasan, M. R., & Habib, K. A. (2021). Estimation of size at sexual maturity, spawning and peak spawning season of the Hooghly Croaker *Panna heterolepis* Trewavas, 1977 from the BoB, Southern Bangladesh: A key to fix appropriate fish banning period. 2nd Biennial Fisheries Conference by Fisheries Society of Bangladesh in Bangladesh Agricultural University, Mymensingh, Bangladesh, 25-26 December, 2021. 5. Hossain, M. Y., Rahman, M. A., Sarmin, M. S., & Habib, K. A. (2022). Stock Assessment of Commercially Important Fishes in the BoB through Multi-model inferences: Management policy implications in Bangladesh. JSPS International Seminar organized by Bangladesh JSPS Alumni Association (BJSPSAA) and Japan Society for the Promotion of Science (JSPS) held at Sylhet Agriculture University on 18 March 2022. 6. Hossain, M. Y., Rahman, M. A., Sarmin, M. S., & Habib, K. A. (2022). Fisheries of the BoB: current status and management policy implications in Bangladesh. 9th Biennial Conference organized by Bangladesh Fisheries Research Forum (BFRF) held at Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka on 28-29 May 2022.
PhD Thesis		1	Stock Assessment of the Hooghly Croaker *Panna heterolepis* from the BoB in Bangladesh through Multi-models
	2		1. Stock Assessment of *Megalaspis cordyla* from the BoB in Bangladesh 2. Stock Assessment of Indian Pellona *Pellona ditchela* in the BoB through multi-model analysis
MS Thesis		4	1. Study on population Dynamics of Smoothbelly sardinella, *Amblygaster*

Publication	Number of publications		Remarks (e.g., paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
			leiogaster in the BoB through Multi-models: A Management Approach 2. Stock assessment of the flathead Sillago *Sillaginopsis panijus (*Hamilton 1822*)* in the BoB 3. Biometric indices of Black Pomfret, *Parastromateus niger* (Bloch 1795) in the BoB, Bangladesh 4. Biological features of Skipjack tuna, *Euthynnus affinis* (Cantor 1849) from the BoB, Bangladesh
	2		1. Assessment of stock's status (Growth parameters, mortality and exploitation rate) of Bombay duck, *Harpadon nehereus* (Hamilton, 1822) in the BoB (Bangladesh) 2. Estimation of maximum suatainable yield (MSY) for Topse fish (*Polynemus paradiseus*) in the BoB (Bangladesh)
Book	1		Hossain, M. Y., Habib, K. A., Islam, M. J., & Rahman, M. A. (2022). Stock Status of 50 Commercially Important Marine Fishes in Bangladesh.

Component 2 (SAU)

Publication	Number of publications		Remarks (e.g., paper title, name of journal, conference name etc.)
	Under prepa-ration	Comp-leted & published	
Technology bulletin/ booklet/leaflet/flyer etc.	-	-	-
Journal publication	4	1	Habib, K. A., & Islam, M. J. (2020). An updated checklist of Marine Fishes of Bangladesh. Bangladesh Journal of fisheries, 32(2), 357-367.
Video/ TV program	1		NATP-2, BARC
News paper/ Popular Article		3	Prothom Alo, Janakontho, Samakal

<table>
<tr><th rowspan="2">Publication</th><th colspan="2">Number of publications</th><th>Remarks (e.g., paper title, name of journal, conference name etc.)</th></tr>
<tr><th>Under prepa-ration</th><th>Comp-leted & published</th><th></th></tr>
<tr><td>Other publications, if any:
Abstracts in conference book</td><td></td><td>3</td><td>1. Genetic diversity and population structure of two commercial Pomfret species (Pompus argenteus and Pompus chinensis) in the BoB, Bangladesh. Fisheries Society of Bangladesh Biennial Conference-2021.
2. Genetic diversity and population structure of two commercial Pomfret species (Pompus argenteus and Pompus chinensis) in the BoB, Bangladesh. ZSB 22nd Biennial International Conference and AGM-2022
3. Genetic diversity and population structure of Kawakawa tuna (Euthynnus affinis) in the BoB, angladesh. BFRF 9th Biennial Conference and Research fair-2022.</td></tr>
<tr><td>Award</td><td colspan="3">

Best paper award by BFRF in Fisheries Biology and Genetics Section at the 9th Biennial Conference and Research Fair-2022</td></tr>
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G. Description of generated technology/knowledge/policy

i. **Technology factsheet (title of the technology, introduction, description, suitable location/ecosystem, benefits, name and contact address of author):**

Not applicable

ii. **Effectiveness in policy support (if applicable)**

Amendment of existing fishing ban period in the BoB, Bangladesh

The BoB is blessed with a range of fish and fisheries resources for its hydrological features. The marine fisheries sector has been considered an essential part of Bangladesh's economy. The production of marine fish in BoB has increased slightly over the last 10 years, but its comparative share of production has reduced as well as the qualitative features of fish species. Marine fish stocks may be undefined but can become extinct within a period of time. Thus, it is very important to take initiatives before the extinction of any species. The imposition of ban and areas to control fishing effort is a basic management tool for open water fisheries dates back to centuries.

To conserve the marine fisheries resources, it is necessary to give them opportunity to spawn as well as management through sustainable harvest. Spawning of fishes mostly depends on surrounding uninterrupted environment. For this reason, different countries impose a fishing ban period in their marine areas. India imposed its first ban in the BoB from 15 June to 31 July1988 in Kerala, and subsequently in other states but in different periods. In 2000, they adjusted it from 15 April to 31 May in East coast and 15 June to 31 July in the West coast. However, in 2015, they again adjusted it from 15 April to 14 June in the East coast and 1 June to 31 July in the West coast.

To enhance the marine fish production from the BoB, Bangladesh government imposed a ban period from 20 May to 23 July in 2015 for the first time according to the Marine Fisheries Ordinance 1983. Though, 22 days ban period was established for hilsa fishes and also applied in the marine waters. The imposed ban period was only applicable for industrial fisheries from 2015 to 2018. From 2019, it was applicable for both the industrial and artisanal fisheries.

Could there be different fishing ban periods in the same habitat, BoB? On the other hand, the prolonged fishing ban has a negligible impact on the income and livelihoods of the poor subsistence coastal fishers. To get the answer, study was done on the spawning and peak spawning season of marine fishes from the BoB, Bangladesh. Monthly samples were collected and their gonadal maturation was studied in the laboratory. Based on the GSI, modified gonadosomatic index (MGSI) and Dobriyal index (DI) estimation of the spawning and peak spawning season done for commercially important marine fishes in the BoB and confirmed by histological studies. In depth studies revealed that most of the commercially important marine fishes spawn from April to September each year. However, May to July is the peak spawning season of 9 species out of studied 15 commercially important fishes. Further, study of relevant literature on this aspect designates that most of the commercially important fishes in the BoB spawn within April to June each year. Therefore, it is strongly recommended that, the present fishing banning period in the BoB (20 May to 23 July) should to be amended or adjusted from April (or mid-April) to June (or mid-June) each year.

To facilitate spawning and conservation of marine fisheries resources within the economic zone of Bangladesh all types of fishing ought to be banned during April (or mid-April) to June (or mid-June) both in coastal rivers and deep-sea regions.

H. Technology/knowledge generation/policy support (as applied)

i. Immediate impact on generated technology (commodity & non-commodity)

- Implementation of justified/ adjusted ban period in the BoB, Bangladesh
- Setting catch limit of commercially important marine fishes in the BoB, Bangladesh
- Mesh size of fishing gear selection for commercially important marine fishes in the BoB, Bangladesh

ii. Generation of new knowledge that help in developing more technology in future

- Under the research, sexual maturity and optimum catchable length for 15 commercially important fishes were estimated. Based on the used formula, sexual maturity and optimum catchable length of other fish species from the BoB can be estimated. This information will help for mesh size selection of fishing gears used by the fishers.
- Spawning and nursery ground of commercially important marine fishes can be identified from the availability of fishes larger than L_m can during spawning and peak spawning period.
- Brood fish can be easily collected during the spawning and peak spawning season for artificial breeding of over exploited marine fish stock, as well as development of mariculture of highly demanded species

iii. Technology transferred that help increased agricultural productivity and farmers' income

Not applicable

iv. Policy support

Component-1 (RU)

- Estimated size at sexual maturity and optimum catchable length (L_{opt}) effective to select the mesh size of fishing gear. Small individual smaller than L_m able to skip and contribute in increase fish production.
- Justification of the existing fishing ban period through estimated spawning and peak-spawning season of commercially important marine fishes allow them to spawn and new recruits that will increase fish production and fishers' income.
- Estimated catch limits through MSY will make the stock sustain year after year.
- Remedy can be taken for identified man-made & climatic causal factors for declining marine fishes that will be effective for increasing fish production and fishers' income as well.

Component-2 (SAU)

- Localized or coast dwelling amphidromous fishes (e.g. *S tenuifilis, S panijus, P paradiseus* and *C dussumieri*) showed separate genetic stock with variation in rivers (e.g. Bishkhali, Boleshwar, Kirtonkhola, Rupsha, Naf, Matamuhuri etc.) or ecological zones (e.g. Muddy brackishwater zone: Borguna-Khulna-Patuakhali coasts, Sandy clear saline water zones: Chattogram-Cox's Bazar coasts). Therefore, these fishes will require separate monitoring, management and conservation strategies for each separate stock. Because, overfishing in any of these rivers or ecological zones may cause extinction of its fish stock.
- Oceandromous or inter-ocianic dwellers and highly migratory fishes (e.g. *P. chinensis, P. argenteus, E. affinis, A. thazard, M. cordyla, L. calcarifer*) showed no significant population differentiation within the country indicating that these species have single genetic stock and these are panmictic (random mating among populations) throughout Bangladeshi marine water. Bangladesh should manage these species as a single conservation unit.
- Oceandromous and highly migratory fishes showed its own genetic structure (F_{ST} $P \leq 0.05$) within the BoB when compared with other neighbouring seas such as Arabian Sea, Andaman Sea, Gulf of Thailand, South China Sea etc. So, the BoB countries should manage and conserve these vital and shared marine species through cooperation with each other.

- Inter population breeding should be conducted for production of good quality seed and avoiding inbreeding problem for developing mariculture or coastal aquaculture for a coast dwelling amphidromous fish species having separate genetic population/stock (e.g. *P. paradeseus*, *S. panjius* etc.).
- Some fishes such as *M. cordyla* and *L. calcarifer* showed very low genetic diversities. This result implies that these two fish species have experienced recent bottleneck. Immediate conservation measures should be taken for these two species, such as limiting catch, banning on the fishing season, making long term sanctuary or protected area etc.
- Fishing with mosquito net in estuaries & mangrove and fishing through Behundi net was found as the major man-made causes or threats for declining commercially important marine fishes in the BoB followed by catches of fry, fingerlings, & jatka, poison fishing in mangroves, illegal fishing by Indian and Myanmar's fishers, catches of brood fish and use of destructive fishing gears (e.g. China net, behundi nets in rivers/channels' mouth). And, climatic changes are also a common factor like other parts of the world. Government should take immediate actions for removing these obstacles.

I. Information regarding desk and field monitoring

i. Information on desk monitoring

Consulting meetings, workshops, seminars, coordination meetings etc	Date & Venue	Output
Component 1 (RU)		
1) Inception workshop	22/12/2019; BARC, Dhaka	Necessary correction of stock assessment by correcting the number of species and terminologies done
2) 1st & 2nd half yearly progress report	20.06.20 and 29.07.21 BARC; DHAKA	Necessary correction of stock assessment data done
3) 3rd half-yearly progress report	02.06.2022; BARC	• Clear highlights on progress achievement focused in the follow-up presentations • Proposed fishing ban period was justifiably discussed
4) 1st Co-ordination meeting	07/09/2020; BARC, Dhaka	Data collection on morphometric, meristic and truss-networking and then to estimate the size at sexual maturity, age at sexual maturity, spawning- and peak-spawning season of fishes done properly.
5) 1st Annual progress workshop	30/09/2020; BARC, Dhaka	Information of fish species size at sexual maturity, age at sexual maturity, spawning and post-spawning season and GSI values incoporated
6) Meeting with World bank representative	25/08/2021; BARC, Dhaka	Sub-project revision along with activity time plan
7) 2nd Annual progress workshop	23/11/2021; BARC Dhaka	Causes of difference in hilsa catch ban period in Bangladesh, India and Myanmar, discarded from the study

Consulting meetings, workshops, seminars, coordination meetings etc	Date & Venue	Output
8) 2nd Co-ordination meeting	12/12/21; BARC Dhaka	Survey activities on identification of the major man-made and climatic threats/ factors to fisheries resources ended as per revised plan
9) Progress meeting on zoom platform	02.05.2021, Virtual platform	Incorporated all review suggestions of PIU-NATP
10) 3rd Co-ordination meeting		Data collection continued up too June 2022 as per revised plan
11)Workshop on PCR preparation	11/05/22; BARC Dhaka	Orientation guidelines improves the knowledge of PCR writing
12)Progress meeting on zoom platform	02.05.2021, Virtual platform	Incorporated all review suggestions of PIU-NATP
13) 4th Coordination meeting	08.10.2022	Finalized PCR workshop plan
14)Draft PCR review workshop	24-25 October'22	Improvement of draft PCR
Component 2 (SAU)		
1) Inception workshop	22/12/2019; BARC, Dhaka	Project document improved
2) 1st & 2nd half yearly progress report	20.06.20 and 29.07.21 BARC; DHAKA	Provosion of stocks to be assessed through multiple model approach and genetic marker followed for bith the components
3) 3rd half yearly progress report	02.06.2022; BARC	All aspects of audit information included as per format
4) 1st Co-ordination meeting	07/09/2020; BARC, Dhaka	Data collection and laboratory analysis to determine the whether there are discrete or single genetic stocks of commercial marine fish completed
5) 1st Annual progress workshop	30/09/2020; BARC, Dhaka	New information on marine fish stock management aspect with proper technical/scientific information included
6) Meeting with World bank representative	25/08/2021; BARC, Dhaka	Sub-project revision along with activity time plan
7) 2nd Annual progress workshop	23/11/2021; BARC Dhaka	As per general suggestion all technical aspects of the research re=examined and necessary correction done
8) 2nd Co-ordination meeting	12/12/21; BARC Dhaka	Procurement of all pending equipmemts/chemicals completed as per revised plan
9) Progress meeting on zoom platform	02.05.2021, Virtual platform	Incorporated all review suggestions of PIU-NATP
10) 3rd Co-ordination meeting	12.12.21, BARC, Dhaka	• Data collection continued up too June 2022 as per revised plan • Gene sequence data analysis through bioinformatics and statistical programs also completed as per revised plan

Consulting meetings, workshops, seminars, coordination meetings etc	Date & Venue	Output
11)Workshop on PCR preparation	11/05/22; BARC Dhaka	Orientation guidelines improves the knowledge of PCR writing
12)Progress meeting on zoom platform	02.05.2021, Virtual platform	Incorporated all review suggestions of PIU-NATP
13) 4th Coordination meeting	08.10.2022	Finalized PCR workshop plan
14)Draft PCR review workshop	24-25 October'22	Improvement of draft PCR

Plate 16. Visited ABR Lab of SAU by BARC and SAURES officials

ii. Information on field onitoring

Date	No. of visit	Name/s of visitors	Addresses	Output
Component I (RU)				
07.10.20	1	1. Md. Abdur Rahman 2. Dipok Kumar 3. Md. Hasan Mahmud	Monitoring associates & Capacity dev. Associate, PIU, NATP. BARC	Visited research field and Instruction given by the team was executed.
19.12.20	1	Dr. Md. Monirul Islam (Member Director, BARC)	BoB, Cox's Bazar	Visited research site. Advice given by Coordinator was executed.
26-27.02.22	1	1. Dr. Md. Harunur Rashid 2. Dr. Mohammad Abdullah Al Faroque 3. Mr. Md Ashequar Rahman	Director, Assistant Manager, Admn & Assistant Manager, Account PIU-BARC, NATP-2	Visited research field; Some advice given; action was taken accordingly.
25.03.22	1	1. Dipok Kumar (monitoring associate	Monitoring associate & Capacity dev.	Visited research field and Instruction given by the team was executed.

Date	No. of visit	Name/s of visitors	Addresses	Output
		2. Md. Hasan Mahmud (Capacity development associate)	Associate, PIU, NATP. BARC	
18-19.05.22	1	1. Dr. Md. SalehUddin Ahmed	Department of Fisheries, University of Rajshahi	Visited and observed laboratory works and progress. Given instructions on data analysis and PCR preparation was executed.
Component 2 (SAU)				
07.10.2020	1	1. Md. Abdur Rahman 2. Dipok Kumar 3. Md. Hasan Mahmud	Monitoring associates & Capacity dev. Associate, PIU, NATP. BARC	Separate record keeping of fish breeding/spawning, GSI index, fecundity facilitate analytical activities
19.12.2020	1	Dr. Md. Monirul Islam	Sub-Project Coordinator and MD, Fisheries, BARC, Farmgate, Dhaka	Established effective coordination between the components
18/01/2021	1	Dr. Md. Harunur Rashid,	Director, PIU-BARC, NATP-2	Suggestion for technical improvement of data analysis followed and improved
		Prof. Dr. Md. Abdur Razzaque,	SAURES, SAU, Dhaka	Inspired research activities
		Prof. Dr. Md. Nazrul Islam,	Treasurer, SAU, Dhaka.	Inspired research activities
26-27.02.2022	1	1. Dr. Md. Harunur Rashid (Director) 2. Dr. Mohammad Abdullah Al Faroque 3. Mr. Md Ashequar Rahman	Director, Assistant Manager, Admn & Assistant Manager, Account PIU-BARC, NATP-2	Strengthen activities of sub project.
25.03.2022	1	1. Dipok Kumar 2. Md. Hasan Mahmud	Monitoring associate & Capacity dev. Associate, PIU, NATP. BARC	Deviation of activities identified and mitigated
24.04.2022**22**	1	1. Dipok Kumar 2. Md. Hasan Mahmud	Monitoring associate & Capacity dev. Associate, PIU, NATP. BARC	Acitivity progress as per revised action action plan monitored and expressd satisfaction.

Plate 17. Filed monitoring by PI and BARC monitoring team.

iii. Weather data, flood/salinity/drought level (combind) and natural calamities

Three years average information on weather for BoB region (2019 -2022))

Parameters	Seasons						Remarks
	Pre-Monson (Jan – April)		Monson (May – Aug)		Post Monson (Sept – Dec)		
	Max	Min	Max	Min	Max	Min	
Av. Rainfall (mm)	132.4	9	650.1	258.5	357.7	10.6	
Av. Temperature (^{O}C)	33.4	25.6	33.3	31.0	31.7	26.8	
Av. Humidity (%)	76.66	70.66	85.44	76.73	82.73	75.80	
Flood (year & category)	Not reporting						
Av. Salinity (ppt)	1.88 – 4.16 ppt in south western coastal areas; 19.0 – 33.0 ppt in deep sea and southeastern coastal areas						
Draught	Not applicable						
Natural calamity (Frequency & category)	Tides due to Cyclone "Cyclone ***Bulbul and Amphan***" inundated low-lying areas and hampered fish catch in the BoB.						

Ref: Ragional metrological office, Chattogram and Khulna

J. Sub-project auditing (covers all types of audits performed)

Coordination component (BARC)

Types of audit	Major observation/ issues/ objections raised; if any	Amount of Audit (Tk.)	Status at the sub-project end	Remarks
Financial audit by FAPAD for the year 2019- 20	No objection raised, found all relevant documents updated as per guideline	306902.50	Financial management of the component found running smoothly till the end of the project No query or objection raised at any stage of operation by the audit teams	Financial management & project performance found satisfactory in all the audit cases
Financial audit by FAPAD for the year 2020- 21		182147.00		
Financial audit by FAPAD for the year 2021- 22		429115.00		

Component I (RU)

Types of audits	Major observation/ issues/ objections raised; if any	Amount of Audit (Tk.)	Status at the sub-project end	Remarks
Financial & Performance audit by the FAPAD Audit Team (2019-2020)	No objection raised by the audit team	4071680.00	Financial progress and management of the record found satisfactory	Financial management found satisfactory
Financial & Performance audit by the FAPAD Audit Team (2020-2021)		8883197.00		
Financial & Performance audit by the M.I. Chowdhury & Co. (2020-2021)		8883197.00		

Component II (SAU)

Types of audits	Major observation/ issues/ objections raised; if any	Amount of Audit (Tk.)	Status at the sub-project end	Remarks
Financial audit by the FAPAD Audit Team for the year 2019-2020	No objection raised by the audit team	3101345.00	Financial progress and management of the record found satisfactory	Financial management found satisfactory
Financial audit by the FAPAD Audit Team for the year (2020-2021)		3101345.00		
Financial audit by M.I. Chowdhury & Co for the year 2021-2022		999047.00		
Financial audit by the FAPAD Audit Team for the year 2021 - 2022		595716.00		

K. Lessons learned

- Proper implementation of the proposed fishing ban period could be one of the best options to enhance the marine fish production and protection of fish biodiversity.
- Lack of coordination between government, non-government agencies and stakeholder hampers the successful implementation of any beneficent initiatives.
- Availability of marine fishes is sufficient in the capital and southern region but insufficient in the northern region of the country. Market development in the northern region could increase the income of marine fishers.
- Tendency to get benefit from dishonest means like fishers' practices illegal or destructive fishing as well as boat owners arotdars (merchant) tendency to deceive fishers.

L. Challenges (if any)

- Sometimes fishing has no results in the BoB especially from last week of September to October'20 and February to March'21. Most fishes were not landed in the landing centers caused data collecton problem;
- In most cases, the fishers caught a smaller number of fishes. As a result, data collection from markets and landing centers at that period may mislead research result;
- Intensive sampling and data collection were challenging due to COVID-19 lock down;
- Intensive observation on fishing ban period was disrupted due to Covid -19 pandemic;
- Procurement plan was also disrupted due to the pandemic.
- DNA sequencing from local company is difficult due to higher service charge, time consuming and complex official formalities.
- Fishing/samplings are difficult during 65 days ban-period;
- Price of chemical increased during Corona pandemic;

M. Suggestions for future planning

- More marine protected area should be established and its long-term management should be ensured;
- Transboundary management action plan should be taken for sustainable production of marine migratory fishes;
- Marketing channel of marine fishes should be developed throughout the country and abroad, if possible
- It is needed to identify the breeding ground, feeding ground on these species to set proper management and conservation plan;
- Stock assessment should be done of some localized fish having potential (on going trial) as aquaculture species such as Chitra/ bishtara (spotted scat, *Scatophagus argus*), Datina (Yellow-fin Sea bream, *Acanthopagrus latus*), Kain magur (grey eel catfish; *Plotosus canius*).
- Marine fish species under study those are mostly oceandromous, pelagic and highly migratory and widely distributed throughout the Indian Ocean and South-West Pacific (or, Indo-west Pacific), these fishes showed no significant population differentiation within the country indicating that these six species have a single genetic stock and these are panmictic (random mating among populations) throughout Bangladeshi marine water. Therefore, Bangladesh should consider appropriate management plan for these species as a single conservation unit.
- Government, non-government, political and local local collaboration are needed for proper implementation of management action plans.

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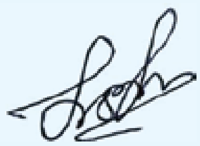
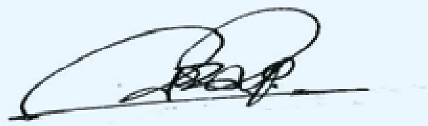
Signature of the Coordinator	**Counter signature of the Head of the organization/authorized representative**
	
(Dr. Mohammad Rafiqul Islam) Date: 20.12.2022 ***Director (Nutrition)*** ***Bangladesh Agricultural Research Council***	***(Dr. Shaikh Mohammad Bokhtiar)*** Date: 20.12.2022 ***Executive Chairman*** ***Bangladesh Agricultural Research Council***

1. Coordination component (BARC)

Annexure – BARC: A

Recommendation of the inception workshop and status of action taken

Recommendations General comment Component 1 (RU)	Action Taken
• Stock assessment of number of fish species is not clearly stated during presentation. However, the number should have consistency with the other component (SAU component) of the sub project;	Necessary correction done
• Stock assessment of fish to be done denoted as "Commercial important" in the title; Only "important fish species" under output list (sl. 2) and simply as "fish stock" under specific no-1. The term should be common and acceptable one;	Correction done by putting correct common term
Component 2 (SAU)	
Number of species stocks to be assessed through multiple model approach (comp-1) and genetic marker (com -2) should have consistency/similarities for both the components: that should be checked for necessary correction;	Suggestion complied

Annexure – BARC:B

Recommendation of the half yearly workshops

Recommendations of the first half yearly workshop General recommendation	Action taken
Development of pretested questionnaire for survey and data collection from different markets and landing centers and orientation of field staffs should be done immediately	Necessary action taken by both the components
Recommendations of the second half yearly workshop	
General recommendation	
Data on stock assesssmet should ne analysed as per standard multi model approach	Complied as per suggestion
Recommendations of the third half yearly workshop	**Action taken**
Component 1 (RU)	
Presentation of objective wise research highlights in tables and with data is not proper. It should be presented in language describing finding supported by data/information.	Followed properly in the next presentations

Avoid duplication of presentation in all cases (such as data table and graph on the basis of same data etc);	Complied
"Justification of existing fishing ban period in BoB, Bangladesh" mentioned in the presentation under technology generation, which is not correct at all. PL. Put the information in right place.	Discussed in the right place
Under information/knowledge generation table, first three points need to be rewrite for expressing the result/generated findings properly;	Necessary correction done
Outputs of desk and field monitoring activities are not discussed	Output included in the PCR format
Information on auditing not presented with required information;	Presented in PCR following the standard form
Information on weather not presented;	Included in the report
Instead of presenting media coverage and documentation links separately, it is suggesting to put them in the respective places of materials development/publication related tables;	Siggestion followed
Component 2 (SAU)	
The total presentation was informative. But in all most all cases the format was deviated and in more than 80% area of the presentation handout was highly darkened with black coloration printing, so the data/information and outcomes were simply unreadable and not understandable.	Will be taken care off in future
Information on audit and weather was not properly included.	Both are shown in the final report
Separate paras on lesson learned, challenges and suggestions for future planning not discussed in the presentation at all;	Presented in the PCR

Annexure – BARC: C

Recommendation of the annual workshop

Recommendations of the first annual workshop	Action taken
Component 1 (RU)	
• Detail information on estimation of collected fish species size at sexual maturity, age at sexual maturity, spawning and post-spawning season and GSI values was not presented in detail. Particularly for review sessions, detail presentation with information rich handout should be ensured so that the review activity can be carried out thoroughly and critically. Immediate monitoring of research progress is necessary;	Information on estimation of collected fish species size at sexual maturity, age at sexual maturity, spawning and post-spawning season and GSI values completed intime
Component 2 (SAU)	
• No comment;	

Recommendations of the second annual workshop	Action taken
Component 1 (RU)	
• Causes of difference in hilsa catch ban period in Bangladesh, India and Myanmar, if not related with the present study, it is not to be cited in the report. In case of true requirement, causes may be mentioned with authentic information (like reports related with stock variation, environmental impact, or any other causes study etc).	Necessary correction done
Component 2 (SAU)	
• Based on new knowledge on marine fish stock management aspect need to be presented with proper technical/scientific information season, areas, biological characteristics-based statistics for framing act/regulations/management policy	Next presentations were updated with cited information

Annexure – BARC:D

Recommendation of the coordination meetings

Centraly organized 2 (two) virtual coordination meeting	
Recommendations	**Action taken**
Component 1 (RU)	
• As per previous plan, data collection on morphometric, meristic and truss-networking and then to estimate the size at sexual maturity, age at sexual maturity, spawning- and peak-spawning season of fishes through multiple functions for the justification of fishing-ban period in the BoB should limit within 12 months from project starting covering different locations and seasons and finish within December'20; Same timeline should be followed for calculate the growth parameters through multi-models using length-frequency analysis and then to assess the stock's status of commercially important fishes in the BoB;	Activities done as per plan
• On-going survey activities on identification of the major man-made and climatic threats/ factors to fisheries resources under objective 3 of the project must be ended by December'20. Analysis of data of this part may require another three months; The coordination unit feels to run these activities in collaboration with the other component (B S_bAU) of the sub-project applying same questionnaire. Secondary data on climate change trend from meteorological department may contribute in this area;	Partial work done. Lock down due to Covid -19 interrupted research activities
Component 2 (SAU)	
• As per previous plan, data collection and laboratory analysis to determine the whether there are discrete or single genetic stocks of commercial marine fish with variation of habitat and seasons using mitochondrial	Most of the activities complted within the stipulated time

and/or microsatellite DNA markers should limit within 12 months prorating different locations and seasons and finish within December'20; Same timeline should be followed for assessing the intra and inter population genetic diversity and divergence of commercial fish in the BoB;	
• Hanged out activities of laboratories for various analysis of fish samples collected from different locations and in difference seasons due Covid-19 problem, a strong and special effort should be given to complete the pending laboratory analysis by involving more manpower and money as per outline of the sub-project;	Approximately 50-60% work done within the planned period. Covid-19 disrupted project activities.
• On-going survey activities on identification of the major man-made and climatic threats/ factors to fisheries resources under objective 3 of the project must be ended by December. Analysis of data of this part may require another three months; The coordination unit feels to run these activities in collaboration with the other component (A RU) of the sub-project applying same questionnaire. Secondary data on climate change trend from meteorological department may contribute in this area;	
3rd coordination meeting	
Component 1 (RU)	
• Suggested for continuation of samplings and data collection by the **component 1 (RU)** from the field-level up to June 2022 for successful completion. As the stocked brood fish (in January, 2020) produced F-1 generation during June-July, 2020 and F-2 generation during June-July, 2021. If, F-2 generation takes in spawning, it will be sustaining in those habitats and will be continue which should be focused in the end result.	Partial activity (approx.. 60%) completed within the planned period
Component 2 (SAU)	
Based on the previous progress it is recommended to perform the following activities by the component 2 (SAU):	
• From September 2021 to February 2022, collection of samples of all of the seven fishes from the South-east (Kukata- Pathorghata- Sundarbans, KP) and South-west (Chattogram- Cox's Bazar, CC) coast.	Rest of the all activities completed within June 2022 as per revised approved activity plan of the sub project.
• DNA extraction, PCR, purification and DNA sequencing beside sample collection. Sampling of all fish species and DNA sequencing should be completed by March 2022.	
• Gene sequence data analysis through bioinformatics and statistical programs should be completed by June 2022.	
4rth coordination meeting	
• Decision was taken to organize the two days workshop by the Coordination component within the first half of Oct'22;	PCR workshop held smoothly on 24-25 Oct'22 under the organizership of

• The sub-project will be presented by Prof. Dr. Kazi Ahsan Habib of SAU, Principal Investigator on behalf of the other sub-project components; • Coordination component will prepare a list of expert members, general participants, session Chairman, Chief guest/Special guest along with a draft copy of workshop program; • The two days workshop will be held in the auditorium of the Training building of BARC. Coordination component will ensure the proposed venue;	the Coordination component following all the instruction of the respective meeting.

Annexure – BARC:E

Recommendations of the draft PCR review workshop	
General comment	**Action taken**
• Updating of financial, procurement and audit reports of all the sub-project components including the co-ordination component	Complied
Component 1(RU)	
• Source of 60 – 100 years data on temperature, rainfall, water level rise etc need to be mentioned specifically in proper place of the methodology section	Mentioned accordingly
• Avoid presenting of full scientific name (such as, *Lates calcarifer*) of selected all marine fish species in all related sections of the text by using the abbreviation in case of generic name (such as, *L. calcarifer)*	Necessary action taken
• Gonadal histology figure should have clear indication of male - female type	Correction done
• Revision of GSI standard deviation chart suggested	Complied
• Component 2 (SAU)	
• In several cases, a section of methodology has been discussed under the head "Results and discussion" particularly in case of genetic stock assessment of selected important commercial marine fish species. It is therefore, suggested to revise the section by shifting information related to methodology to the respective section	Necessary revision done in the text report
• Basis of selection of the fish species should be clearly shown under the methodology section	Added accordingly
• Sub-project research-based publications prepared and under process should be included in the respective section of the report	Necessary action taken
• GSI-Genetic Variation relation may be shown, if studied	Basic information are shown
• Discuss the justification of use of single marker in case of PCR analysis	Discussed in the report

2. Component 1 (RU)

Annexure RU: 1. Checklist of Marine fish species of Bangladesh

The column of Habitat denotes the species as marine (M), brackishwater (B) or primarily marine but secondary freshwater (F), reef associated (R) and Sundarbans mangrove region (S). The numbers given in the column of References (REF) denotes the chronological numbers of following citations: 1. Hussain (1970), 2. Bernacsek (2001), 3. Huda *et al.* (2003), 4. Rahman (2005), 5. Rahman *et al.* (2009), 6. Thompson and Islam (2010), 7. Khan *et al.* (2013), 8. BOBLME (2014), 9. Hoq and Haroon (2014), 10. Hoq *et al*. (2014), 11. Hossain *et al.* (2015a), 12. Roy *et al.* (2015), 13. Baki *et al*. (2017), 14. Saha *et al.* (2017), 15. Shamsunnahar *et al.* (2017), 16. Akash *et al.*(2018), 17. Alam *et al.* (2018), 18. Haque and Hossain (2018), 19. Habib *et al.* (2018a), 20. Habib *et al.* (2018b), 21. Kabir *et al.* (2018), 22. Saha *et al.* (2018), 23. Ahmed *et al.* (2019), 24. Fanning *et al.* (2019), 25. Habib *et al.* (2019), 26. Hanif (2019), 27. Singha *et al.* (2019), 28. Ahmed *et al.* (2020), 29. Akash *et al.* (2020), 30. Datta *et al*. (2020), 31. Fuad *et al.* (2020), 32. Habib *et al.* (2020a), 33. Habib *et al.* (2020b), 34. Habib *et al*. (2020c), 35. Islam and Habib (2020), 36. Islam *et al.* (2020a), 37. Islam *et al.* (2020b), 38. Saha *et al.* (2020), 39. Siddik and Hanif (2020) 40. Habib *et al.* (2021), and 41. Sarkar *et al.* (2021) were arranged as per published years.

Sl No.	Family	Species	Common Name	Bangla/ Local Name	Habitat	IUCN**	REF	Abundance
Class: Elasmobranchii								
Order: Orectolobiformes								
1	Hemiscylliidae	*Chiloscyllium burmensis* Dingerkus & DeFino, 1983	Burmese bamboo shark	Muichya hangor	M	LC	23	Uncommon
2		*Chiloscyllium griseum* Müller & Henle, 1838	Grey bambooshark	Muichya hangor	M, B, R, S	NT	1, 5, 20	Rare
3		*Chiloscyllium hasseltii* Bleeker, 1852	Hasselt's bambooshark		M, R	NE	30	Uncommon
4		*Chiloscyllium indicum* (Gmelin, 1789)	Slender bambooshark	Muichya hangor	M, B, F	NT	1, 5, 27	
5		*Chiloscyllium punctatum* Müller & Henle, 1838	Brownbanded bamboo shark	Bilai hangor	M, R	NT	5	
6	Stegostomatidae	*Stegostoma fasciatum* (Hermann, 1783)	Zebra shark	Bagha hangor	M, B, R	EN	1, 5, 6	
7	Rhincodontidae	*Rhincodon typus* Smith, 1828	Whale Shark	Timi hangor	M, R	EN	1, 5, 6	Rare
Order: Lamniformes								
8	Alopiidae	*Alopias vulpinus* (Bonnaterre, 1788)	Thresher		M	VU	10	
Order: Carcharhiniformes								
9	Scyliorhinidae	*Atelomycterus marmoratus* (Anonymous [Bennett], 1830)	Coral Catshark	Hangor	M, R	NT	1, 5	Rare

10	Carcharhinidae	*Carcharhinus amblyrhynchos* (Bleeker, 1856)		Kalo lota boli hangor	M	NT	9	
11		*Carcharhinus amboinensis* (Müller & Henle, 1839)	Pigeye shark	Boli hangor	M, B	DD	9	
12		Carcharhinus dussumieri (Müller & Henle, 1839)	Whitecheek shark	Hangor	M, R	EN	1, 5, 24	Uncommon
13		*Carcharhinus falciformis* (Müller & Henle, 1839)	Silky shark	Nil hangor	M, R	VU	1,5,24	
14		*Carcharhinus leucas* (Müller & Henle, 1839)	Bull shark	Boli hangor	M, B, F	NT	9	
15		*Carcharhinus limbatus* (Müller & Henle, 1839)	Blacktip shark	Kala hangor	M, B, R	NT	1,5,24,27	-
16		*Carcharhinus macloti* (Müller & Henle, 1839)	Hardnose shark	Tutta hangor	M	NT	1,5	Common
17		*Carcharhinus melanopterus* (Quoy & Gaimard, 1824)	Blacktip reef shark	Kala hangor	M, B, R, S	NT	1,5,24,27	Commercial
18		*Carcharhinus sorrah* (Müller & Henle, 1839)	Spot-tail shark	Hangor	M, B, R	NT	1,5,24,27	Common
19		*Galeocerdo cuvier* (Péron & Lesueur, 1822)	Tiger shark	Bangha hangor	M, B	NT	1,5,27	Uncommon
20		*Glyphis gangeticus* (Müller & Henle, 1839)	Ganges shark	Kamot	M, B, F	CR	1,5	Uncommon
21		*Glyphis glyphis* (Müller & Henle, 1839)	Speartooth shark	Hangor	M, B, F, S	EN	2	
22		Rhizoprionodon acutus (Rüppell, 1837)	Milk Shark	Nak choukkha hangor	M, B, F, S	LC	1,5,6,20,24	
23		*Scoliodon laticaudus* Müller & Henle, 1838	Spadenose shark	Churi hangor	M, B, S	NT	1,5,6,20,24	
24		*Scoliodon macrorhynchos* (Bleeker, 1852)	Pacific spadenose shark	Churi hangor	M	NE	8	Uncomon
25		*Triaenodon obesus* (Rüppell, 1837)	Whitetip reef shark	Hangor	M, R	NT	1,5	
27	Hemigaleidae	*Chaenogaleus macrostoma* (Bleeker, 1852)	Hooktooth shark	Barshi deto hangor	M	VU	1,5	
27		*Hemipristis elongata* (Klunzinger, 1871)	Snaggletooth shark		M	VU	1,6	
28	Sphyrnidae	*Eusphyra blochii* (Cuvier, 1816)	Winghead shark	Boro haturi hangor	M, B, S	EN	1,5,6,24,27	Commercial
29		*Sphyrna lewini* (Griffith & Smith, 1834)	Scalloped hammerhead	Haturi hangor	M, B, S	VU	20	
30		*Sphyrna mokarran* (Rüppell, 1837)	Great hammerhead	Haturi hangor	M, B	CR	10	
31		**Sphyrna tudes* (Valenciennes, 1822)	Smalleye hammerhead		M	VU	1	-
32		*Sphyrna zygaena* (Linnaeus, 1758)	Smooth hammerhead	Choto haturi hangor	M,	VU	1,5	Uncommon
33	Triakidae	**Galeorhinus galeus* (Linnaeus, 1758)	Tope shark		M	VU	1	
34		*Mustelus griseus* Pietschmann, 1908	Spotless smooth-hound	Hangor	M	DD	9	
35		*Mustelus manazo* Bleeker, 1855	Starspotted smooth-houd	Hangor	M	DD	1,5	
36		*Mustelus mosis* Hemprich & Ehrenberg, 1899	Arabian smooth-hound	Hangor	M, S	NT	32	
Order: Torpediniformes								
37	Narcinidae	*Narcine brunnea* Annandale, 1909	Spotless smooth-hound	Badami bidyut machh	M, S	VU	1,5,6,20	Rare

38		*Narcine prodorsalis* Bessednov, 1966	Tonkin numbfish	Bidyut machh	M	DD	18	
39		*Narcine timlei* (Bloch & Schneider, 1801)	Spotted numbfish	Bidyut machh	M, S	DD	1,5,24,27	Common
40	Narkidae	*Narke dipterygia* (Bloch & Schneider, 1801)	Numbray	Bidyut machh	M, S	DD	1,5,20,24	Rare
Order: Rajiformes								
41	Rhinobatidae	*Rhina ancylostoma* Bloch & Schneider, 1801	Bowmouth guitarfish	Titamarmari	M, R	CR	1,5,24,27	Rare
42		*Rhinobatos annandalei* Norman, 1927	Annandale's guitarfish	Matia bailla	M, B	DD	1,5,27	Rare
43		*Rhynchobatus djiddensis* (Forsskål, 1775)	Giant guitarfish	Titamarmari	M, B, R, S	CR	1,5,24	Common
Order: Rhinopristiformes								
44	Glaucostegidae	*Glaucostegus granulatus* (Cuvier, 1829)	Granulated guitarfish	Pitambori	M, S	CR	1,6,20,24,27	
45		*Glaucostegus typus* (Anonymous [Bennett], 1830)	Giant shovelnose ray	Pitambori	M, B, F	CR	12	
Order: Pristiformes								
46	Pristidae	*Anoxypristis cuspidata* (Latham, 1794)	Pointed sawfish	Karati hangor	M, B, F, S	EN	1,5,24	Commercial
47		*Pristis microdon* Latham, 1794	Largetooth sawfish	Korati hangor	M, B, F, S	CR	1,5	Common
48		*Pristis pectinata* Latham, 1794	Smalltooth sawfish	Korati hangor	M, B, F	CR	1	-
49		*Pristis pristis* (Linnaeus, 1758)	Common sawfish	Korati hangor	M, B, F	CR	11	
50		*Pristis zijsron* Bleeker, 1851	Longcomb sawfish	Korati hangor	M, B, F	CR	1,5	Uncommon
Order: Myliobatiformes								
51	Dasyatidae	*Brevitrygon imbricata* (Bloch & Schneider, 1801)	Scaly whipray	Haush pata	M, B, F, S	DD	1,5,20,24	Uncommon
52		*Brevitrygon walga* (Müller & Henle, 1841)	Dwarf whipray	Haush pata	M, S	NT	1,5,6,20,24,27	Common
53		*Hemitrygon bennettii* (Müller & Henle, 1841)	Bennett's stingray	Haush pata	M	NE	5	
54		*Himantura fluviatilis* (Hamilton, 1822)	Ganges stingray	Haush pata	M, B, F, S	NE	5	
55		*Himantura marginata* (Blyth, 1860)	Blackedge whipray	Haush pata	M, B	DD	1,5	Uncommon
56		*Himantura uarnak* (Gmelin, 1789)	Honeycomb stingray	Chitra haush	M, B, R, S	VU	1,5,6,20,24,27	Commercial
57		*Himantura undulata* (Bleeker, 1852)	Leopard whipray	Chitra haush	M, S	VU	2	
58		*Maculabatis gerrardi* (Gray, 1851)	Sharpnose Stingray	Haush	M, B, S	VU	2	
59		*Maculabatis pastinacoides* (Bleeker, 1852)	Round whip ray	Hash	M	VU	9	
60		*Neotrygon indica* Pavan-Kumar, Kumar, Pitale, Shen and Borsa, 2018		Chitra haush	M	DD	1,5,23,27	
61		*Pastinachus gracilicaudus* Last & Manjaji-Matsumoto, 2010	Narrowtail stingray	Haush	M	NE	9	
62		*Pastinachus sephen* (Forsskål, 1775)	Cowtail stingray	Haush	M, B, F, R, S	NT	1,5	Common

63		*Pateobatis bleekeri* (Blyth, 1860)	Bleeker's whipray	Haush pata	M, B	NE	1,5,24,27	Unommon
64		*Pateobatis uarnacoides* (Bleeker, 1852)	Bleeker's whipray	Haush	M, S	VU	24,2	
65		*Taeniura lymma* (Forsskål, 1775)	Ribbontail stingray	Sapla pata	M, R	NT	1,5,6	Rare
66		*Taeniurops meyeni* (Müller & Henle, 1841)	Round ribbontail ray	Haush	M, R	VU	24	
67		*Telatrygon zugei* (Müller & Henle, 1841)	Sharp Snout Stingray	Chokha mukho haush	M, B, S	NT	1, 5, 20	
68		*Urogymnus asperrimus* (Bloch & Schneider, 1801)	Porcupine ray	Haush	M, B, R	VU	1,5	Rare
69	Gymnuridae	*Gymnura micrura* (Bloch & Schneider, 1801)	Smooth butterfly ray	Padmamoni	M, B	DD	1,6	Uncommon
70		*Gymnura poecilura* (Shaw, 1804)	Long-tailed butterfly ray	Padmamoni, Kulta	M, S	NT	1,5,20,24,27	Common
71	Myliobatidae	*Aetobatus narinari* (Euphrasen, 1790)	Spotted eagle ray	Chilmach	M, B	NT	1,5,6	Common
72		*Aetomylaeus maculatus* (Gray, 1834)	Mottled eagle ray	Shankhachil	M, B, R	EN	1,5	Rare
73		*Aetomylaeus nichofii* (Bloch & Schneider, 1801)	Banded eagle ray	Shankhachil	M, B	VU	1,5	Common
74		*Mobula birostris* (Walbaum, 1792)	Giant manta		M	VU	6	
75		*Mobula eregoodootenkee* (Bleeker, 1859)	Longhorned mobula	Deo mach	M	NT	1	
76		*Mobula japanica* (Müller & Henle, 1841)	Spinetail mobula	Deo mach	M, R	NT	5,27	
77		*Mobula kuhlii* (Müller & Henle, 1841)	Shortfin devil ray	Deo mach	M	EN	12	
78		*Mobula mobular* (Bonnaterre, 1788)	Giant devil ray	Deo mach	M	EN	5	
79		*Mobula tarapacana* (Philippi, 1892)	Chilean devil ray	Deo mach	M	EN	27	
80		*Rhinoptera javanica* Müller & Henle, 1841	Flapnose ray	Sankhachil	M, B, R	VU	1	Uncommon
81		*Rhinoptera neglecta* Ogilby, 1912	Australian cownose ray	Sankhachil	M, R	DD	6	
Class: Actinopterygii								
Order: Elopiformes								
82	Elopidae	*Elops machnata* (Forsskål, 1775)	Tenpounder	Solemani mach	M, B, S	LC	1,5,24,27	Uncommon
83	Megalopidae	*Megalops cyprinoides* (Broussonet, 1782)	Indo-Pacific tarpon		M, B, F, S	DD	1,20	Uncommon
Order: Anguilliformes								
84	Muraenidae	*Echidna nebulosa* (Ahl, 1789)	Starry moray	Tara baim	M, R	LC	1,5,2	
85		*Gymnothorax favagineus* Bloch & Schneider, 1801	Laced moray	Chita bagh machh	M, B, R	LC	5	
86		*Gymnothorax prolatus* Sasaki & Amaoka, 1991	Moray eel	Sap machh	M	DD	24	
87		*Gymnothorax pseudothyrsoideus* (Bleeker, 1853)	Highfin moray	Metka	M, R	LC	1,5,24	-
88		*Gymnothorax punctatus* Bloch & Schneider, 1801	Red Sea whitespotted moray	Bamosh	M, R, S	LC	5,6,20,24	-

89		*Gymnothorax reticularis* Bloch, 1795	Reticulated moray	Chitral eel	M	NE	24	
90		*Gymnothorax tile* (Hamilton, 1822)	Indian mud moray	Eel	M, B, F, S	LC	20	
91		*Gymnothorax undulatus* (Lacepède, 1803)	Undulated moray	Mauri Baim	M, B, R	LC	1,5,24	Uncommon
92		*Strophidon sathete* (Hamilton, 1822)	Slender Giant Moray	Sap machh	M, B, F, S	NE	20	
93	Ophichthidae	*Caecula pterygera* Vahl, 1794	Finny snake eel	Hizra	M, B,	NE	5,24	
94		*Lamnostoma orientalis* (McClelland, 1844)	Oriental worm-eel	Hizra	M, B, F, R	LC	1,5	Uncommon
95		*Muraenichthys gymnopterus* (Bleeker, 1853)	Worm-eel	Sap machh	M, B, R	NE	1	Uncommon
96		*Pisodonophis boro* (Hamilton, 1822)	Rice-paddy eel	Bamosh	M, B, F, S	LC	1,20	Rare
97		*Pisodonophis cancrivorus* (Richardson, 1848)	Longfin snake-eel	Boro pakhna sap mach	M, B, F, R	NE	1,24	-
98	Muraenesocidae	*Congresox talabon* (Cuvier, 1829)	Yellow pike conger	Kamila	M, B	NE	1	Uncommon
99		*Congresox talabonoides* (Bleeker, 1853)	Indian pike conger	Kamila	M, B, S	NE	1,6,24,27	Commercial
100		*Muraenesox bagio* (Hamilton, 1822)	Common pike conger	Kamila	M, B	NE	24,27	
101		*Muraenesox cinereus* (Forsskål, 1775)	Daggertooth pike conger	Kamila	M, B, F, S	NE	1,24,	Uncommon
102	Congridae	*Ariosoma anago* (Temminck & Schlegel, 1846)	Silvery conger	Kamila	M	DD	1,5,24,27	Uncommon
103		*Ariosoma gnanadossi* Talwar & Mukherjee 1977	Eel	Kamila	M, B	LC	24	
104		*Conger cinereus* Rüppell, 1830	Longfin African conger	Kamila	M, B, R	LC	1,5,24	Rare
105		*Conger conger* (Linnaeus, 1758)	European conger	Kamila	M	LC	1	Rare
106		*Heteroconger perissodon* Böhlke & Randall, 1981	Black garden eel		M	LC	13	
107		*Uroconger lepturus* (Richardson, 1845)	Slender conger	Kamila	M	LC	1,5,24	Uncommon
108	Anguillidae	*Anguilla bengalensis* (Gray, 1831)	Indian mottled eel	Baim machh	M, B, F, S	NT	1,20	Common
109		*Anguilla bicolor* McClelland, 1844	Indonesian shortfin eel	Baim machh	M, B, F	NT	1,5	Uncommon/Rare
110		**Anguilla celebesensis* Kaup, 1856	Celebes longfin eel		M, B, F	DD	1	-
111		*Anguilla marmorata* Quoy & Gaimard, 1824	Giant mottled eel	Baow baim	M, B, F	LC	1,5	-
Order: Clupeiformes								
112	Pristigasteridae	*Ilisha elongata* (Anonymous [Bennett], 1830)	Elongate ilisha	Ramgasa	M, B	LC	1,5,6,24,	Common
113		*Ilisha filigera* (Valenciennes, 1847)	Coromandel ilisha	Boro choukka	M, B, F, S	DD	1,5,24	Commercial
114		*Ilisha megaloptera* (Swainson, 1839)	Bigeye ilisha	Choukka	M, B, F, S	LC	1,6,24	Commercail
115		*Ilisha melastoma* (Bloch & Schneider, 1801)	Indian ilisha	Choukka	M, B, S	LC	1,5,6,24,	
116		*Opisthopterus tardoore* (Cuvier, 1829)	Tardoore	Fasa	M, B, S	LC	1,5,20,27,	Uncommon

117		*Pellona ditchela* Valenciennes, 1847	Indian pellona	Fasa	M, B, F, S	LC	1,6,24	Uncommon
118		*Raconda russeliana* Gray, 1831	Raconda	Kunnafasa	M, B, S	LC	1,6,24,27,	Commercial
119	Engraulidae	*Coilia dussumieri* Valenciennes, 1848	Goldspotted grenadier anchovy	Olua	M, B, F, S	LC	1,6,20,24	Common
120		*Coilia mystus* (Linnaeus, 1758)	Osbeck's grenadier anchovy	Olua	M, B, F,	EN	24	
121		*Coilia neglecta* Whitehead, 1967	Neglected Grenadier Anchovy	Olua, boiragi	M, B, S	LC	5,6,20	
122		*Coilia ramcarati* (Hamilton, 1822)	Ramcarat grenadier anchovy	Boga olua	M, B, S	DD	1,6,20,27	Common
123		*Coilia reynaldi* Valenciennes, 1848	Reynald's grenadier anchovy	Olua	M, B, F,	LC	1,5,24	-
124		*Coilia macrognathos* Bleeker, 1852	Longjaw grenadier anchovy	Olua	M, B, F	DD	24	
125		*Setipinna breviceps* (Cantor, 1849)	Shorthead hairfin anchovy	Fasha	M, B	LC	1,5,24	Uncommon
127		*Setipinna taty* (Valenciennes, 1848)	Scaly hairfin anchovy	Ram faisha	M, B, S	LC	1,20,24,27	Commercial
127		*Setipinna tenuifilis* (Valenciennes, 1848)	Common Hairfin Anchovy	Fasha	M, B, F, S	DD	20	
128		*Stolephorus commersonnii* Lacepède, 1803	Commerson's anchovy	Mola	M, B	LC	1,5,6,24,27	
129		*Stolephorus indicus* (van Hasselt, 1823)	Indian anchovy	Fasha	M, B, S	LC	1,5,6,20,24	Common
130		*Stolephorus tri* (Bleeker, 1852)	Spined anchovy	Kata fasha	M, B, S	LC	1,5,20	Common
131		*Thryssa dussumieri* (Valenciennes, 1848)	Dussumier's thryssa	Fasha	M, B, S	LC	1,5,6,24,27	Common
132		*Thryssa hamiltonii* Gray, 1835	Hamilton's thryssa	Fasha	M, B, F, S	LC	1,5,6,20,24	-
133		*Thryssa kammalensis* (Bleeker, 1849)	Kammal thryssa	Fasha	M, B	DD	1	Rare
134		*Thryssa malabarica* (Bloch, 1795)	Malabar thryssa	Fasha	M, B	DD	24	
135		*Thryssa mystax* (Bloch & Schneider, 1801)	Moustached thryssa	Fasha	M, B	LC	1,5,24,27	-
136		*Thryssa purava* (Hamilton, 1822)	Oblique Jaw Thryssa, Gangetic Anchovy	Fasha	M, B, S	DD	20	
137		*Thryssa setirostris* (Broussonet, 1782)	Longjaw thryssa	Fasha	M, B	LC	1,5,6,24,27	Commercial
138	Chirocentridae	*Chirocentrus dorab* (Forsskål, 1775)	Dorab wolf-herring	Karati chela	M, B, R, S	LC	1,5,6,20,24,27	Commercial
139		*Chirocentrus nudus* Swainson, 1839	Whitefin wolf-herring	Karati chela	M, S	LC	1,5,6,24,27	Rare
140	Clupeidae	*Anodontostoma chacunda* (Hamilton, 1822)	Chacunda gizzard shad	Koi puti	M, B, F, S	LC	1,5,20,24,27	Commercial
141		*Escualosa thoracata* (Valenciennes, 1847)	White Sardine	Hichiri machh	M, B, F, S	LC	5,20,24,27	
142		*Hilsa kelee* (Cuvier, 1829)	Kelee shad	Gurta ilish	M, B, F, S	LC	1,5,20,24,27,	Common
143		*Nematalosa nasus* (Bloch, 1795)	Bloch's gizzard shad	Khoira	M, B, F, S	LC	1,5,20	Common

144		*Sardinella albella* (Valenciennes, 1847)	White sardinella	Chapila	M, R	LC	24,27	
145		*Sardinella fimbriata* (Valenciennes, 1847)	Fringescale sardinella	Khaira	M, B, S	LC	1,5,6,20,24,27	Commercail
146		*Sardinella gibbosa* (Bleeker, 1849)	Gold stripe sardine	Sonali khaira	M, S	LC	24,27,2	
147		*Sardinella longiceps* Valenciennes, 1847	Indian Oil Sardine	Khoira	M, S	LC	20,24,27,15	
148		*Sardinella melanura* (Cuvier, 1829)	Blacktip sardinella	Chandana	M, S	LC	1,5,20,24	Commercail
149		*Tenualosa ilisha* (Hamilton, 1822)	Hilsa shad	Ilish	M, B, F, S	LC	1,6,20,24,27	Commercail
150		*Tenualosa toli* (Valenciennes, 1847)	Toli shad	Chandana ilish	M, B, F, S	LC	1,20,24	Rare
151	Dussumieriidae	*Dussumieria acuta* Valenciennes, 1847	Rainbow sardine	Nailya	M, B, F, S	LC	1,5,6,24	Commercail
152		*Dussumieria elopsoides* Bleeker, 1849	Slender rainbow sardine	Moricha	M	LC	24,27	
Order: Gonorynchiformes								
153	Chanidae	*Chanos chanos* (Forsskål, 1775)	Milkfish	Duiddha mach	M, B, F	LC	27	
Order: Siluriformes								
154	Plotosidae	*Plotosus canius* Hamilton, 1822	Gray eel-catfish	Kain magur	M, B, F, S	NE	1,6,20,27	Common
155		*Plotosus lineatus* (Thunberg, 1787)	Striped ell tail cat fish	Sagor kawun	M, B, R, S	NE	5,24,27	
156	Ariidae	*Arius arius* (Hamilton, 1822)	Threadfin sea catfish	Kata machh	M, B, S	LC	5,6,20,27	
157		*Arius gagora* (Hamilton, 1822)	Gagora Catfish	Kata machh	M, B, F, S	NT	6,20	Commercial
158		*Arius jella* Day, 1877	Gagora catfish	Kata machh	M, B	NE	1	Common
159		*Arius maculatus* (Thunberg, 1792)	Spotted catfish	Kata machh	M, B, F, S	NE	1,5,6,20,24	Rare
160		*Arius venosus* Valenciennes, 1840	Yellow Sea Catfish, Marine Catfish	Kata veni	M, B, S	NE	5,20,24	
161		*Batrachocephalus mino* (Hamilton, 1822)	Beardless sea catfish	Katabukha	M, B	NE	1,5	Uncommon
162		*Cephalocassis jatia* (Hamilton, 1822)	River catfish	Kata machh	M, B, F	DD	1,5	-
163		*Hexanematichthys sagor* (Hamilton, 1822)	Sagor catfish	Sagor guizza	M, B	NE	5	
164		*Ketengus typus Bleeker*, 1846	Bigmouth sea catfish	Medha	M, B, F	NE	1,5	Rare
165		*Nemapteryx caelata* (Valenciennes, 1840)	Engraved cat fish	Kata machh	M, B, S	NE	3	Common
166		*Nemapteryx macronotacantha* (Bleeker, 1846)		Katanil	M, B, F	NE	5,6	
167		*Nemapteryx nenga* (Hamilton, 1822)	Engraved catfish	Kata gogat	M, B, S	NE	1,5,6,20	
168		*Netuma bilineata* (Valenciennes, 1840)	Bronze Catfish	Kata machh	M, B, F, S	NE	5,20	
169		*Netuma thalassina* (Rüppell, 1837)	Giant catfish	Katamachh	M, B, F, S	NE	1,5,6	Commercial
170		*Osteogeneiosus militaris* (Linnaeus, 1758)	Soldier catfish	Apuia	M, B, F,	NE	1,5,27	Common

171		*Plicofollis dussumieri* (Valenciennes, 1840)	Blacktip sea catfish	Kata	M, B, F, S	LC	1,5,6,24	Common
172		*Plicofollis layardi* (Günther, 1866)	Thinspine sea catfish	Kata	M, B	NE	5	
173		*Plicofollis nella* (Valenciennes, 1840)	Smooth-headed catfish	Kata nela	M, B	NE	5	
174		*Plicofollis platystomus* (Day, 1877)	Flatmouth sea catfish	Samuddrik kata	M, B, S	LC	5	
175		*Plicofollis tonggol* (Bleeker, 1846)	Roughback sea catfish	Samuddrik kata	M, B	NE	5	
176		*Sciades sona* (Hamilton, 1822)	Dusky Catfish	chai kata machh	M, B, S	NE	5,20	
Order: Aulopiformes								
177	Chlorophthalmidae	*Chlorophthalmus agassizi* Bonaparte, 1840	Shortnose greeneye	Sobujchokhi	M, B	LC	1,5	Common
178		*Chlorophthalmus corniger* Alcock, 1894	Spinyjaw greeneye	Sobujchokhi	M	LC	1,5	Uncommon
179	Synodontidae	*Harpadon nehereus* (Hamilton, 1822)	Bombay-duck	Loittya	M, B, S	NT	1,5,6,20,24,27	Commercial
180		*Saurida gracilis* (Quoy & Gaimard, 1824)	Gracile lizardfish	Tiktiki machh	M, R	LC	1,5	Rare
181		*Saurida longimanus* Norman, 1939	Longfin lizardfish	Anchila	M	LC	24,27	
182		*Saurida micropectoralis* Shindo & Yamada, 1972	Shortfin lizardfish	Anchila	M	LC	Present study	
183		*Saurida tumbil* (Bloch, 1795)	Greater lizardfish	Tiktiki machh	M, R, S	LC	1,5,6,20,24,27	Common
184		*Saurida undosquamis* (Richardson, 1848)	Brushtooth lizardfish	Tiktiki machh	M, R	LC	1,5,24,27	Common
185		*Synodus indicus* (Day, 1873)	Indian lizardfish	Achila	M, R	LC	1,5,24	Rare
186		*Trachinocephalus myops* (Forster, 1801)	Snakefish	Achila	M, R	LC	1,5,6,24	Rare
187	Paralepididae	*Lestrolepis japonica* (Tanaka, 1908)	Japanese barracudina		M	LC	27	
Order: Myctophiformes								
188	Myctophidae	*Diaphus metopoclampus* (Cocco, 1829)	Spothead lantern fish		M	LC	27	
Order: Polymixiiformes								
189	Polymixiidae	**Polymixia berndti* Gilbert, 1905	Pacific beardfish		M, R	LC	1	
Order: Zeiformes								
190	Zeniontidae	*Zenion leptolepis* (Gilchrist & von Bonde, 1924)	Elongate dory		M	NE	1,5	Rare
Order: Gadiformes								
191	Bregmacerotidae	*Bregmaceros mcclellandi* Thompson, 1840	Unicorn Cod	Puiya	M, B, S	NE	20,24,27	
192	Macrouridae	*Coelorinchus parallelus* (Günther, 1877)	Spiny grenadier	Edur leizza	M	NE	1,5	-
193		*Coryphaenoides woodmasoni* (Alcock, 1890)	Wood-Mason's rattail	Edur leizza	M,	NE	1,5	Uncomoon
194		*Hymenocephalus italicus* Giglioli, 1884	Glasshead grenadier		M	LC	1,5	-
195	Moridae	*Physiculus argyropastus* Alcock, 1894			M	NE	1,5	Uncommon

Order: Beryciformes								
196	Holocentridae	*Myripristis botche* Cuvier, 1829	Blacktip soldierfish	Soinik machh	M, R	LC	24	
197		*Myripristis hexagona* (Lacepède, 1802)	Doubletooth soldierfish	Soinik machh	M, R	LC	27	
198		*Myripristis murdjan* (Forsskål, 1775)	Pinecone soldierfish	Soinik machh	M, R	LC	1,5,24,27	Uncommon
199		*Myripristis vittata* Valenciennes, 1831	Whitetip soldierfish	Soinik machh	M, R	LC	6	
200		*Sargocentron caudimaculatum* (Rüppell, 1838)	Silverspot squirrelfish	Ruplai katbirali machh	M, R	LC	1,5,24	-
201		*Sargocentron rubrum* (Forsskål, 1775)	Redcoat	Soinik mach	M, R	LC	5,24,27	
202	Diretmidae	*Diretmus argenteus* Johnson, 1864	Silver spinyfin		M	LC	1,5	-
203	Monocentridae	*Monocentris japonica* (Houttuyn, 1782)	Pineconefish		M, R	LC	1	Rare
204	Trachichthyidae	*Gephyroberyx darwinii* (Johnson, 1866)	Darwin's slimehead	Lal pakhna chanda	M	LC	1,5	Comoon
Order: Ophidiiformes								
205	Ophidiidae	*Brotula multibarbata* Temminck & Schlegel, 1846	Goatsbeard brotula	Shamuddro magur	M	LC	27	
206		*Hypopleuron caninum* Smith & Radcliffe, 1913	Whiptail cusk	Samudra chewa	M	LC	1,5,24	Uncommon
207		*Monomitopus conjugator* (Alcock, 1896)	Scaly-headed blindfish		M	LC	1,5	
Order: Batrachoidiformes								
208	Batrachoididae	*Allenbatrachus grunniens* (Linnaeus, 1758)	Grunting Toadfish	Byang machh	M, B, S	NE	20	
209		*Batrachomoeus trispinosus* (Günther, 1861)	Three-spined frogfish	Te-Kata byang machh	M, B	NE	28	
210		*Colletteichthys dussumieri* (Valenciennes 1837)	Flat toadfish	Byang machh	M	NE	Present Study	
Order: Mugiliformes								
211	Mugilidae	*Chelon parsia* (Hamilton, 1822)	Goldspot Mullet	Bata, Parshe	M, B, F, S	NE	20	Commercial
212		*Ellochelon vaigiensis* (Quoy & Gaimard, 1825)	Squaretail mullet	Bata	M, B, F, R	LC	16	
213		*Liza parsia* (Hamilton, 1822)	Goldspot mullet	Bata, Parshe	M, B, F, S	NE	1,6	Common
214		*Mugil cephalus* Linnaeus, 1758	Flathead grey mullet	Khorul bata	M, B, F, S	LC	1,6,20,24,27	Commercial
215		*Osteomugil cunnesius* (Valenciennes, 1836)	Longarm mullet	Bata	M, B, F, S	NE	1,5,20,27,	
216		*Paramugil parmatus* (Cantor, 1849)	Broad-mouthed mullet	Bata machh	M, B, F	NE	5	
217		*Planiliza planiceps* (Valenciennes 1836)	Tade gray mullet	Bata machh	M, B, S	NE	5	Common
218		*Planiliza subviridis* (Valenciennes, 1836)	Greenback mullet	Bata	M, B, F, S	NE	1,5,20,24,27	Commercial
219		*Valamugil speigleri* (Bleeker, 1858)	Speigler's mullet	Pata bata	M, B, F, S	NE	1,5	Uncommon
Order: Atheriniformes								

220	Atherinidae	*Atherinomorus lacunosus* (Forster, 1801)	Wide-banded hardyhead silverside		M, B, F, R	NE	6	
Order: Beloniformes								
221	Exocoetidae	*Cheilopogon furcatus* (Mitchill, 1815)	Spotfin flyingfish	Urumachh	M	LC	Present study	
222		*Cypselurus comatus* (Mitchill, 1815)	Clearwing flyingfish	Urumachh	M	LC	1,5	-
223		*Cypselurus poecilopterus* (Valenciennes, 1847)	Yellowing flyingfish	Urumachh	M	NE	5	
224		*Exocoetus volitans* Linnaeus, 1758	Tropical two-wing flyingfish	Urumachh	M, S	LC	1,5,6,20	Common
225	Hemiramphidae	*Hemiramphus far* (Forsskål, 1775)	Black-barred halfbeak	Ek-thutey, Ek-thute	M, B	NE	Present study	
227		*Hemiramphus marginatus* (Forsskål, 1775)	Yellowtip halfbeak	Ek-thutey	M	LC	1,5,24,27	-
227		*Hyporhamphus limbatus* (Valenciennes, 1847)	Congaturi halfbeak	Ek-thuitta	M, B, F, S	LC	2	Common
228		*Hyporhamphus quoyi* (Valenciennes, 1847)	Quoy's garfish	Ek-thuitta	M, B, F	NE	1	-
229		*Hyporhamphus unifasciatus* (Ranzani, 1841)	Common halfbeak	Ek-thutey	M, B, R	LC	1,5	-
230		*Rhynchorhamphus georgii* (Valenciennes, 1847)	Long billed half beak	Ek-thutey	M, B, F, S	NE	1,5,6,20	-
231	Zenarchopteridae	*Zenarchopterus buffonis* (Valenciennes, 1847)	Buffon's river-garfish	Ek-thutey	M, B, R, S	NE	1,5,20	Uncommon
232		*Zenarchopterus dispar* (Valenciennes, 1847)	Feathered river-garfish	Ek-thutey	M, B, F, R	LC	1,5	Common
233	Belonidae	*Ablennes hians* (Valenciennes, 1846)	Flat needlefish	Kaikka, Kakila	M, B, R	LC	6	
234		*Strongylura leiura* (Bleeker, 1850)	Banded needlefish	Kaikka	M, B, R, S	NE	1,5,20,27	Common
235		*Strongylura strongylura* (van Hasselt, 1823)	Spottail needlefish	Kaikka	M, B, S	NE	1,5,6,27	Uncommon
236		*Tylosurus crocodilus* (Péron & Lesueur, 1821)	Hound needlefish	Boro tuitta	M, R, S	LC	1,5,6,27	-
Order: Pleuronectiformes								
237	Psettodidae	*Psettodes belcheri* Bennett, 1831	Halibut	Samudra serboti	M, B, S	DD	2	
238		*Psettodes bennettii* Steindachner, 1870	Spiny turbot	Samudra serboti	M	DD	13	
239		*Psettodes erumei* (Bloch & Schneider, 1801)	Indian halibut	Samudra serboti	M, S	NE	1,5,6,24,27	Common
240	Citharidae	*Brachypleura novaezeelandiae* Günther, 1862	Yellow-dabbled flounder	Bash pata	M	LC	5,24	
241	Paralichthyidae	*Cephalopsetta ventrocellatus* Dutt & Rao, 1965	Large-tooth flounder	Chepta machh	M	DD	27	
242		*Pseudorhombus arsius* (Hamilton, 1822)	Largetooth flounder	Boro dati chepta machh	M, B, S	NE	1	Common
243		*Pseudorhombus elevatus* Ogilby, 1912	Deep flounder	Serboti	M, S	NE	1,5,24	Rare
244		*Pseudorhombus javanicus* (Bleeker, 1853)	Javan flounder	Chepta machh, Serboti	M, S	NE	1,5,20,24,27	
245		*Pseudorhombus malayanus* Bleeker, 1865	Malayan flounder	Chepta machh	M, S	NE	1,5,6,24,27	Uncommon

246		*Pseudorhombus triocellatus* (Bloch & Schneider, 1801)	Three spotted flounders	Tinphota chepta machh	M	NE	1,24	
247	Pleuronectidae	*Paralichthodes algoensis* Gilchrist, 1902	Peppered flounder	Chepta machh	M	LC	24	
248	Bothidae	*Arnoglossus aspilos* (Bleeker, 1851)	Spotless lefteye flounder	Chepta machh	M	LC	1,5,27	
249		*Bothus myriaster* (Temminck & Schlegel, 1846)	Indo-Pacific oval flounder	Chepta machh	M	LC	1,5,24	
250		*Grammatobothus polyophthalmus* (Bleeker, 1865)	Threespot flounder	Tinphota chepta machh	M	LC	16	
251		*Laeops nigrescens* Lloyd, 1907	Lefteye flounders	Bamchouka chepta machh	M	NE	24	
252	Soleidae	*Aesopia cornuta* Kaup, 1858	Unicorn sole	Shingra zebra, Pata machh	M, R	LC	1,5,6,24,27	
253		*Brachirus orientalis* (Bloch & Schneider, 1801)	Oriental sole	Botpata, Kathal pata	M, B, F, S	NE	1,6,20,24	
254		*Brachirus pan* (Hamilton, 1822)	Sole	Pata machh	M, B, F, S	LC	2	
255		*Synaptura commersonnii* (Lacepède, 1802)	Commerson's sole	Serboti	M, B, S	NE	1,5,20,27	
256		*Heteromycteris oculus* (Alcock, 1889)	Eyed sole	Chitra serboti	M	DD	1,5	
257		*Solea elongata* Day, 1877	Elongate sole	Sole	M	NE	1,5,24,27	Uncommon
258		*Solea ovata* Richardson, 1846	Ovate sole	Pata machh	M	NE	1,5,24	
259		*Zebrias altipinnis* (Alcock, 1890)	Zebra sole	Dora Soli	M, S	LC	2,5,6,27	
270		*Zebrias quagga* (Kaup, 1858)	Fringefin zebra sole	Zebra Soli	M	NE	1,5	
271		*Zebrias synapturoides* (Jenkins, 1910)	Indian zebra sole	Zebra Serboti	M	NE	24	
272		*Zebrias zebra* (Bloch, 1787)	Zebra sole	Zebra Serboti	M, B, R	NE	24	
273	Cynoglossidae	*Cynoglossus arel* (Bloch & Schneider, 1801)	Largescale tonguesole	Kukur jeeb	M, B, S	NE	1,20,24	Commmon
274		*Cynoglossus bilineatus* (Lacepède, 1802)	Fourlined tonguesole	Kukur jeeb	M, B, S	NE	1,5,6,24,27	
275		*Cynoglossus capensis* (Kaup, 1858)	Sand tonguefish	Kukur jeeb	M, B	NE	24	
276		*Cynoglossus cynoglossus* (Hamilton, 1822)	Bengal tongue sole	Kukur jeeb	M, B, S	LC	1,6,24	Common
277		*Cynoglossus kopsii* (Bleeker, 1851)	Long tonguesole	Kukur jeeb	M, S	NE	5,6	
278		*Cynoglossus lida* (Bleeker, 1851)	Roughscale tonguesole	Kukur jeeb	M	NE	1,5	
279		*Cynoglossus lingua* Hamilton, 1822	Long tongue sole	Lombu kukur jeeb	M, B, F, S	LC	1,6,24,27	
270		*Cynoglossus macrolepidotus* (Bleeker, 1851)	Largescaled tonguesole	Kukur jeeb	M	NE	1,5,24,	
271		*Cynoglossus macrostomus* Norman, 1928	Malabar tonguesole	Kukur jeeb	M, B	VU	5	
272		*Cynoglossus puncticeps* (Richardson, 1846)	Speckled tonguesole	Kukur jeeb	M, B, F, S	NE	1,5,24	
273		*Paraplagusia bilineata* (Bloch, 1787)	Doublelined tonguesole	Jihoba sole	M, B, S	NE	1,24,27	
274		*Symphurus septemstriatus* (Alcock, 1891)	Sevenband tonguesole	Kukur jeeb	M	NE	1,5	

275		*Symphurus trifasciatus* (Alcock, 1894)	Tongusole	Kukur jeeb	M, S	NE	2	
Order: Syngnathiformes								
276	Centriscidae	*Centriscus scutatus* Linnaeus, 1758	Grooved razor-fish	Ciruni machh	M, B, R,	LC	27	
277	Fistulariidae	*Fistularia commersonii* Rüppell, 1838	Bluespotted cornetfish	Bongshi bashi	M, R	NE	24,27	
278	Fistulariidae	*Fistularia petimba* Lacepède, 1803	Red cornetfish	Bongshi bashi	M, B, R, S	LC	1,5,20,24,27	Common
279	Syngnathidae	*Hippocampus kuda* Bleeker, 1852	Spotted seahorse	Ghora machh	M, B, R, S	VU	1,5,6,20,24,27	Rare
280		*Ichthyocampus carce* (Hamilton, 1822)	Pipefish	Pipemachh	M, B, F,	LC	1	Rare
281		*Trachyrhamphus serratus* (Temminck & Schlegel, 1850)	Crested Pipefish	Sharu leza thute	M, R	DD	1,5	Rare
Order: Perciformes								
282	Polynemidae	*Eleutheronema tetradactylum* (Shaw, 1804)	Fourfinger threadfin	Tailla	M, B, F, S	NE	1,5,6,20,24,27	Commercial
283		*Filimanus heptadactyla* (Cuvier, 1829)	Sevenfinger threadfin	Tailla	M, B	LC	1,5	Rare
284		*Leptomelanosoma indicum* (Shaw, 1804)	Indian threadfin	Lakhua	M, B, S	NE	1,5,6,20,24,27	Commercial
285		*Polydactylus mullani* (Hora, 1927)	Arabian blackspot threadfin	Lakhua	M	NE	24	
286		*Polydactylus plebeius* (Broussonet, 1782)	Striped threadfin	Choto lakhua	M, B	NE	1,5,6	Common
287		*Polydactylus sexfilis* (Valenciennes, 1831)	Sixfinger threadfin	Sona tailla	M, B, F, R, S	NE	1,5	-
288		*Polydactylus sextarius* (Bloch & Schneider, 1801)	Blackspot threadfin	Kala tailla	M, B, S	NE	1,5,20,24,27	Uncomon
289		*Polynemus paradiseus* Linnaeus, 1758	Paradise threadfin	Topshe machh	M, B, F, S	LC	1,4,20,24,27,	Commercial
290	Kurtidae	*Kurtus indicus* Bloch, 1786	Indian hump head	Choto phaisha	M, B, F, S	NE	1,5,6,27	Common
291	Apogonidae	*Apogonichthyoides maculipinnis* (Regan, 1908)	Specklehead cardinalfish	Duiddya	M, R	NE	24	
292		*Apogonichthyoides sialis* (Jordan & Thompson, 1914)	Twinbar cardinalfish	Duidagi duiddya	M	NE	40	
293		*Fibramia thermalis* (Cuvier, 1829)	Half-barred cardinal	Duiddya	M, R	NE	1,5	-
294		*Jaydia ellioti* (Day, 1875)	Flag-in cardinal-fish	Duiddya	M, R	NE	1,5,24,27	-
295		*Jaydia queketti* (Gilchrist, 1903)	Spotfin cardinal	Duiddya	M	NE	24,27	
296		*Lepidamia kalosoma* (Bleeker, 1852)	Pinstripe cardinalfish	Duiddya	M, R	NE	40	
297		*Ostorhinchus cookii* (MacLeay, 1881)	Pinstripe cardinalfish	Duiddya	M, R	NE	40	
298		*Ostorhinchus endekataenia* (Bleeker, 1852)	Candystripe cardinalfish	Pach dagi Duiddya	M, R	NE	5	
299		*Ostorhinchus fasciatus* (White, 1790)	Broadbanded cardinalfish	Motadagi duiddya	M, R, S	NE	1,5,20,24,27	
300		*Ostorhinchus gularis* (Fraser & Lachner, 1984)	Gular cardinalfish	Duiddya	M	LC	24	
301		*Ostorhinchus novemfasciatus* (Cuvier, 1828)	Sevenstriped cardinalfish	Chardagi Duiddya	M, R	NE	5,6,24	

302		*Ostorhinchus septemstriatus* (Günther, 1880)	Sevenband cardinalfish	Tindagi duiddya	M, R, S	NE	1,5,6,20	Uncommon
303	Gobiidae	*Acentrogobius cyanomos* (Bleeker, 1849)	Blue-spotted Goby	Nil photBaila	M, B	LC	4	
304		*Acentrogobius viridipunctatus* (Valenciennes, 1837)	Spotted green goby	Sobujbaila	M, B, F	LC	6,4	
305		*Amblyeleotris steinitzi* (Klausewitz, 1974)	Steinitz' prawn-goby	Chingri baila	M, R	LC	6	
306		*Apocryptes bato* (Hamilton, 1822)	Mudskipper	Chiring, Cheowa bele, Dali cheowa	M, B, F, S	LC	1,6	Commercial
307		*Awaous guamensis* (Valenciennes, 1837)	Scribbled Goby	Baila, Bele	M, B, F	LC	6,4	
308		*Boleophthalmus boddarti* (Pallas, 1770)	Boddart's goggle-eyed goby	Chiring, Dahuk, Meni	M, B, F, S	LC	1,20	
309		*Boleophthalmus dussumieri* Valenciennes, 1837	Mudskipper	Chiring, Dahuk	M, B, F	LC	24	
310		*Cryptocentrus cinctus* (Herre, 1936)	Yellow prawn-goby	Chingri baila	M	NE	6	
311		*Glossogobius giuris* (Hamilton, 1822)	Tank goby	Baila, Bele, Bailla	M, B, F, S	LC	1,6,20,24	Commercial
312		*Gobiopsis macrostoma* Steindachner, 1861	Longjaw goby	Baila	M, B, F	NE	4	
313		*Odontamblyopus rubicundus* (Hamilton, 1822)	Rubicusdus eelgoby	Sap baila	M, B, S	LC	1,6,20,24	
314		*Oxyurichthys papuensis* (Valenciennes, 1837)	Frogface goby	Bayang mukho baila	M, B, R	LC	24	
315		*Oxyurichthys petersii* (Klunzinger, 1871)	Peters's goby	Baila	M, R,	LC	24	
316		*Periophthalmodon schlosseri* (Pallas, 1770)	Giant mudskipper	Boro Chiring, Boro dahuk	M, B, F, S	LC	1	Common
317		*Periophthalmus barbarus* (Linnaeus, 1766)	Atlantic mudskipper	Chiring, Cheowa bele	M, B, F, R, S	LC	1,5	Common
318		*Pseudapocryptes elongatus* (Cuvier 1816)	Mud Skipper	Cheowa	M,B,F	LC	1, 6, 27	
319		*Scartelaos histophorus* (Valenciennes, 1837)	Walking goby	Cheowa	M, B, S	LC	1,20	
320		*Taenioides anguillaris* (Linnaeus, 1758)	Eel worm goby	Cheowa	M, B, F	LC	1,5	
321		*Taenioides buchanani* (Day, 1873)	Burmese gobyeel	Cheowa	M, B, S	DD	1	
322		*Taenioides cirratus* (Blyth, 1860)	Bearded worm goby	Cheowa	M, B, F, S	DD	24	
323		*Taenioides esquivel* Smith, 1947	Bulldog eelgoby	Cheowa	M, B	NE	24	
324		*Trypauchen vagina* (Bloch & Schneider, 1801)	Sada chewa	Sada cheowa	M, B, S	LC	1,5,6,20,24	Common
325		*Zappa confluentus* (Roberts, 1978)	Slender mudskipper	Kalo cheowa	M, B, F, S	NE	2	
327	Ambassidae	*Ambassis ambassis* (Lacepède, 1802)	Commerson's glassy	Kata chanda	M, B, F	LC	1,5,24	Uncommon
327		*Ambassis nalua* (Hamilton, 1822)	Scalloped perchlet	Kata chanda	M, B, F	LC	1,5,	-
328	Blenniidae	*Blenniella periophthalmus* (Valenciennes, 1836)	Blue-dashed rockskipper	Dai baila	M	LC	25	
329		*Cirripectes castaneus* (Valenciennes, 1836)	Chestnut eyelash-blenny	Baila	M, B, R	LC	6	
330		*Ecsenius bicolor* (Day, 1888)	Bicolor blenny	Baila	M, R	LC	6	

331		*Istiblennius dussumieri* (Valenciennes, 1836)	Streaky rockskipper	Baila	M, B, R	LC	31	
332		*Omobranchus punctatus* (Valenciennes, 1836)	Muzzled blenny	Gat baila	M, B	LC	16	
333		*Petroscirtes breviceps* (Valenciennes, 1836)	Striped poison-fang blenny mimic	Baila	M, B, R	LC	1,5	Rare
334		*Salarias fasciatus* (Bloch, 1786)	Jewelled blenny	Baila	M, B	LC	6	
335		*Xiphasia setifer* Swainson, 1839	Hairtail blenny	Shap Baila	M	LC	24	
336	Coryphaenidae	*Coryphaena equiselis* Linnaeus, 1758	Pompano dolphinfish	Dolphin machh	M,	LC	29	
337		*Coryphaena hippurus* Linnaeus, 1758	Common dolphinfish	Dolphin machh	M, B	LC	1,5,27	Rare
338	Rachycentridae	*Rachycentron canadum* (Linnaeus, 1766)	Cobia	Raja gazari	M, B, R, S	LC	1,5,6,20,24,27	Uncommon
339	Echeneidae	*Echeneis naucrates* Linnaeus, 1758	Live sharksucker	Hangar chaat	M, B, R	LC	1,5,6,24,27	
340		*Remora remora* (Linnaeus, 1758)	Shark sucker	Hangar chaat	M, R, S	LC	1,5,20,24	
341	Eleotridae	*Butis butis* (Hamilton, 1822)	Duckbill sleeper	Baila, Bele	M, B, F, S	LC	1,20	Common
342		*Butis humeralis* (Valenciennes, 1837)	Black spot sleeper Goby	Baila	M, B, F, S	NE	20	
343		*Butis melanostigma* (Bleeker, 1849)	Sleeper Goby	Baila	M, B, F, S	NE	3	
344		*Eleotris fusca* (Forster, 1801)	Dusky sleeper	Baila	M, B, F, S	LC	1,6,20	Common
345		*Eleotris lutea* Day, 1876	Lutea sleeper	Baila	M, B	NE	4	
346	Carangidae	*Alectis ciliaris* (Bloch, 1787)	African pompano	Pekhom mouri	M, R, S	LC	1,5,24,27	
347		*Alectis indica* (Rüppell, 1830)	Indian threadfish	Pekhom mouri	M, B, R, S	LC	1,5,6,24,27	Rare
348		*Alepes djedaba* (Forsskål, 1775)	Shrimp scad	Mouri	M, R, S	LC	1,5,24,27	
349		Alepes kleinii (Bloch, 1793)	Razorbelly scad	Mouri	M, R, S	LC	1,20,27	
350		*Alepes melanoptera* (Swainson, 1839)	Blackfin scad	Dora mouri	M, B, S	LC	1,5,6,20,24	
351		*Alepes vari* (Cuvier, 1833)	Herring scad	Mouri	M, B	LC	24	
352		*Atropus atropos* (Bloch & Schneider, 1801)	Cleftbelly trevally	Bangada	M, S	LC	1,5,20,24,27	ommon
353		*Atule mate* (Cuvier, 1833)	Yellowtail scad	Bom maittya	M, B, R	LC	1,5,24	
354		*Carangoides armatus* (Rüppell, 1830)	Longfin trevally	Mouri	M, B, R, S	LC	1,5,20,24,27	
355		*Carangoides chrysophrys* (Cuvier, 1833)	Longnose trevally	Mouri	M, B, R	LC	1,5,24,27	Rare
356		*Carangoides coeruleopinnatus* (Rüppell, 1830)	Coastal trevally	Mouri	M, R	LC	24	
357		*Carangoides ferdau* (Forsskål, 1775)	Blue trevally	Mouri	M, B, R	LC	1,5,24,27	Uncommon
358		*Carangoides hedlandensis* (Whitley, 1934)	Bumpnose Trevally	Mouri	M, R, S	LC	20,27	
359		*Carangoides malabaricus* (Bloch & Schneider, 1801)	Malabar trevally	Malabar moori	M, R, S	LC	1,5,6,24,27	Common

360		*Caranx heberi* (Bennett, 1830)	Blacktip trevally	Mouri	M, B, R	LC	Present study	
361		**Caranx hippos* (Linnaeus, 1766)	Crevalle jack		M, B, R	LC	1	
362		*Caranx ignobilis* (Forsskål, 1775)	Giant trevally	Nilambori	M, B, R, S	LC	1,5,6,20	
363		*Caranx melampygus* Cuvier, 1833	Bluefin trevally	Nilambori	M, B, R	LC	1,5,6,24	
364		*Caranx sexfasciatus* Quoy & Gaimard, 1825	Bigeye trevally	Boro choukka	M, B, F, R, S	LC	1,5,20,24,27	
365		*Decapterus kurroides* Bleeker, 1855	Redtail scad	Lalamburi	M, R, S	LC	1,5,20,24	Uncommon
366		*Decapterus macrosoma* Bleeker, 1851	Shortfin scad	Lalamburi	M, R	LC	24	
367		*Decapterus maruadsi* (Temminck & Schlegel, 1843)	Japanese scad	Nilambori	M, R	LC	24,27	
368		*Decapterus russelli* (Rüppell, 1830)	Indian scad	Sada maittya	M	LC	1,5,24,27	Common
369		*Elagatis bipinnulata* (Quoy & Gaimard, 1825)	Rainbow runner	Tota machh	M, R	LC	27,38	
370		*Gnathanodon speciosus* (Forsskål, 1775)	Golden trevally	Ghora maittya	M, R	LC	1,5,24,	
371		*Megalaspis cordyla* (Linnaeus, 1758)	Torpedo scad	Kaowa	M, B, R, S	LC	1,5,6,20,24,27	Commoercial
372		*Naucrates ductor* (Linnaeus, 1758)	Pilotfish	Pilot machh	M, R	LC	1,5	
373		*Parastromateus niger* (Bloch, 1795)	Black pomfret	Kala chanda	M, B, R, S	LC	1,5,6,20,24,27	Commercial
374		*Scomberoides commersonnianus* Lacepède, 1801	Double Spotted Queenfish	Chapa kori	M, B, R, S	LC	5,6,20,24,27	Commercial
375		*Scomberoides lysan* (Forsskål, 1775)	Doublespotted queenfish	Chapa	M, B, R	LC	1,5	Commercial
376		*Scomberoides tala* (Cuvier, 1832)	Barred queenfish	Bom maittya	M, R	LC	1,5,24	
377		*Scomberoides tol* (Cuvier, 1832)	Needlescaled queenfish	Bom maittya	M, B, R, S	LC	1,5,20,24,27	Uncommon
378		*Selar boops* (Cuvier, 1833)	Oxeye scad	Shitap	M, R, S	LC	5,6,24,2	
379		*Selar crumenophthalmus* (Bloch, 1793)	Bigeye scad	Boro choukka	M, R, S	LC	1,5,6,24,27	
380		*Selaroides leptolepis* (Cuvier, 1833)	Yellowstripe scad	Holde dora choukka	M, B, R	LC	1,5	
381		*Seriola rivoliana* Valenciennes, 1833	Longfin yellowtail	Mouri	M, R	LC	24,27	
382		*Seriolina nigrofasciata* (Rüppell, 1829)	Blackbanded trevally	Kalo dora	M, B, R, S	LC	1,5,6,20,24,27	
383		*Trachinotus baillonii* (Lacepède, 1801)	Small spotted dart	Anjupuli	M, B, R	LC	1,5	
384		*Trachinotus blochii* (Lacepède, 1801)	Snubnose pompano	Kata tikka	M, B, R	LC	1,5	Uncommon
385		*Trachurus indicus* Nekrasov, 1966	Arabian scad		M, R	VU	24	
386		*Ulua mentalis* (Cuvier, 1833)	Longrakered Trevally	Chanda	M, R, S	LC	20	
387		*Uraspis uraspis* (Günther, 1860)	Whitemouth jack	Chanda	M	LC	27	Common
388	Menidae	*Mene maculata* (Bloch & Schneider, 1801)	Moonfish	Chan chanda	M, B, R, S	NE	1,5,6,20,24,27	Common

389	Sphyraenidae	*Sphyraena barracuda* (Edwards, 1771)	Great barracuda	Dharkuta	M, B, R, S	LC	1,5,24	
390		*Sphyraena chrysotaenia* Klunzinger, 1884	Yellowstripe Barracuda	Holde dora dharkuta	M, S	NE	20	
391		*Sphyraena forsteri* Cuvier, 1829	Bigeye barracuda	Dharkuta	M, R, S	NE	1,5,6,20,24	-
392		*Sphyraena jello* Cuvier, 1829	Pickhandle barracuda	Dharkuta	M, B, R, S	NE	1,5,20,24	Uncommon
393		*Sphyraena obtusata* Cuvier, 1829	Obtuse barracuda	Dharkuta	M, B, R	NE	1,5,6,24,27,	Common
394		*Sphyraena putnamae* Jordan & Seale, 1905	Sawtooth barracuda	Korat dati dharkuta	M, R	LC	24,27	
395		*Sphyraena qenie* Klunzinger, 1870	Blackfin barracuda	Dharkuta	M, R	NE	6	
396	Xiphiidae	*Xiphias gladius* Linnaeus, 1758	Swordfish	Talwar machh	M	LC	5	Rare
397	Istiophoridae	*Istiompax indica* (Cuvier, 1832)	Black marlin	Kalo talwar	M	DD	1,5	
398		*Istiophorus platypterus* (Shaw, 1792)	Indo-Pacific sailfish	Pal machh	M	LC	1,5	
399	Callionymidae	*Callionymus carebares* Alcock, 1890	Indian deepwater dragonet	Dragonet machh	M	NE	39	
400		*Callionymus erythraeus* Ninni, 1934	Smallhead dragonet	Dragonet machh	M	NE	36	
401		*Callionymus margaretae* Regan, 1905	Margaret's dragonet	Dragonet machh	M	NE	24	
402		*Callionymus profundus* Fricke & Golani, 2013	Dragonet	Dragonet machh	M	NE	39	
403		*Callionymus sagitta* Pallas, 1770	Arrow dragonet	Dragonet machh	M, B	LC	36	
404		*Diplogrammus goramensis* (Bleeker, 1858)	Goram dragonet	Dragonet machh	M, R	NE	1,5,24	Rare
405	Gempylidae	*Neoepinnula orientalis* (Gilchrist & von Bonde, 1924)	Sackfish	Thole machh	M	NE	1,5,24,27	Common
406	Trichiuridae	*Eupleurogrammus muticus* (Gray, 1831)	Smallhead hairtail	Churi	M, B, S	NE	1,5,20,24,27	Commercial
407		*Lepturacanthus savala* (Cuvier, 1829)	Savalai hairtail	Churi	M, B, S	NE	1,5,6,20,24,27	Commercial
408		*Trichiurus gangeticus* Gupta, 1966	Ganges hairtail	Churi	M, B	NE	24	Commercial
409		*Trichiurus lepturus* Linnaeus, 1758	Largehead hairtail	Churi machh	M, B, S	LC	1,5,6,24,27	Commercial
410	Scombridae	*Auxis rochei* (Risso, 1810)	Bullet tuna	Tuna machh	M, B, S	LC	5,24	
411		*Auxis thazard* (Lacepède, 1800)	Frigate tuna	Tuna machh	M	NE	1,5	Uncommon
412		Euthynnus affinis (Cantor, 1849)	Kawakawa	Kawa	M, S	LC	1,5,20,27	Commercial
413		*Katsuwonus pelamis* (Linnaeus, 1758)	Skipjack tuna	Tuna machh	M	LC	1,5	
414		*Rastrelliger brachysoma* (Bleeker, 1851)	Indian mackerel	Kauwa, Maitta	M, B, S	DD	24,2	
415		*Rastrelliger faughni* Matsui, 1967	Island Mackerel	Kauwa, Maitta	M, S	DD	20	
416		*Rastrelliger kanagurta* (Cuvier, 1816)	Indian mackerel	Kauwa, Maitta	M, S	DD	1,5,6,20,24,27	Commercial
417		*Sarda orientalis* (Temminck & Schlegel, 1844)	Striped bonito	Tuna	M, S	LC	5,24,2	

418		*Scomber australasicus* Cuvier, 1832	Blue mackerel	Maitta	M	LC	26	
419		*Scomberomorus commerson* (Lacepède, 1800)	Narrow-barred Spanish mackerel	Champa	M, S	NT	1,5,20,24,27	
420		*Scomberomorus guttatus* (Bloch & Schneider, 1801)	Indo-Pacific king mackerel	Maitta	M, B, S	DD	1,5,6,20,24,27	
421		*Scomberomorus koreanus* (Kishinouye, 1915)	Korean seerfish	Maitta	M	LC	24	
422		*Scomberomorus lineolatus* (Cuvier, 1829)	Seer fish	Maitta	M, S	LC	24,2	
423		*Thunnus albacares* (Bonnaterre, 1788)	Yellowfin tuna	Tuna machh	M, B	NT	1,5	
424		*Thunnus obesus* (Lowe, 1839)	Bigeye tuna	Tuna machh	M	VU	1,5	
425		*Thunnus tonggol* (Bleeker, 1851)	Longtail tuna	Tuna	M	DD	24,27,	
427	Nomeidae	*Cubiceps whiteleggii* (Waite, 1894)	Shadow driftfish		M	NE	1,5,27,	Uncommon
427	Ariommatidae	*Ariomma indicum* (Day, 1871)	Indian driftfish	Makhon chanda	M	NE	1,5,24,27	
428	Stromateidae	*Pampus argenteus* (Euphrasen, 1788)	Silver pomfret	Fali chanda	M, S	NE	1,5,6,20,24,27	
429		*Pampus chinensis* (Euphrasen, 1788)	Chinese silver pomfret	Rup chanda	M, B, S	NE	1,5,6,20,24,27	
430	Champsodontidae	*Champsodon capensis* Regan, 1908	Gaper	Kumirdati machh	M	LC	1,5,24,27	Rare
431	Pinguipedidae	*Parapercis alboguttata* (Günther, 1872)	Whitespot sandsmelt	Bailla machh	M	LC	24,27	
432		*Parapercis clathrata* Ogilby, 1910	Latticed sandperch	Bailla machh	M, R,	NE	13	
433		*Parapercis diplospilus* Gomon, 1981	Doublespot grubfish	Bailla machh	M	NE	13	
434	Trichonotidae	*Trichonotus setiger* Bloch & Schneider, 1801	Spotted sand-diver		M, B,	LC	16	
435	Percophidae	*Bembrops caudimacula* Steindachner, 1876	Green humphead parrotfish	Chepta bailla	M	NE	1,5,24	Rare
436	Uranoscopidae	*Astroscopus guttatus* Abbott, 1860	Stargazer	Sagor bailla	M, S	LC	2	
437		*Ichthyscopus lebeck* (Bloch & Schneider, 1801)	Longnosed stargazer	Sagor bailla	M, S	NE	1,5,27	Rare
438		*Uranoscopus cognatus* Cantor, 1849	Two Spined Yellowtail Stargazer	Tara gajar	M, S	NE	20,27	
439		*Uranoscopus dollfusi* Brüss, 1987	Dollfus' stargazer	Sagor bailla	M	LC	24	
440		*Uranoscopus fuscomaculatus* Kner, 1868	Stargazer	Sagor bailla	M	NE	1,5,24,27	Rare
441		*Uranoscopus guttatus* Cuvier, 1829	Dollfus' Stargrazer	Tara gajar	M, S	NE	5,24	
442		*Uranoscopus marmoratus* Cuvier, 1829	Stargazer	Tara gajar	M	NE	24	
443	Labridae	*Bodianus neilli* (Day, 1867)	BoB hogfish		M, R	LC	13	
444		*Cheilinus chlorourus* (Bloch, 1791)	Floral wrasse	Kala sundori	M, R	LC	1,5	Uncommon
445		*Choerodon robustus* (Günther, 1862)	Robust tuskfish		M, R	NE	5	
446		*Coris aygula* Lacepède, 1801	Clown coris	Kala clown	M, R	LC	1,5	

447		*Coris gaimard* (Quoy & Gaimard, 1824)	African coris		M, R	LC	6	
449		*Halichoeres hortulanus* (Lacepède, 1801)	Checkerboard wrasse	Shundori machh	M, R	LC	Present study	
449		*Halichoeres marginatus* Rüppell, 1835	Dusky wrasse	Shundori machh	M, R	LC	1,5	
450		*Hemigymnus fasciatus* (Bloch, 1792)	Barred thicklip		M, R	LC	1,5	
451		*Labroides dimidiatus* (Valenciennes, 1839)	Bluestreak cleaner wrasse	Shundori machh	M	LC	6	
452		*Thalassoma lunare* (Linnaeus, 1758)	Moon wrasse	Nihola	M, R	NE	5,6,24	
453	Scaridae	*Bolbometopon muricatum* (Valenciennes, 1840)	Green humphead parrotfish	Sobuj kujomathatia machh	M, R	VU	6	
454		**Chlorurus japanensis* (Bloch, 1789)	Palecheek parrotfish		M, R	LC	1	
455		*Chlorurus rhakoura* Randall & Anderson, 1997	Raggedfin parrotfish	Kala tia machh	M, B, R	LC	33	
456		*Scarus ghobban* Forsskal, 1775	Blue-barred parrotfish	Nil tia machh	M, B, R	LC	33	
457		*Scarus psittacus* Forsskål, 1775	Common parrotfish	Tia Machh	M, R	LC	1,5	
458		*Scarus rivulatus* Valenciennes, 1840	Rivulated parrotfish	Tia machh	M, R	LC	1	Uncommon
459		*Scarus zufar* Randall & Hoover, 1995	Dhofar parrotfish	Tia machh	M	LC	13	
460	Latidae	*Lates calcarifer* (Bloch, 1790)	Asian Seabass	Koral macch	M, B, F, S	LC	1,6,20	Commercial
461	Gerreidae	*Gerres argyreus* (Forster, 1801)	Common silver-biddy		M	NE	6	
462		*Gerres erythrourus* (Bloch, 1791)	Deep-bodied mojarra		M, B, R	LC	24,13	
463		*Gerres filamentosus* Cuvier, 1829	Whipfin silver-biddy	Dom machh	M, B, F, S	LC	1,5,6,20,24,27	Common
464		*Gerres infasciatus* Iwatsuki & Kimura, 1998	Nonbanded whipfin mojarra	Dom machh	M	DD	24	
465		*Gerres oblongus* Cuvier, 1830	Slender silver-biddy		M, R	LC	1,5,24	Uncomon
466		*Pentaprion longimanus* (Cantor, 1849)	Longfin mojarra	Jagiri	M, B	LC	1,5,24,27	Common
467	Acropomatidae	*Acropoma japonicum* Günther, 1859	Glowbelly	Samudrik punti mach	M	NE	1,5,24,27	Common
468		*Synagrops japonicus* (Döderlein, 1883)	Blackmouth splitfin		M	LC	24	
469	Mullidae	*Mulloidichthys vanicolensis* (Valenciennes, 1831)	Yellowfin goatfish	Chhagol machh	M, R	LC	1,5,24	
470		*Parupeneus forsskali* (Fourmanoir & Guézé, 1976)	Red Sea goatfish	Chhagol machh	M, B, R, S	NE	1,5,20,24	
471		*Parupeneus heptacanthus* (Lacepède, 1802)	Goatfish	Chhagol machh	M, B, R, S	LC	2	
472		*Upeneus japonicus* (Houttuyn, 1782)	Japanese goatfish	Chhagol machh	M, R	NE	24,27	Common
473		*Upeneus moluccensis* (Bleeker, 1855)	Goldband goatfish	Sonalidagi chagol mach	M, B, R, S	LC	1,20,24	
474		*Upeneus sulphureus* Cuvier, 1829	Sulphur goatfish	Sonali bata	M, B, S	LC	1,5,6,20,24,27	Commercial
475		*Upeneus sundaicus* (Bleeker, 1855)	Ochrebanded goatfish	Sonali bata	M, B	LC	1,5	

476		*Upeneus supravittatus* Uiblein & Heemstra, 2010	Long-fin goatfish	Chhagol mach	M, R	LC	24,27,13	
477		*Upeneus taeniopterus* Cuvier, 1829	Finstripe goatfish	Chhagol mach	M, R, S	LC	20	
478		*Upeneus tragula* Richardson, 1846	Freckled goatfish	Sonali bata	M, B, R	LC	1,5,24,27	Rare
479		*Upeneus vittatus* (Forsskål, 1775)	Yellowstriped goatfish	Holdedagi chagol mach	M, B, R,	LC	22	
480	Pempheridae	*Pempheris molucca* Cuvier, 1829	Moluccan-sweeper	Lal phaisa	M, B, R,	NE	1,5	Uncomon
481	Bathyclupeidae	**Neobathyclupea malayana* (Weber 1913)	Deepsea herring		M	NE	1	-
482	Kyphosidae	*Kyphosus cinerascens* (Forsskål, 1775)	Blue sea chub	Kalafuni, Bida machh	M, R	LC	1,5,6	Uncommon
483		*Kyphosus vaigiensis* (Quoy & Gaimard, 1825)	Brassy chub	Bida machh	M	LC	6	
484	Terapontidae	*Pelates quadrilineatus* (Bloch, 1790)	Fourlined terapon	Barguni	M, B, R	NE	1,5,24	Uncommon
485		*Terapon jarbua* (Forsskål, 1775)	Jarbua terapon	Barguni	M, B, F, S	LC	1,5,6,20,24,27	Common
486		*Terapon theraps* Cuvier, 1829	Largescaled terapon	Barguni	M, B, F, R, S	LC	1,5,6,20,24,27	-
487	Serranidae	*Cephalopholis boenak* (Bloch, 1790)	Chocolate hind	Chitra bole	M, R	LC	1,5,6,24,27	Uncommon
488		*Cephalopholis formosa* (Shaw, 1812)	Bluelined hind	Neel Dagi Bole	M, R	LC	5,27	
489		*Cephalopholis miniata* (Forsskål, 1775)	Vermillion Grouper	Bole Machh	M, R, S	LC	2	
490		*Cephalopholis sonnerati* (Valenciennes, 1828)	Tomato hind	Chatki	M, R	LC	1,5	Uncommon
491		*Chelidoperca margaritifera* Weber, 1913	Pearly perchlet		M	NE	1	Rare
492		*Cromileptes altivelis* (Valenciennes, 1828)	Humpback grouper	Kalophotshada bole	M, R	DD	1,5	Rare
493		*Epinephelus bleekeri* (Vaillant, 1878)	Duskytail grouper	Bole macch	M	NT	24,27,13	
494		*Epinephelus chlorostigma* (Valenciennes, 1828)	Brownspotted grouper	Badami bole	M, R	LC	24	
495		*Epinephelus coioides* (Hamilton, 1822)	Orangespotted Grouper	Futki bole	M, B, R, S	LC	20,24,27	
496		*Epinephelus erythrurus* (Valenciennes, 1828)	Cloudy Grouper, Cloudy Rock Cod	Chitra bole	M, B, R, S	LC	20,27	
497		*Epinephelus fasciatus* (Forsskål, 1775)	Blacktip Grouper	Lal bole	M, B, R, S	LC	2	
498		*Epinephelus hexagonatus* (Forster, 1801)	Starspotted grouper	Chitra bole	M, R	LC	6	
499		*Epinephelus lanceolatus* (Bloch, 1790)	Giant grouper	Bol koral	M, B, R, S	DD	1,5,6,20,24	Common
500		*Epinephelus latifasciatus* (Temminck & Schlegel, 1842)	Striped grouper	Dagi bole	M	LC	1,5,24,27	Rare
501		*Epinephelus malabaricus* (Bloch & Schneider, 1801)	Malabar grouper	Bole coral	M, B, R	LC	1,5,24,27	Common
502		*Epinephelus merra* Bloch, 1793	Honeycomb grouper	Guti bole	M, R	LC	1,5	-
503		*Epinephelus morrhua* (Valenciennes, 1833)	Comet grouper	Bole coral	M, R	LC	1,5,24	Rare
504		*Epinephelus polyphekadion* (Bleeker, 1849)	Camouflage grouper	Kalo bole	M, R	VU	6	

505		*Epinephelus quoyanus* (Valenciennes, 1830)	Longfin grouper	Chitra bole	M, R	LC	6	
506		*Epinephelus radiatus* (Day, 1868)	Oblique-banded grouper	Bol Machh	M, R	LC	27	
507		*Epinephelus tauvina* (Forsskål, 1775)	Grouper	Bole	M, R, S	DD	24,2	
508		*Grammistes sexlineatus* (Thunberg, 1792)	Goldenstriped soapfish	Choydagi Perch	M, R	LC	1,5,24	Uncommon
509		*Plectropomus leopardus* (Lacepède, 1802)	Leopard coralgrouper	Chitra bole	M	LC	6	
510		*Plectropomus pessuliferus* (Fowler, 1904)	Roving coralgrouper	Lal koral bole	M	LC	37	
511	Lactariidae	*Lactarius lactarius* (Bloch & Schneider, 1801)	False trevally	Sokedi	M, B, S	NE	1,5,6,24,27	Common
512	Monodactylidae	*Monodactylus argenteus* (Linnaeus, 1758)	Silver moony	Akali chanda	M, B, F	LC	1,5,6	Uncommon
513	Leiognathidae	*Aurigequula fasciata* (Lacepède, 1803)	Striped ponyfish	Dagi chanda	M, B, S	LC	1,5,6,24	Uncommon
514		*Equulites elongatus* (Günther, 1874)	Elongate ponyfish	Tak chanda	M	NE	24	
515		*Equulites lineolatus* (Valenciennes, 1835)	Ornate ponyfish	Tak chanda	M	NE	1,5	Uncommon
516		*Eubleekeria splendens* (Cuvier, 1829)	Splendid ponyfish	Katali chanda	M, B	LC	1,5,24	Uncommon
517		*Gazza minuta* (Bloch, 1795)	Toothpony	Deto chanda	M, B, S	LC	1,5,6,20,24,27	Common
518		*Leiognathus brevirostris* (Valenciennes, 1835)	Shortnose ponyfish	Tak chanda	M, B, S	NE	1,20	Uncommon
519		*Leiognathus equula* (Forsskål, 1775)	Common ponyfish	Tak chanda	M, B, F, S	LC	20	Common
520		*Nuchequula gerreoides* (Bleeker, 1851)	Decorated ponyfish	Chanda	M	NE	5	
521		*Photopectoralis bindus* (Valenciennes, 1835)	Orangefin ponyfish	komola chanda	M, B, S	NE	1,6,20,24,27	Common
522		*Secutor insidiator* (Bloch, 1787)	Pugnose ponyfish	Thutuni chanda	M, B, S	NE	1,20,24,27	Uncommon
523		*Secutor ruconius* (Hamilton, 1822)	Deep pugnose ponyfish	Thutuni chanda	M, B, F, S	NE	1,24,27	Common
524	Chaetodontidae	*Chaetodon collare* Bloch, 1787	Redtail butterflyfish	Lal Lezza projapati Machh	M, R	LC	1,5,6	
525		*Chaetodon decussatus* Cuvier, 1829	Indian vagabond butterflyfish	Projapati machh	M, R	LC	6	
527		*Chaetodon melannotus* Bloch & Schneider, 1801	Blackback butterflyfish	Projapati machh	M, R	LC	1,5,6	
527		*Chaetodon octofasciatus* Bloch, 1787	Indian vagabond butterflyfish	Projapati machh	M, R	LC	6	
528		*Chaetodon vagabundus* Linnaeus, 1758	Vagabond butterflyfish	Halud projapati machh	M, R	LC	1,5,6	
529		*Heniochus acuminatus* (Linnaeus, 1758)	Pennant coralfish	Dorakata projapati machh	M, B, R	LC	1,5,6	Uncommon
530		*Heniochus singularius* Smith & Radcliffe, 1911	Singular Bannerfish	Projapati machh	M, R	LC	6	
531		*Parachaetodon ocellatus* (Cuvier, 1831)	Sixspine butterflyfish	Dorakata projapati machh	M, R	LC	1,5,24	
532		*Roa jayakari* (Norman, 1939)	Indian golden-barred butterflyfish	Projapati machh	M	LC	27	

533	Pomacanthidae	*Pomacanthus annularis* (Bloch, 1787)	Bluering angelfish	Dudhkomol	M, R	LC	1,5,6,24,27	Common
534		*Pomacanthus imperator* (Bloch, 1787)	Emperor angelfish	Raja dudhkomol	M, R	LC	1,5	
535		*Pomacanthus semicirculatus* (Cuvier, 1831)	Semicircle angelfish	Dudhkomol	M, R	LC	1,5,24	Uncommon
536		*Pomacanthus sexstriatus* (Cuvier, 1831)	Sixbar angelfish	Chhoi dagi dudhkomol	M, R	LC	Present study	
537	Pomacentridae	*Abudefduf bengalensis* (Bloch, 1787)	Bengal sergeant	Pathari	M, B, R,	LC	1,5,6	Rare
538		*Abudefduf septemfasciatus* (Cuvier, 1830)	Banded sergeant	Pathari	M, R	LC	1,5	Uncommon
539		*Abudefduf sexfasciatus* (Lacepède, 1801)	Scissortail sergeant	Pathari	M, R	NE	5,6	
540		*Abudefduf sordidus* (Forsskål, 1775)	Blackspot sergeant	Pathari	M, B, R	LC	6	
541		*Abudefduf vaigiensis* (Quoy & Gaimard, 1825)	Indo-Pacific sergeant	Pathari	M, R	LC	1	
542		*Amphiprion ephippium* (Bloch, 1790)	Saddle anemonefish	Mudhah	M, R	LC	1,5	
543		*Amphiprion percula* (Lacepède, 1802)	Orange clownfish	Parri Mach	M, R	NE	1,5	
544		*Cheiloprion labiatus* (Day, 1877)	Big-lip damsel	Mudhah	M, R	NE	1,5	
545		*Chromis cinerascens* (Cuvier, 1830)	Green puller	Pettoli	M, R	LC	Present Study	
546		*Chromis ternatensis* (Bleeker, 1856)	Ternate chromis	Pettoli	M, R	NE	1	
547		*Chromis viridis* (Cuvier, 1830)	Blue green damselfish	Neelima	M, R	NE	5	
548		*Chrysiptera brownriggii* (Bennett, 1828)	Surge damselfish	Pettoli	M, R	NE	6	
549		*Chrysiptera unimaculata* (Cuvier, 1830)	Onespot demoiselle	Pettoli	M	LC	6	
550		*Dascyllus marginatus* (Rüppell, 1829)	Marginate dascyllus	Pandua	M, R	NE	1,5	Uncommon
551		*Dischistodus perspicillatus* (Cuvier, 1830)	White damsel	Aphoo	M, B, R	NE	1,5	Rare
552		*Dischistodus prosopotaenia* (Bleeker, 1852)	Honey-head damsel	Pettoli	M, B, R	NE	1	
553		*Neopomacentrus azysron* (Bleeker, 1877)	Yellowtail demoiselle	Pettoli	M, R	NE	6	
554		*Neopomacentrus cyanomos* (Bleeker, 1856)	Regal demoiselle	Pettoli	M, R	VU	6	
555		*Neopomacentrus taeniurus* (Bleeker, 1856)	Freshwater demoiselle	Pettoli	M, B, F	DD	1	
556		*Pomacentrus adelus* Allen, 1991	Obscure damsel	Pettoli	M, R	NE	35	
557		*Pomacentrus bangladeshius* Habib, Islam, Nahar & Neogi, 2020	Bengal demoiselle	Pettoli	M	NE	34	
558		*Pomacentrus caeruleus* Quoy & Gaimard, 1825	Caerulean damsel	Pettoli	M, R	NE	6	
559		*Pomacentrus coelestis* Jordan & Starks, 1901	Neon damselfish	Pettoli	M, R	NE	6	
560		*Pomacentrus proteus* Allen, 1991	Colombo damsel	Pettoli	M, R	NE	35	
561		*Pomacentrus similis* Allen, 1991	Similar damsel	Pettoli	M, R	NE	35	

562		*Pomacentrus tripunctatus* Cuvier, 1830	Threespot damsel	Aphoo	M, B, R	NE	1,5	
563		Pomacentrus vaiuli Jordan & Seale, 1906	Ocellate damselfish	Pettoli	M, R	NE	6	
564		*Premnas biaculeatus* (Bloch, 1790)	Spinecheek anemonefish	Lal clown mach	M, R	NE	1,5	Uncomon
565		*Pristotis obtusirostris* (Günther, 1862)	Gulf damselfish	Pettoli	M, R	NE	1,5	
566		*Stegastes fasciolatus* (Ogilby, 1889)	Pacific gregory	Pettoli	M, R	NE	6	
567		*Stegastes lividus* (Forster, 1801)		Pettoli	M, R	NE	5	
568		*Stegastes obreptus* (Whitley, 1948)	Western gregory	Pettoli	M, R	NE	35	
569	Priacanthidae	*Heteropriacanthus cruentatus* (Lacepède, 1801)	Glasseye		M, R	LC	24	
570		*Priacanthus hamrur* (Forsskål, 1775)	Moontail bullseye	Ranga pori	M, R, S	LC	1,5,20,24,27	Uncommon
571		*Priacanthus sagittarius* Starnes, 1988	Arrow bulleye	Ranga pori	M	LC	24	Common
572		*Priacanthus tayenus* Richardson, 1846	Purple-spotted bigeye	Ranga pori	M, R, S	LC	1,5,6,24,27	
573	Haemulidae	*Diagramma pictum* (Thunberg, 1792)	Painted sweetlips	Rongin thuta	M, R	NE	1,5,27	
574		*Plectorhinchus cinctus* (Temminck & Schlegel, 1843)	Crescent sweetlips	Datina	M, R	NE	1,5	
575		*Plectorhinchus vittatus* (Linnaeus, 1758)	Indian Ocean oriental sweetlips	Datina	M, R	LC	1,5	
576		*Pomadasys argenteus* (Forsskål, 1775)	Silver grunt	Rupali datina	M, B, F, S	LC	1,5,6,20,24	
577		*Pomadasys argyreus* (Valenciennes, 1833)	Bluecheek silver grunt	Nilgalirupali datina	M	LC	1	Uncommon
578		*Pomadasys furcatus* (Bloch & Schneider, 1801)	Banded grunter	Dorakata datina	M, R	LC	13	
579		*Pomadasys kaakan* (Cuvier, 1830)	Javelin grunter	Nak coral	M, B, R,	NE	27,13	
580		*Pomadasys maculatus* (Bloch, 1793)	Saddle grunt	Guti datina	M, B, R, S	LC	1,5,6,20,24,27	Commercial
581		*Pomadasys multimaculatus* (Playfair, 1867)	Cock grunter	Ranga chhoi	M, B	LC	24	
582	Lutjanidae	*Lutjanus argentimaculatus* (Forsskål, 1775)	Mangrove red snapper	Ranga chhoi, Ranga choukhha	M, B, F, R	LC	1,5,24,27	Commercial
583		*Lutjanus bohar* (Forsskål, 1775)	Two-spot red snapper	Lal Ranga chhoi	M, B, F, R	LC	1,5,24	
584		*Lutjanus ehrenbergii* (Peters, 1869)	Blackspot snapper	Ranga chhoi	M, B, F, R	LC	1	
585		*Lutjanus erythropterus* Bloch, 1790	Crimson snapper	Choukhha, chhoi	M, R	LC	24,27,41	
586		*Lutjanus fulviflamma* (Forsskål, 1775)	Dory snapper	Dori chhoi, rashori	M, B, R	LC	6	
587		*Lutjanus fulvus* (Forster, 1801)	Blacktail snapper	Kalo lenja choukhha	M, B, F, R	LC	41	
588		*Lutjanus gibbus* (Forsskål, 1775)	Humpback red snapper	Kujo ranga choukhha	M, R	LC	1,5	
589		*Lutjanus indicus* Allen, White & Erdmann, 2013	Indian Snapper	Ranga choukhha	M, B, F, R	LC	22	
590		*Lutjanus johnii* (Bloch, 1792)	John's snapper	Ranga chhoi	M, B, R, S	LC	1,5,6,20,24,27	Commercial

591		*Lutjanus lemniscatus* (Valenciennes, 1828)	Yellowstreaked snapper	Lal koral	M, R	LC	1,5,27	
592		*Lutjanus lunulatus* (Park, 1797)	Lunartail snapper	Ranga chhoi	M, R	LC	1,24,27	Uncommon
593		*Lutjanus lutjanus* Bloch, 1790	Bigeye snapper	Kholaddia machh	M, R	LC	1,5,24,27	
594		*Lutjanus malabaricus* (Bloch & Schneider, 1801)	Malabar blood snapper	Mota thot koral	M, B, R, S	LC	1,6,24	Uncommon
595		*Lutjanus rivulatus* (Cuvier, 1828)	Blubberlip snapper	Ranga chhoi, Mota thotta chhoi	M, R	LC	1,5,27	Commercial
596		*Lutjanus sanguineus* (Cuvier, 1828)	Humphead snapper	Ranga chhoi	M, R, S	LC	1,5,6	Common
597		*Lutjanus sebae* (Cuvier, 1816)	Emperor red snapper	Ranga chhoi	M, B, R	LC	1,5	-
598		*Lutjanus vitta* (Quoy & Gaimard, 1824)	Brownstripe red snapper	Badamidagi ranga chhoi	M, B, R	LC	6	
599		*Lutjanus xanthopinnis* Iwatsuki, Tanaka & Allen, 2015	Yellowfin snapper	Kholaddia machh	M, R	DD	27,22	
600		*Pinjalo pinjalo* (Bleeker, 1850)	Pinjalo snapper	Pinjalo chhhoi	M, R, S	LC	24,27,2	
601		*Pristipomoides filamentosus* (Valenciennes, 1830)	Crimson jobfish	Lal machh	M	LC	24,27	
602		*Pristipomoides multidens* (Day, 1871)	Goldbanded jobfish	Lal machh	M	LC	27	
603	Caesionidae	*Caesio caerulaurea* Lacepède, 1801	Blue and gold fusilier	Nil sonali fusilar	M	LC	27	
604		*Caesio cuning* (Bloch, 1791)	Redbelly yellowtail fusilier	Lalpethh holdeleje fusilar	M, R	LC	13	
605		*Caesio xanthonota* Bleeker, 1853	Yellowback fusilier	Holdepithhe fusilar	M, R	LC	6	
606	Cirrhitidae	*Cirrhitichthys bleekeri* Day, 1874	Hawkfish		M, R	NE	5	
607	Cepolidae	*Acanthocepola indica* (Day, 1888)	Deep Sea Snake Fish		M	NE	24,27,14	
608	Scatophagidae	*Scatophagus argus* (Linnaeus, 1766)	Spotted scat	Bishtara	M, B, F, R, S	LC	1,6,20,24,27	Common
609	Siganidae	*Siganus canaliculatus* (Park, 1797)	White-spotted spinefoot	Shada phot bishkatali	M, B, R, S	LC	1,5,20,24,27	
610		*Siganus javus* (Linnaeus, 1766)	Streaked spinefoot	Bishkatali, Bishthi	M, B, R, S	LC	1,5,24,27	
611		*Siganus stellatus* (Forsskål, 1775)	Brown-spotted spinefoot	Khoyeriphotbishkatali	M, R	LC	6	
612		*Siganus vermiculatus* (Valenciennes, 1835)	Vermiculated spinefoot	Pann machh	M, B, R,	LC	1,5	
613	Drepaneidae	*Drepane longimana* (Bloch & Schneider, 1801)	Banded Drepane	Paan machh	M, B, R, S	NE	20,24,27	Comoon
614		*Drepane punctata* (Linnaeus, 1758)	Spotted sicklefish	Paan machh	M, B, F, R, S	LC	1,5,6,24,27	Common
615	Ephippidae	*Ephippus orbis* (Bloch, 1787)	Orbfish	Badur Machh	M, R, S	NE	1,5,6,20,24,27	Common
616		*Platax orbicularis* (Forsskål, 1775)	Orbicular batfish	Taayramachh	M, B, R	LC	1,5,27	-
617		*Platax teira* (Forsskål, 1775)	Longfin batfish	Kula machh	M, R	LC	1,5,6,27	Uncommon
618		*Tripterodon orbis* Playfair, 1867	African spadefish	Poa	M, R	NE	24	

619	Sciaenidae	*Argyrosomus amoyensis* (Bleeker, 1863)	Amoy croaker	Poa	M	EN	1,5	
620		*Argyrosomus japonicus* (Temminck & Schlegel, 1843)	Japanese meagre	Poa	M, B	EN	24	
621		*Argyrosomus thorpei* Smith, 1977	Japanese meagre	Poa	M	EN	21	
622		*Atrobucca nibe* (Jordan & Thompson, 1911)	Blackmouth croaker	Kalomukhi poa	M, S	LC	2	
623		*Chrysochir aureus* (Richardson, 1846)	Croaker	Dhari poa	M, B, S	LC	27,2	
624		*Dendrophysa russelii* (Cuvier, 1829)	Goatee croaker	Poa	M, B, F, S	LC	1,5,20	Common
625		*Johnius amblycephalus* (Bleeker, 1855)	Bearded croaker	Rupali poa	M, B, F	LC	6,27	
627		*Johnius belangerii* (Cuvier, 1830)	Belanger's croaker	Mete ranger poa	M, B	NE	5,6,24,27,	Common
627		*Johnius borneensis* (Bleeker, 1851)	Sharpnose hammer croaker	Poa	M, B, F, S	LC	1,5,20,24,27	Commercial
628		*Johnius carutta* Bloch, 1793	Karut croaker	Poa	M, B, F	LC	1,5,24	Uncommon
629		*Johnius coitor* (Hamilton, 1822)	Coitor, Crocker	Kala poa	M, B, F, S	LC	20	
630		*Johnius dussumieri* (Cuvier, 1830)	Sin croaker	Bansh poa	M, B, S	LC	1,5,24,27	Common
631		*Johnius elongatus* Lal Mohan, 1976	Spindle croaker	Poa	M	DD	24	
632		*Johnius macropterus* (Bleeker, 1853)	Largefin croaker	kala poa	M, S	LC	1,5,20,24	Uncommon
633		*Johnius plagiostoma* (Bleeker, 1849)	Large-eye Croaker	Poa machh	M, B, F, S	LC	20	
634		*Kathala axillaris* (Cuvier, 1830)	Kathala croaker	Poa	M, S	LC	1,5,20	Common
635		*Macrospinosa cuja* (Hamilton, 1822)	Cuja Croaker	Poa	M, B, F, S	DD	20	
636		*Nibea maculata* (Bloch & Schneider, 1801)	Blotched croaker	Poa	M	LC	24	
637		*Otolithes cuvieri* Trewavas, 1974	Lesser tiger toothed croaker	Poa	M, S	LC	24,2	
638		*Otolithes ruber* (Bloch & Schneider, 1801)	Tigertooth croaker	Lambu	M, B, S	LC	1,5,20,24,27	Common
639		*Otolithoides biauritus* (Cantor, 1849)	Bronze croaker	Lombu poa	M, S	DD	1,5,20,24,27	Uncommon
640		*Otolithoides pama* (Hamilton, 1822)	Pama croaker	Leijja poa	M, B, F, S	DD	1, 2, 6,20,24,27	Commercial
641		*Panna heterolepis* Trewavas, 1977	Hooghly croaker	Chotta lambu	M,	LC	27	Commercial
642		*Panna microdon* (Bleeker, 1849)	Panna croaker	Lal poa	M, B, S	LC	1,5,6,20,24	Commercial
643		*Paranibea semiluctuosa* (Cuvier, 1830)	Half-mourning croaker	Sada poa	M	LC	1,27	Rare
644		*Pennahia anea* (Bloch, 1793)	Bigeye croaker	Borochokha poa	M, S	LC	1,5,20,24	Common
645		*Pennahia argentata* (Houttuyn, 1782)	Silver croaker	Ruplai poa	M, S	LC	6,24	Commercial
646		*Pennahia ovata* Sasaki, 1996	Big Head Pennah Croaker	kala Poa	M	DD	27	
647		*Protonibea diacanthus* (Lacepède, 1802)	Blackspotted croaker	Kalo poa	M, B, S	NT	1,5,6,20,24,27	Commercial

648		*Pseudotolithus elongatus* (Bowdich, 1825)	Spindle Croaker	Poa	M, B, F, S	LC	2	
649		**Pterotolithus lateoides* (Bleeker, 1849)	Bigmouth croaker		M, B	DD	1	
650		*Pterotolithus maculatus* (Cuvier, 1830)	Blotched tiger-toothed croaker	Guti Poa	M, B, S	LC	1,5,6,20,24,27	Common
651	Acanthuridae	*Acanthurus lineatus* (Linnaeus, 1758)	Lined surgeonfish	Sundori machh	M	LC	6	
652		*Acanthurus mata* (Cuvier, 1829)	Elongate surgeonfish	Sundori machh	M	LC	27	
653		*Acanthurus xanthopterus* Valenciennes, 1835	Yellowfin surgeonfish	Sundori machh	M, R	LC	6,24,27	
654	Sillaginidae	*Sillaginopsis panijus* (Hamilton, 1822)	Flathead sillago	Tulardandi	M, B, F, S	NE	1,6,20,24,27	Commercial
655		*Sillago maculata* Quoy & Gaimard, 1824	Trumpeter sillago	Sundra	M, B	NE	1,5	Rare
656		*Sillago sihama* (Forsskål, 1775)	Silver sillago	Sundori bailla	M, B, R, S	LC	1,5,6,20,24,27	Common
657	Lobotidae	*Lobotes surinamensis* (Bloch, 1790)	Tripletail	Brown tripletail	M, B, S	LC	1,6,24,27	Commercial
658	Nemipteridae	*Nemipterus bipunctatus* (Valenciennes, 1830)	Delagoa threadfin bream	Golapi ruppan	M	LC	24	
659		*Nemipterus furcosus* (Valenciennes, 1830)	Fork-tailed threadfin bream	Sat Dagi ruppan	M, B, R,	LC	1,5	Uncommon
660		*Nemipterus gracilis* (Bleeker, 1873)	Graceful threadfin bream	Rupbam	M	NE	1,5	Rare
661		*Nemipterus japonicus* (Bloch, 1791)	Japanese threadfin bream	Rupbam	M, S	LC	1,5,6,20,24,27	Commercial
662		*Nemipterus nematophorus* (Bleeker, 1854)	Double whip threadin bream	Pakhna kata sonabam	M, S	LC	5,24,2	
663		*Nemipterus peronii* (Valenciennes, 1830)	Notchedfin threadfin bream	Sonabam	M, B	LC	1,5,24	
664		*Nemipterus randalli* Russell, 1986	Randall's threadfin bream	Lal machh	M	LC	24,27	
665		*Parascolopsis aspinosa* (Rao & Rao, 1981)	Smooth dwarf monocle bream	Sonaban machh	M	LC	24,27	
666		*Scolopsis bimaculata* Rüppell, 1828	Thumbprint monocle bream	Karua koral	M, R	LC	1,5	Rare
667		*Scolopsis vosmeri* (Bloch, 1792)	Whitecheek monocle bream	Karua koral	M, R	LC	6	
668	Lethrinidae	*Gymnocranius griseus* (Temminck & Schlegel, 1843)	Grey large-eye bream	Boro chokha koral	M, R	LC	1,5,24	Rare
669		*Lethrinus erythracanthus* Valenciennes, 1830	Orange-spotted emperor	Karua koral	M, R	LC	6	
670		*Lethrinus lentjan* (Lacepède, 1802)	Pink ear emperor	Karua koral	M, B, R	LC	1,5,24	
671		*Lethrinus nebulosus* (Forsskål, 1775)	Spangled emperor	Datina	M, B, R	LC	1,5,24,27	Common
672		*Lethrinus olivaceus* Valenciennes, 1830	Longface emperor	Datina	M, R	LC	6	
673		*Lethrinus ornatus* Valenciennes, 1830	Ornate emperor	Ota	M, R, S	LC	6,24,27,2	
674	Sparidae	*Acanthopagrus berda* (Forsskål, 1775)	Goldsilk seabream	Kalo datina	M, B, F, S	LC	1,20,27	Common
675		*Acanthopagrus latus* (Houttuyn, 1782)	Yellow seabrem	Lal datina	M, B, F, S	DD	2	Common

676		*Argyrops spinifer* (Forsskål, 1775)	King soldier bream	Datina	M, S	LC	1,5,6	Commercial
677		*Sparidentex datnia* (Hamilton, 1822)	Yellowfin seabream	Datina	M	DD	1,27	Common
678	Caproidae	*Antigonia rubescens* (Günther, 1860)	Indo-Pacific boarfish		M	NE	1,5	Common
679	Zanclidae	*Zanclus cornutus* (Linnaeus, 1758)	Moorish idol	Urukku machh	M, R	LC	Present study	
Order: Scorpaeniformes								
680	Dactylopteridae	*Dactyloptena orientalis* (Cuvier, 1829)	Oriental flying gurnard	Urukku machh	M, R	LC	1,5,24,27	Common
681	Scorpaenidae	*Ebosia falcata* Eschmeyer & Rama-Rao, 1978	Cocks comb fire fish	Rongila	M	LC	24	
682		*Pterois miles* (Bennett, 1828)	Miles lion fish	Mili rangila	M, R, S	LC	5,24,27,2	
683		*Pterois mombasae* (Smith, 1957)	Frillfin turkeyfish	Rongila	M, R	LC	24	
684		*Pterois russelii* Bennett, 1831	Plaintail turkeyfish	Rongila	M, B, R, S	LC	1,5,6,20,24,27	Common
685		*Pterois volitans* (Linnaeus, 1758)	Red lionfish	Rongila	M, R	LC	1,5,24	Uncommon
686		*Scorpaenodes guamensis* (Quoy & Gaimard, 1824)	Guam scorpionfish	Katabul	M, R	LC	1,5	Uncommon
687		*Scorpaenodes investigatoris* Eschmeyer & Rama-Rao, 1972	Scorpionfish	Katabul	M	LC	24	
688		*Scorpaenodes scaber* (Ramsay & Ogilby, 1886)	Pygmy scorpionfish	Bamon katabul	M, B, R	DD	5	
689	Triglidae	*Lepidotrigla bispinosa* Steindachner, 1898	Bullhorn gurnard	Singi Rongila	M	LC	24,27	Uncommon
690		*Lepidotrigla spiloptera* Günther, 1880	Spotwing gurnard	Dagipakhna rongila	M	LC	24	Uncommon
691		*Pterygotrigla arabica* (Boulenger, 1888)	Gurnard fish	Kumir machh	M	NE	24	
692	Peristediidae	*Satyrichthys laticeps* (Schlegel, 1852)	Flatheads	Baila	M	LC	1,5	Common
693	Bembridae	*Bembras japonica* Cuvier, 1829	Deepwater flathead	Baila	M	NE	1,5	Rare
694	Platycephalidae	*Cociella crocodilus* (Cuvier, 1829)	Spotted flathead	Baila	M, B, R, S	LC	24,2	
695		*Cociella punctata* (Cuvier, 1829)	Flat Head	Mur baila	M, R, S	LC	2	
696		*Grammoplites scaber* (Linnaeus, 1758)	Rough flathead	Mur baila	M, B, S	NE	1,5,6,20,24	
697		*Grammoplites suppositus* (Troschel, 1840)	Spotfin flathead	Mur baila	M	LC	24	
698		*Kumococius rodericensis* (Cuvier, 1829)	Spiny Flat Head	Mur bailla	M, S	LC	20	
699		*Onigocia pedimacula* (Regan, 1908)	Broadband flathead	Boro matha baila	M	LC	24	
700		*Platycephalus indicus* (Linnaeus, 1758)	Bartail flathead	Sagor Baila	M, B, R, S	DD	1,20,24,27	Common
701		*Rogadius asper* (Cuvier, 1829)	Olive-tailed flathead	Sagor baila	M, S	LC	1,5,24	
702		*Rogadius pristiger* (Cuvier, 1829)	Flat Head	Sagor baila	M, S	LC	2	Uncommon
703		*Sorsogona tuberculata* (Cuvier, 1829)	Tuberculated flathead	Sagor baila	M	LC	1,5,24	Uncommon

704		*Sunagocia carbunculus* (Valenciennes, 1833)	Papillose flathead	Sagor baila	M	LC	1,5	Rare
705	Apistidae	*Apistus carinatus* (Bloch & Schneider, 1801)	Ocellated waspfish		M	NE	24	
706	Tetrarogidae	*Tetraroge niger* (Cuvier, 1829)	Roguefish	Kata koral	M, B, F	LC	6	
707	Synanceiidae	*Minous monodactylus* (Bloch & Schneider, 1801)	Grey stingfish	Kata koral	M, S	LC	1,5,6,20,24,27	Uncommon
708		*Minous pictus* Günther, 1880	Painted stinger	Rongilakata koral	M, S	LC	1,5,20,24	
Order: Lophiiformes								
709	Lophiidae	*Lophiodes mutilus* (Alcock, 1894)	Smooth angler	Samudra cheka	M	LC	24,27	
710		*Lophiodes naresi* (Günther, 1880)	Goosefish	Samudra cheka	M	LC	1,5,24,27	
711	Antennariidae	*Antennarius hispidus* (Bloch & Schneider, 1801)	Shaggy angler	Byang machh	M, R, S	NE	1,5,20,24,27	
712	Ogcocephalidae	*Halieutaea indica* Annandale & Jenkins, 1910	Indian handfish	Lal Badur machh	M	LC	1,5,24	
713		*Halieutaea stellata* (Vahl, 1797)	Minipizza batfish	Somudra badur	M	LC	1,5,27	
Order: Tetraodontiformes								
714	Triacanthodidae	*Halimochirurgus alcocki* Weber, 1913	Alcock's Spikefish	Sukura	M	NE	1,5	
715	Triacanthidae	*Pseudotriacanthus strigilifer* (Cantor, 1849)	Long-spined tripodfish	Sukura	M, B, S	LC	1,5,24	
716		*Triacanthus biaculeatus* (Bloch, 1786)	Short-nosed tripodfish	Pan Biri sigaret, Tekathi	M, B, S	LC	1,5,20,24,27	
717		*Triacanthus nieuhofii* Bleeker, 1852	Silver tripodfish	Pan biri sigaret, Tekathi	M	NE	24	
718	Ostraciidae	*Lactoria cornuta* (Linnaeus, 1758)	Longhorn cowfish	Bakshaw machh	M, B, R	NE	7	
719		*Ostracion cubicus* Linnaeus, 1758	Yellow boxfish	Bakshaw machh	M, R, S	LC	1,5,20,24	
720		*Rhynchostracion nasus* (Bloch, 1785)	Shortnose boxfish	Bakshaw machh	M, R	NE	1,5,24	
721		*Tetrosomus gibbosus* (Linnaeus, 1758)	Humpback turretfish	Sagor potka	M, R	LC	1,5,24,27	
722	Balistidae	*Abalistes stellatus* (Anonymous 1798)	Starry Triggerfish	Shorol	M, S	NE	1,5	
723		*Pseudobalistes flavimarginatus* (Rüppell, 1829)	Yellowmargin triggerfish	Shorol	M, B, R	NE	17	
724		*Sufflamen fraenatum* (Latreille, 1804)	Masked triggerfish	Shorol	M, R	LC	1,5	
725	Monacanthidae	*Aluterus monoceros* (Linnaeus, 1758)	Unicorn leatherjacket filefish	Potka, File machh	M, R	LC	1,24	
727		*Aluterus scriptus* (Osbeck, 1765)	Scribbled leatherjacket filefish	Potka, File machh	M, R,	LC	1	
727	Tetraodontidae	*Arothron immaculatus* (Bloch & Schneider, 1801)	Immaculate puffer	Bagha potka	M, B, R,	LC	1,5,24,27	
728		*Arothron leopardus* (Day, 1878)	Banded leopardblowfish	Rekha potka	M	DD	1,5,24	
729		*Arothron reticularis* (Bloch & Schneider, 1801)	Reticulated pufferfish	Badami potka	M, B, R	LC	1,5	
730		*Arothron stellatus* (Anonymous, 1798)	Stellate puffer	Potka	M, B, R, S	LC	1,5,6	

731		*Chelonodontops bengalensis* Habib, Neogi, Oh, Lee & Kim 2018.	Bengal Reticulated Puffer	Boro jali potka	M, B, S	NE	19	
732		*Chelonodontops patoca* (Hamilton 1822)	Milkspotted puffer	Shadaphota potka	M, B, F, R, S	LC	1,6,20	
733		*Lagocephalus guentheri* Miranda Ribeiro, 1915	Diamond-back Puffer	Potka	M, S	LC	20,24,27	
734		*Lagocephalus lagocephalus* (Linnaeus, 1758)	Oceanic puffer	Sagor potka	M	LC	24	
735		*Lagocephalus lunaris* (Bloch & Schneider, 1801)	Lunartail puffer	Potka	M, B, S	LC	1,5,6,20,24,27	
736		*Lagocephalus sceleratus* (Gmelin, 1789)	Silver-cheeked toadfish	Potka, Rupali potka	M, R	LC	1,5	
737		*Lagocephalus spadiceus* (Richardson, 1845)	Half-smooth golden pufferfish	Dora potka, Sonali ava potka	M, B	LC	24,13	
738		*Takifugu oblongus* (Bloch, 1786)	Lattice Blaasop	Dora potka	M, B, S	LC	5,6,20,24,27	
739	Diodontidae	*Cyclichthys orbicularis* (Bloch, 1785)	Birdbeak burrfish	Sajaru Potka	M, R	NE	24,27	
740		*Diodon hystrix* Linnaeus, 1758	Spot-fin porcupinefish	Sjaru potka	M, R, S	LC	1,5,6,20,24,27	

*Questionable occurrence; **Global conservation status by IUCN is presented as Critically Endangered (CR), Endangered (EN), vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD) and Not Evaluated (NE) for the enlisted marine fish species of Bangladesh.

Annexure RU: 2

Descriptive statistics and estimated parameters of the length-weight relationships of few selected marine species of Bangladesh

Table 1. Descriptive statistics and estimated parameters of the length-weight relationships of *Euthynnus affinis* from the BoB, Bangladesh

Equations	Regression parameters		95% CL of *a*	95% CL of *b*	r^2	GT
	a	*b*				
$BW = a \times TL^b$	0.0053	3.23	0.0022 - 0.0130	2.98 - 3.49	0.954	A+
$BW = a \times FL^b$	0.0045	3.37	0.0016 - 0.0130	3.06 - 3.68	0.939	A+
$BW = a \times SL^b$	0.0030	3.57	0.0011 - 0.0079	3.28 - 3.87	0.950	A+
$BW = a \times HL^b$	0.2198	3.64	0.0883 - 0.5467	3.21 - 4.08	0.900	A+
$BW = a \times OprL^b$	1.5784	2.95	0.7019 - 3.5494	2.52 - 3.37	0.862	A-
$BW = a \times PrDL^b$	0.2749	3.39	0.1223 - 0.6180	3.01 - 3.76	0.915	A+
$BW = a \times PoDL^b$	0.0007	4.70	0.0002 - 0.0028	4.22 - 5.18	0.926	A+
$BW = a \times PcL^b$	3.1889	2.34	1.8864 - 5.3908	2.09 - 2.59	0.919	A-
$BW = a \times PvL^b$	0.0153	4.76	0.0053 - 0.0447	4.26 - 5.25	0.923	A+
$BW = a \times AnsL^b$	0.0024	4.11	0.0007 - 0.0082	3.69 - 4.52	0.927	A+
$BW = a \times PrAnL^b$	0.0026	4.06	0.0007 - 0.0091	3.64 - 4.48	0.923	A+
$BW = a \times PoAnL^b$	0.0005	4.49	0.0002 - 0.0013	4.16 - 4.82	0.960	A+

Table 2. Descriptive statistics and estimated parameters of the length-weight relationships of *Polynemus paradiseus* from the BoB, Bangladesh

Equations	Regression parameters		95% CL of *a*	95% CL of *b*	r^2	GT
	a	*b*				
$BW = a \times TL^b$	0.0034	3.19	0.0019 - 0.0060	2.99 - 3.38	0.957	A+
$BW = a \times FL^b$	0.0138	2.97	0.0068 - 0.0279	2.71 - 3.24	0.915	A-
$BW = a \times SL^b$	0.0453	2.65	0.0249 - 0.0825	2.41 - 2.88	0.915	A-
$BW = a \times HL^b$	5.0189	1.72	4.1969 - 6.0019	1.57 - 1.87	0.917	A-
$BW = a \times OprL^b$	4.2522	2.51	3.2723 - 5.5256	2.22 - 2.81	0.857	A-
$BW = a \times PrDL_1{}^b$	0.7584	2.70	0.4867 - 1.1818	2.40 - 3.00	0.869	A-
$BW = a \times PrDL_2{}^b$	0.3105	2.63	0.1892 - 0.5094	2.36 - 2.90	0.889	A-
$BW = a \times PoDL_1{}^b$	0.1949	2.68	0.1248 - 0.3043	2.45 - 2.90	0.922	A-
$BW = a \times PoDL_2{}^b$	0.1343	2.50	0.0807 - 0.2233	2.27 - 2.72	0.913	A-
$BW = a \times PcL^b$	1.0374	2.96	0.7060 - 1.5244	2.65 - 3.28	0.882	A-
$BW = a \times PvL^b$	2.9729	1.80	2.4366 - 3.6273	1.66 - 1.94	0.933	A-
$BW = a \times AnsL^b$	0.5203	2.34	0.3515 - 0.7703	2.12 - 2.55	0.910	A-
$BW = a \times PrAnL^b$	0.6612	2.01	0.4749 - 0.9207	1.85 - 2.17	0.927	A-
$BW = a \times PoAnL^b$	0.1076	2.60	0.0621 - 0.1863	2.36 - 2.85	0.906	A-

Table 3. Descriptive statistics and estimated parameters of the length-weight relationships of *Harpadon nehereus* from the BoB, Bangladesh

Equations	Regression parameters		95% CL of *a*	95% CL of *b*	r^2	GT
	a	*b*				
BW = $a \times TL^b$	0.0004	3.70	0.0001 - 0.0018	3.22 - 4.19	0.931	A+
BW = $a \times SL^b$	0.0042	3.13	0.0015 - 0.0124	2.77 - 3.50	0.945	A+
BW = $a \times HL^b$	2.2284	2.04	1.4618 - 3.3971	1.75 - 2.33	0.919	A-
BW = $a \times PrDL^b$	0.1099	2.75	0.0465 - 0.2601	2.35 - 3.14	0.917	A-
BW = $a \times PoDL^b$	0.0692	2.69	0.0298 - 0.1608	2.34 - 3.04	0.930	A-
BW = $a \times PcL^b$	1.1268	2.41	0.6926 - 1.8334	2.09 - 2.74	0.928	A-
BW = $a \times PvL^b$	0.1466	2.66	0.0743 - 0.2896	2.34 - 2.98	0.941	A-
BW = $a \times AnsL^b$	0.0423	2.64	0.0149 - 0.1203	2.24 - 3.04	0.910	A-
BW = $a \times PrAnL^b$	0.0197	2.87	0.0058 - 0.0673	2.41 - 3.33	0.900	A-
BW = $a \times PoAnL^b$	0.0070	3.11	0.0018 - 0.0274	2.62 - 3.60	0.903	A+

Table 4. Descriptive statistics and estimated parameters of the length-weight relationships of *Coilia dussumieri* from the BoB, Bangladesh

Equations	Regression parameters		95% CL of *a*	95% CL of *b*	r^2	GT
	a	*b*				
BW = $a \times TL^b$	0.0013	3.35	0.0010 - 0.0018	3.23 - 3.46	0.973	A+
BW = $a \times FL^b$	0.0019	3.33	0.0012 - 0.0029	3.16 - 3.49	0.940	A+
BW = $a \times HL^b$	1.4298	2.54	1.2599 - 1.6225	2.36 - 2.71	0.890	A-
BW = $a \times OprL^b$	3.2698	2.42	3.0510 - 3.544	2.26 - 2.58	0.897	A-
BW = $a \times PrDL^b$	0.3043	2.75	0.0252 - 0.3678	2.60 - 2.91	0.924	A-
BW = $a \times PoDL^b$	0.1650	2.82	0.1308 - 0.2081	2.65 - 2.98	0.919	A-
BW = $a \times PcL^b$	0.7598	3.59	0.6333 - 0.9116	3.32 - 3.86	0.876	A+
BW = $a \times PvL^b$	0.1171	3.75	0.0862 - 0.1591	3.49 - 4.02	0.885	A+
BW = $a \times AnsL^b$	0.5730	1.83	0.4742 - 0.6923	1.70 - 1.96	0.890	A-
BW = $a \times PrAnL^b$	0.3584	2.07	0.2963 - 0.4335	1.95 - 2.19	0.917	A-
BW = $a \times PoAnL^b$	0.0012	3.53	0.0008 - 0.0018	3.38 - 3.67	0.958	A+

Table 5. Descriptive statistics and estimated parameters of the length-weight relationships of *Thryssa setirostris* from the BoB, Bangladesh

Equations	Regression parameters		95% CL of *a*	95% CL of *b*	r^2	GT
	a	*b*				
BW = $a \times TL^b$	0.0091	2.98	0.0047 - 0.076	2.72 - 3.24	0.916	A-
BW = $a \times FL^b$	0.0091	3.12	0.0054 - 0.0154	2.90 - 3.34	0.946	I
BW = $a \times SL^b$	0.0197	2.92	0.0107 - 0.0361	2.66 - 3.18	0.913	A-
BW = $a \times HL^b$	1.3680	2.77	1.0869 - 1.7223	2.53 - 3.02	0.914	A-
BW = $a \times OprL^b$	4.7500	2.77	4.2205 - 5.362	2.53 - 3.0	0.914	A-
BW = $a \times PrDL^b$	0.1377	2.85	0.0886 - 0.2140	2.59 - 311	0.911	A-
BW = $a \times PoDL^b$	0.0766	2.92	0.0466 - 0.1259	2.65 - 3.18	0.910	A-
BW = $a \times PcL^b$	1.5338	2.50	1.2136 - 1.9385	2.26 - 2.73	0.903	A-
BW = $a \times PvL^b$	0.3396	2.76	0.2318 - 0.4974	2.49 - 3.02	0.901	A-
BW = $a \times AnsL^b$	0.1629	2.55	0.1016 - 0.2612	2.30 - 2.81	0.893	A-
BW = $a \times PrAnL^b$	0.1167	2.65	0.0725 - 0.1876	2.65 - 22.90	0.902	A-
BW = $a \times PoAnL^b$	0.0289	2.87	0.0161 - 0.0519	2.61 - 3.13	0.911	A-

Table 6. Descriptive statistics and estimated parameters of the length-weight relationships of *Anodontostoma chacunda* from the BoB, Bangladesh

Equations	Regression parameters		95% CL of *a*	95% CL of *b*	r^2	GT
	a	*b*				
$BW = a \times TL^b$	0.0149	2.89	0.0083 - 0.0267	2.64 - 3.13	0.921	A-
$BW = a \times FL^b$	0.0262	2.86	0.0149 - 0.0461	2.60 - 3.11	0.913	A-
$BW = a \times SL^b$	0.0312	2.92	0.0180 - 0.0542	2.66 - 3.18	0.912	A-
$BW = a \times HL^b$	1.6889	2.78	1.4155 - 2.0153	2.55 - 3.00	0.925	A-
$BW = a \times PrDL^b$	0.5186	2.52	0.3930 - 0.6845	2.31 - 2.73	0.923	A-
$BW = a \times PoDL^b$	0.2128	2.58	0.1531 - 0.2957	2.38 - 2.78	0.932	A-
$BW = a \times PcL^b$	1.4072	2.94	1.1854 - 1.6704	2.72 - 3.16	0.939	A-
$BW = a \times PvL^b$	0.2635	2.92	0.1858 - 0.3737	2.67 - 3.18	0.917	A-
$BW = a \times AnsL^b$	0.1082	2.74	0.0714 - 0.1638	2.51 - 2.97	0.921	A-
$BW = a \times PrAnL^b$	0.0953	2.76	0.0637 - 0.1425	2.54 - 2.98	0.929	A-
$BW = a \times PoAnL^b$	0.0302	3.05	0.0193 - 0.0472	2.83 - 3.27	0.941	I

Table 7. Descriptive statistics and estimated parameters of the length-weight relationships of *Ilisha megaloptera* from the BoB, Bangladesh

Equations	Regression parameters		95% CL of *a*	95% CL of *b*	r^2	GT
	a	*b*				
$BW = a \times TL^b$	0.0068	2.97	0.0030 - 0.0154	2.71 - 3.22	0.901	A-
$BW = a \times FL^b$	0.0277	2.67	0.0141 - 0.0546	2.44 - 2.89	0.907	A-
$BW = a \times SL^b$	0.0164	2.94	0.0079 - 0.0342	2.69 - 3.19	0.904	A-
$BW = a \times HL^b$	2.5158	2.33	1.8617 - 3.3997	2.13 - 2.52	0.908	A-
$BW = a \times OprL^b$	2.8620	2.55	2.1773 - 3.7619	2.36 - 2.75	0.918	A-
$BW = a \times PrDL^b$	0.0229	3.65	0.0112 - 0.0466	3.33 - 3.96	0.903	I
$BW = a \times PoDL^b$	0.4425	2.21	0.2815 - 0.6955	2.02 - 2.40	0.905	A-
$BW = a \times PcL^b$	1.3961	2.76	1.0063 - 1.9370	2.55 - 2.98	0.919	A-
$BW = a \times PvL^b$	0.1777	3.04	0.1041 - 03035	2.78 - 3.30	0.903	I
$BW = a \times AnsL^b$	0.3294	2.36	0.2121 - 0.5116	2.18 - 2.55	0.918	A-
$BW = a \times PrAnL^b$	0.0542	3.08	0.0295 - 0.0998	2.83 - 3.33	0.910	I
$BW = a \times PoAnL^b$	0.0056	3.37	0.0025 - 0.0123	3.10 - 3.64	0.911	I

Table 8. Descriptive statistics and estimated parameters of the length-weight relationships of *Priacanrhus macracanthus* from the BoB, Bangladesh

Equations	Regression parameters		95% CL of *a*	95% CL of *b*	r^2	GT
	a	*b*				
$BW = a \times TL^b$	0.0138	2.93	0.0093 - 0.0204	2.80 - 3.06	0.945	A-
$BW = a \times FL^b$	0.0183	2.88	0.0125 - 0.0269	2.75 - 3.01	0.943	A-
$BW = a \times SL^b$	0.0301	2.90	0.0206 - 0.0438	2.76 - 3.03	0.938	A-
$BW = a \times HL^b$	0.5903	2.93	0.4352 - 0.8005	2.75 - 3.11	0.901	A-
$BW = a \times OprL^b$	0.5770	3.12	0.4022 - 0.8278	2.90 - 3.34	0.908	A+
$BW = a \times PrDL^b$	1.6751	2.43	1.3967 - 2.0090	2.31 - 2.54	0.941	A-
$BW = a \times PoDL^b$	0.0522	2.84	0.0346 - 0.0786	2.68 - 2.99	0.918	A-
$BW = a \times PcL^b$	1.5193	2.46	1.2441 - 1.8554	2.34 - 2.58	0.933	A-
$BW = a \times PvL^b$	1.9619	2.52	1.5786 - 2.4383	2.37 - 2.66	0.912	A-
$BW = a \times AnsL^b$	0.3145	2.69	0.2251 - 0.4395	2.53 - 2.85	0.906	A-
$BW = a \times PrAnL^b$	0.1899	2.85	0.1337 - 0.2698	2.684 - 3.01	0.912	A-
$BW = a \times PoAnL^b$	0.0636	2.78	0.0432 - 0.0934	2.63 - 2.92	0.923	A-

Annexure RU: 3.

Relationship between environmental factors with GSI of marine fishes.

Table: Relationship between environmental factors with GSI of 12 selected marine fishes in the BoB, Bangladesh

Relationships	r_s value	95% CL of r_s value	p value	Significant
E. affinis				
DO *vs.* GSI	0.5937	0.01068 to 0.8755	0.0453	*
pH *vs.* GSI	-0.4336	-0.8134 to 0.2054	0.1616	*ns*
TDS *vs.* GSI	-0.3217	-0.7642 to 0.3267	0.3085	*ns*
Salinity *vs.* GSI	-0.6503	-0.8954 to -0.1029	0.0257	*
Resistivity *vs.* GSI	0.6480	0.09886 to 0.8946	0.0259	*
Conductivity *vs.* GSI	-0.4755	-0.8305 to 0.1542	0.1215	*ns*
Water Temp. *vs.* GSI	0.7496	0.2907 to 0.9281	0.0067	**
Rainfall *vs.* GSI	0.6643	0.1272 to 0.9002	0.0219	*
Air Temp. *vs.* GSI	0.6340	0.07526 to 0.8897	0.0304	*
S. taty				
DO *vs.* GSI	-0.6643	-0.9002 to -0.1272	0.0214	*
pH *vs.* GSI	0.6364	0.07924 to 0.8906	0.0299	*
TDS *vs.* GSI	-0.5455	-0.8577 to 0.06067	0.0708	*ns*
Salinity *vs.* GSI	0.5315	-0.08027 to 0.8524	0.0794	*ns*
Resistivity *vs.* GSI	-0.1226	-0.6617 to 0.5001	0.7037	*ns*
Conductivity *vs.* GSI	-0.02797	-0.6048 to 0.5681	0.9388	*ns*
Water Temp. *vs.* GSI	-0.4904	-0.8364 to 0.1353	0.1075	*ns*
Rainfall *vs.* GSI	-0.5105	-0.8443 to 0.1088	0.0936	*ns*
Air Temp. *vs.* GSI	-0.6620	-0.8994 to -0.1231	0.0223	*
S. panijus				
DO *vs.* GSI	-0.4135	-0.8049 to 0.2287	0.1816	*ns*
pH *vs.* GSI	0.1678	-0.4646 to 0.6869	0.6039	*ns*
TDS *vs.* GSI	0.4755	-0.1542 to 0.8305	0.1215	*ns*
Salinity *vs.* GSI	0.1818	-0.4532 to 0.6944	0.5731	*ns*
Resistivity *vs.* GSI	-0.2207	-0.7148 to 0.4205	0.4880	*ns*
Conductivity *vs.* GSI	0.06294	-0.5439 to 0.6265	0.8515	*ns*
Water Temp. *vs.* GSI	-0.3328	-0.7693 to 0.3156	0.2886	*ns*
Rainfall *vs.* GSI	-0.2587	-0.7340 to 0.3867	0.4169	*ns*
Air Temp. *vs.* GSI	-0.2627	-0.7360 to 0.3831	0.4064	*ns*
P. paradiseus				
DO *vs.* GSI	0.6467	0.09663 to 0.8941	0.0262	*

Relationships	r_s value	95% CL of r_s value	*p* value	Significant
pH *vs.* GSI	-0.2587	-0.7340 to 0.3867	0.4169	*ns*
TDS *vs.* GSI	-0.2657	-0.7375 to 0.3803	0.4042	*ns*
Salinity *vs.* GSI	-0.5874	-0.8732 to -0.0012	0.0489	*
Resistivity *vs.* GSI	0.7250	0.2407 to 0.9203	0.0097	**
Conductivity *vs.* GSI	-0.5385	-0.8550 to 0.07053	0.0750	*ns*
Water Temp. *vs.* GSI	0.8441	0.5100 to 0.9569	0.0010	***
Rainfall *vs.* GSI	0.5105	-0.1088 to 0.8443	0.0936	*ns*
Air Temp. *vs.* GSI	0.7005	0.1932 to 0.9123	0.0137	*
M. cordyla				
DO *vs.* GSI	0.4311	-0.2083 to 0.8124	0.1624	*ns*
pH *vs.* GSI	-0.1469	-0.6754 to 0.4813	0.6509	*ns*
TDS *vs.* GSI	-0.4196	-0.8075 to 0.2217	0.1767	*ns*
Salinity *vs.* GSI	-0.3636	-0.7832 to 0.2836	0.2464	*ns*
Resistivity *vs.* GSI	0.2942	-0.3535 to 0.7512	0.3503	*ns*
Conductivity *vs.* GSI	-0.05594	-0.6222 to 0.5488	0.8692	*ns*
Water Temp. *vs.* GSI	0.4238	-0.2168 to 0.8093	0.1702	*ns*
Rainfall *vs.* GSI	0.4336	-0.2054 to 0.8134	0.1616	*ns*
Air Temp. *vs.* GSI	0.3152	-0.3331 to 0.7612	0.3154	*ns*
H. nehereus				
DO *vs.* GSI	0.7280	0.2465 to 0.9212	0.0092	**
pH *vs.* GSI	-0.3427	-0.7738 to 0.3055	0.2762	*ns*
TDS *vs.* GSI	-0.2168	-0.7128 to 0.4238	0.4990	*ns*
Salinity *vs.* GSI	-0.6503	-0.8954 to -0.1029	0.0257	*
Resistivity *vs.* GSI	0.7706	0.3356 to 0.9347	0.0046	**
Conductivity *vs.* GSI	-0.5455	-0.8577 to 0.06067	0.0708	*ns*
Water Temp. *vs.* GSI	0.8546	0.5374 to 0.9600	0.0007	***
Rainfall *vs.* GSI	0.5664	-0.03037 to 0.8655	0.0591	*ns*
Air Temp. *vs.* GSI	0.7671	0.3280 to 0.9336	0.0050	**
C. dussumieri				
DO *vs.* GSI	0.7421	0.2752 to 0.9257	0.0074	**
pH *vs.* GSI	-0.01399	-0.5958 to 0.5775	0.9739	*ns*
TDS *vs.* GSI	0.03497	-0.5633 to 0.6092	0.9210	*ns*
Salinity *vs.* GSI	-0.5594	-0.8629 to 0.04059	0.0628	*ns*
Resistivity *vs.* GSI	0.3678	-0.2792 to 0.7851	0.2385	*ns*
Conductivity *vs.* GSI	-0.06993	-0.6308 to 0.5389	0.8346	*ns*
Water Temp. *vs.* GSI	0.7706	0.3356 to 0.9347	0.0047	**

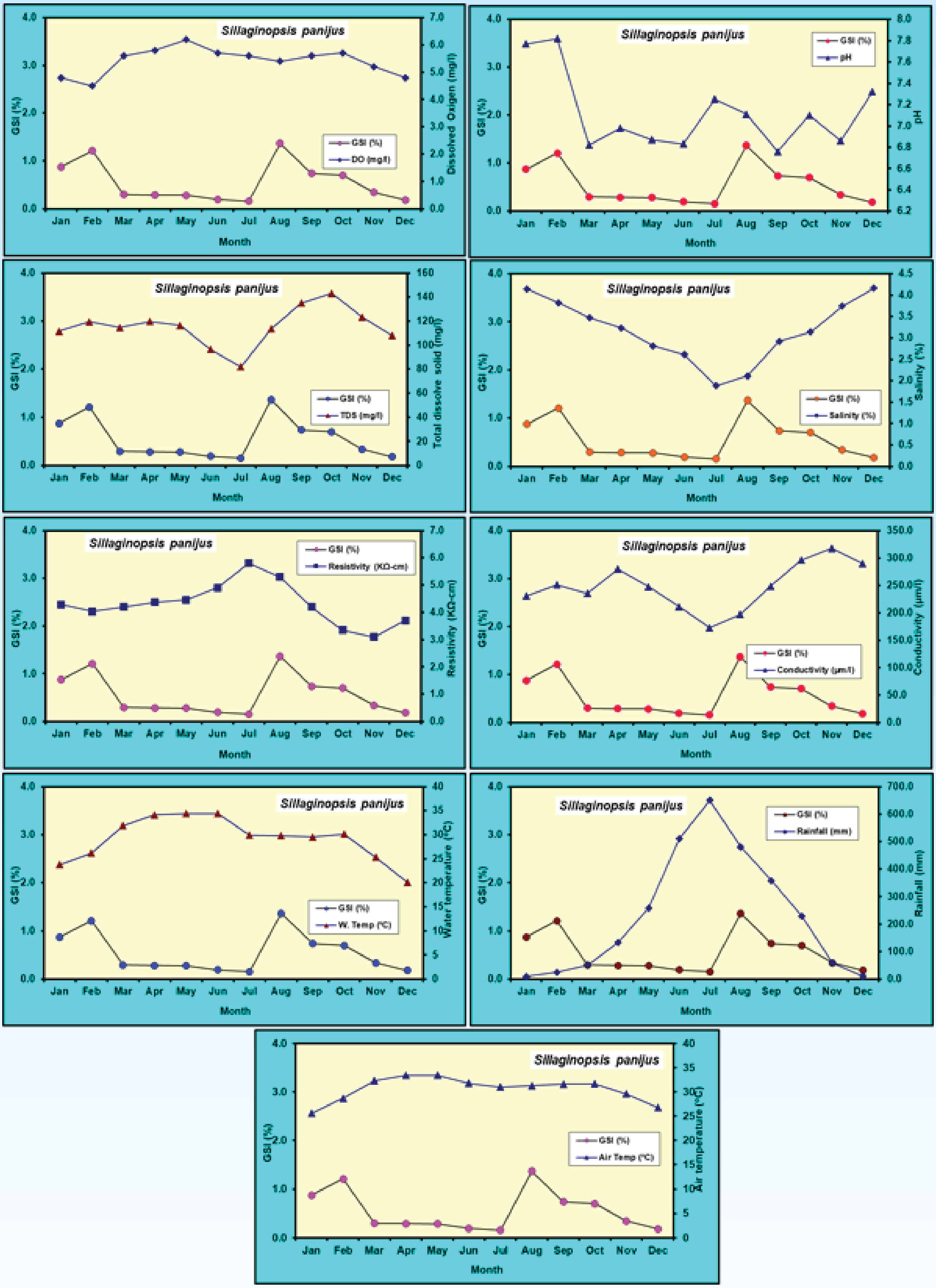
Relationships	r_s value	95% CL of r_s value	*p* value	Significant
Rainfall *vs.* GSI	0.5035	-0.1181 to 0.8416	0.0989	*ns*
Air Temp. *vs.* GSI	0.6725	0.1417 to 0.9029	0.0195	*
T. setirostris				
DO *vs.* GSI	0.1307	-0.4938 to 0.6663	0.6844	*ns*
pH *vs.* GSI	0.1748	-0.4590 to 0.6907	0.5881	*ns*
TDS *vs.* GSI	-0.5594	-0.8629 to 0.04059	0.0628	*ns*
Salinity *vs.* GSI	-0.5804	-0.8706 to 0.009540	0.0521	*ns*
Resistivity *vs.* GSI	0.5009	-0.1216 to 0.8406	0.0996	*ns*
Conductivity *vs.* GSI	-0.4196	-0.8075 to 0.2217	0.1767	*ns*
Water Temp. *vs.* GSI	0.07005	-0.5388 to 0.6308	0.8294	*ns*
Rainfall *vs.* GSI	0.6084	0.03372 to 0.8807	0.0399	*
Air Temp. *vs.* GSI	-0.1226	-0.6617 to 0.5001	0.7034	*ns*
A. chacunda				
DO *vs.* GSI	-0.4877	-0.8354 to 0.1387	0.1098	*ns*
pH *vs.* GSI	0.3287	-0.3197 to 0.7674	0.2973	*ns*
TDS *vs.* GSI	0.2448	-0.3993 to 0.7271	0.4434	*ns*
Salinity *vs.* GSI	0.9021	0.6700 to 0.9735	0.0002	***
Resistivity *vs.* GSI	-0.7916	-0.9412 to -0.3826	0.0031	**
Conductivity *vs.* GSI	0.6084	0.03372 to 0.8807	0.0399	*
Water Temp. *vs.* GSI	-0.5849	-0.8723 to 0.002697	0.0494	*
Rainfall *vs.* GSI	-0.8741	-0.9656 to -0.5900	0.0004	***
Air Temp. *vs.* GSI	-0.4799	-0.8323 to 0.1487	0.1164	*ns*
I. megaloptera				
DO *vs.* GSI	-0.2956	-0.7519 to 0.3522	0.3468	*ns*
pH *vs.* GSI	0.08757	-0.5262 to 0.6413	0.7874	*ns*
TDS *vs.* GSI	0.1086	-0.5107 to 0.6537	0.7368	*ns*
Salinity *vs.* GSI	0.5569	-0.04425 to 0.8620	0.0634	*ns*
Resistivity *vs.* GSI	-0.3158	-0.7614 to 0.3325	0.3141	*ns*
Conductivity *vs.* GSI	0.3047	-0.3434 to 0.7562	0.3330	*ns*
Water Temp. *vs.* GSI	-0.1561	-0.6805 to 0.4740	0.6230	*ns*
Rainfall *vs.* GSI	-0.5849	-0.8723 to 0.002697	0.0493	*
Air Temp. *vs.* GSI	-0.04912	-0.6180 to 0.5535	0.8801	*ns*

Relationships	r_s value	95% CL of r_s value	p value	Significant
P. macracanthus				
DO *vs.* GSI	-0.4771	-0.8311 to 0.1523	0.1185	*ns*
pH *vs.* GSI	0.4126	-0.2297 to 0.8045	0.1845	*ns*
TDS *vs.* GSI	-0.02797	-0.6048 to 0.5681	0.9388	*ns*
Salinity *vs.* GSI	0.7902	0.3794 to 0.9408	0.0033	**
Resistivity *vs.* GSI	-0.4694	-0.8280 to 0.1620	0.1252	*ns*
Conductivity *vs.* GSI	0.3147	-0.3336 to 0.7609	0.3194	*ns*
Water Temp. *vs.* GSI	-0.3292	-0.7677 to 0.3191	0.2935	*ns*
Rainfall *vs.* GSI	-0.8531	-0.9596 to -0.5335	0.0008	***
Air Temp. *vs.* GSI	-0.3187	-0.7628 to 0.3296	0.3103	*ns*
A. leiogaster				
DO *vs.* GSI	0.3781	-0.2681 to 0.7896	0.2246	*ns*
pH *vs.* GSI	-0.5035	-0.8416 to 0.1181	0.0989	*ns*
TDS *vs.* GSI	0.3287	-0.3197 to 0.7674	0.2973	*ns*
Salinity *vs.* GSI	-0.6643	-0.9002 to -0.1272	0.0219	*
Resistivity *vs.* GSI	0.05254	-0.5512 to 0.6201	0.8734	*ns*
Conductivity *vs.* GSI	-0.04196	-0.6136 to 0.5585	0.9039	*ns*
Water Temp. *vs.* GSI	0.2522	-0.3926 to 0.7308	0.4254	*ns*
Rainfall *vs.* GSI	0.7133	0.2177 to 0.9165	0.0118	*
Air Temp. *vs.* GSI	0.2977	-0.3502 to 0.7529	0.3447	*ns*

GSI, gonadosomatic index; DO, dissolved oxygen; TDS, total dissolved solids; r_s, Spearman rank correlation values; CL, confidence limit; p, the level of significance; *ns*, not significant; **, significant ($p \leq 0.01$); ** or ***, highly significant ($p \leq 0.01$)

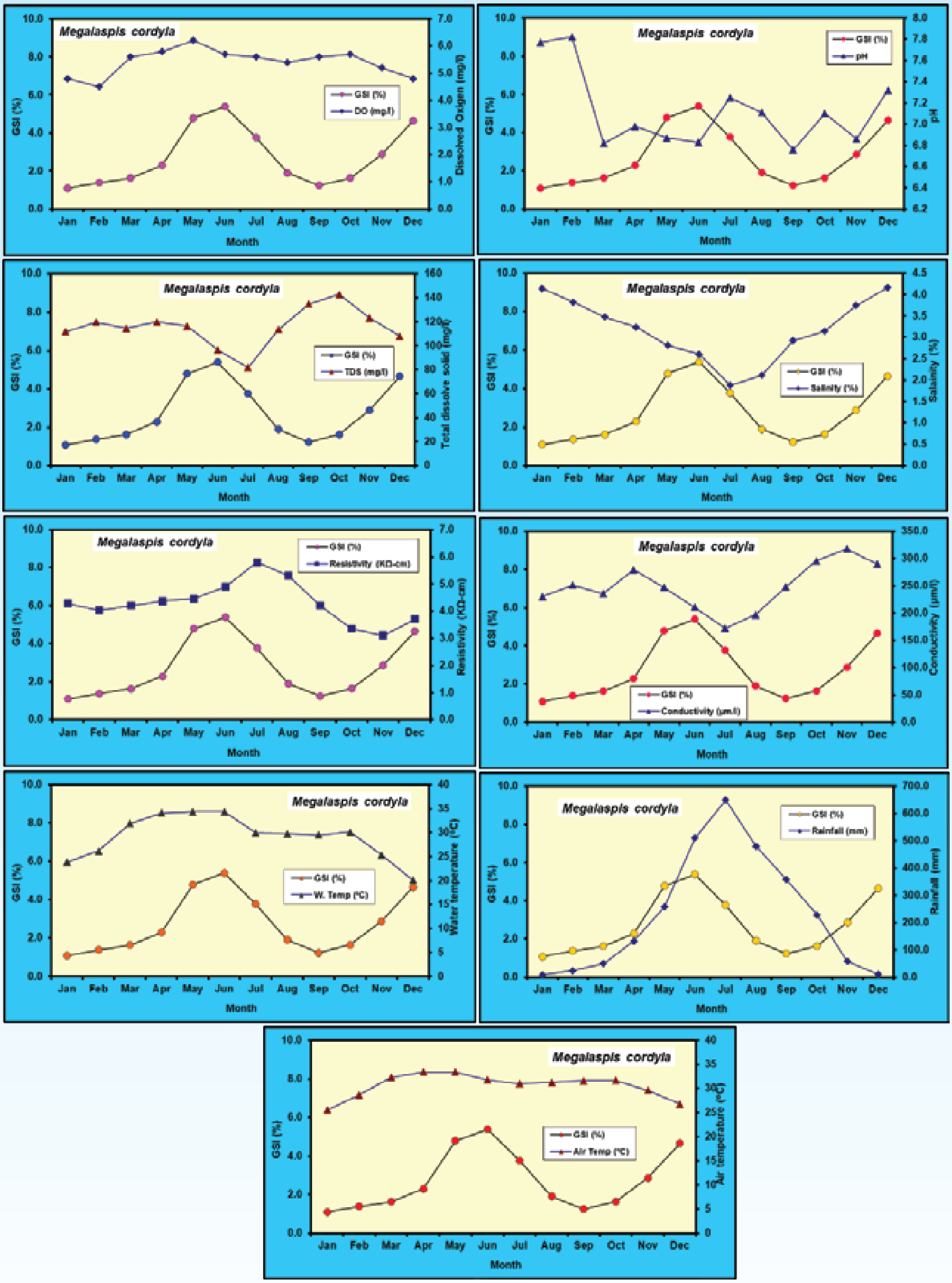
Annexures RU: 3 (1)

Relationship between gonadosomatic index (GSI) and environmental factors of female *Sillaginopsis panijus* in the BoB, Bangladesh



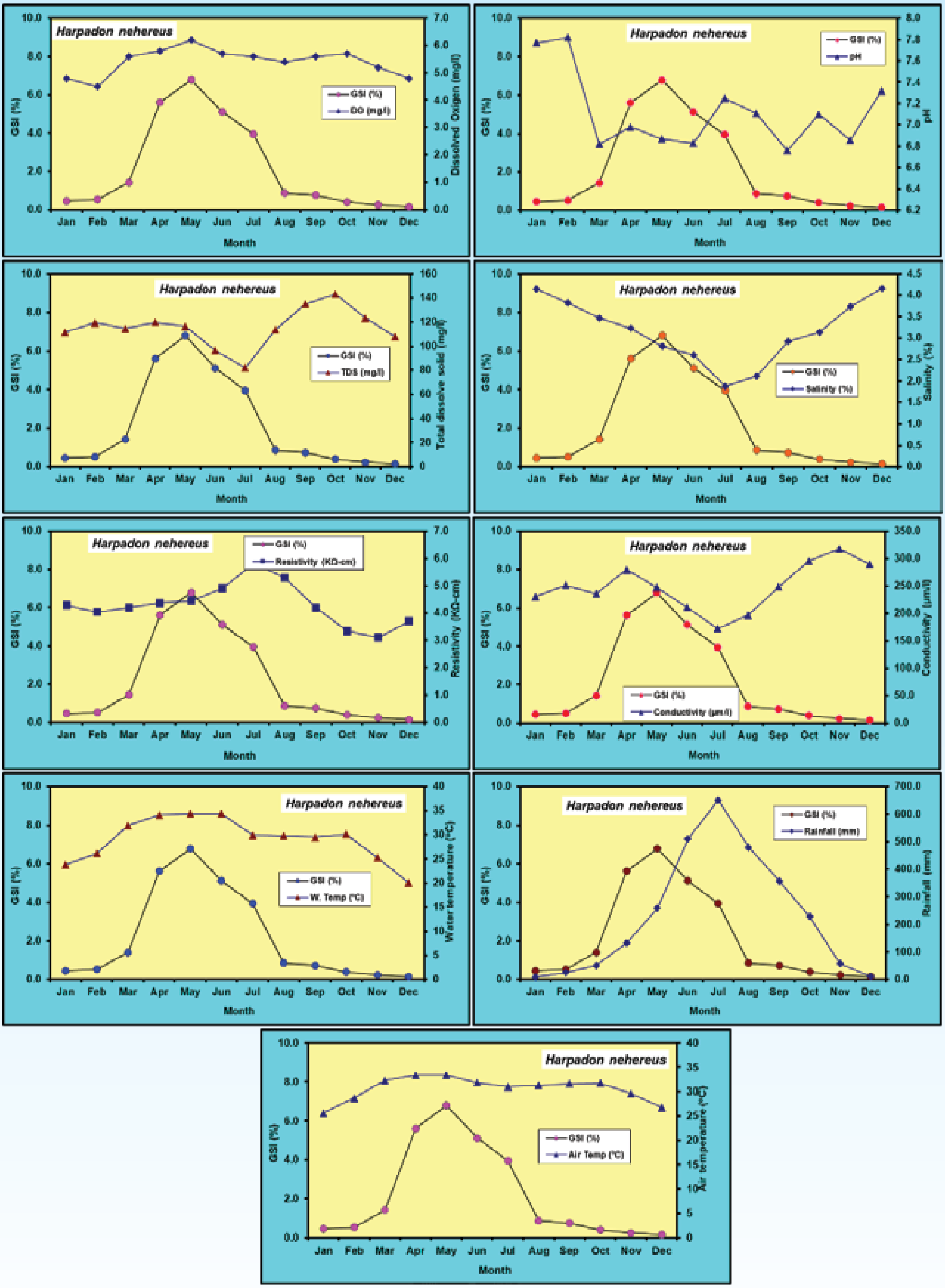
Annexure RU: 3(2)

Relationship between gonadosomatic index (GSI) and environmental factors of female *Megalaspis cordyla* in the BoB, Bangladesh



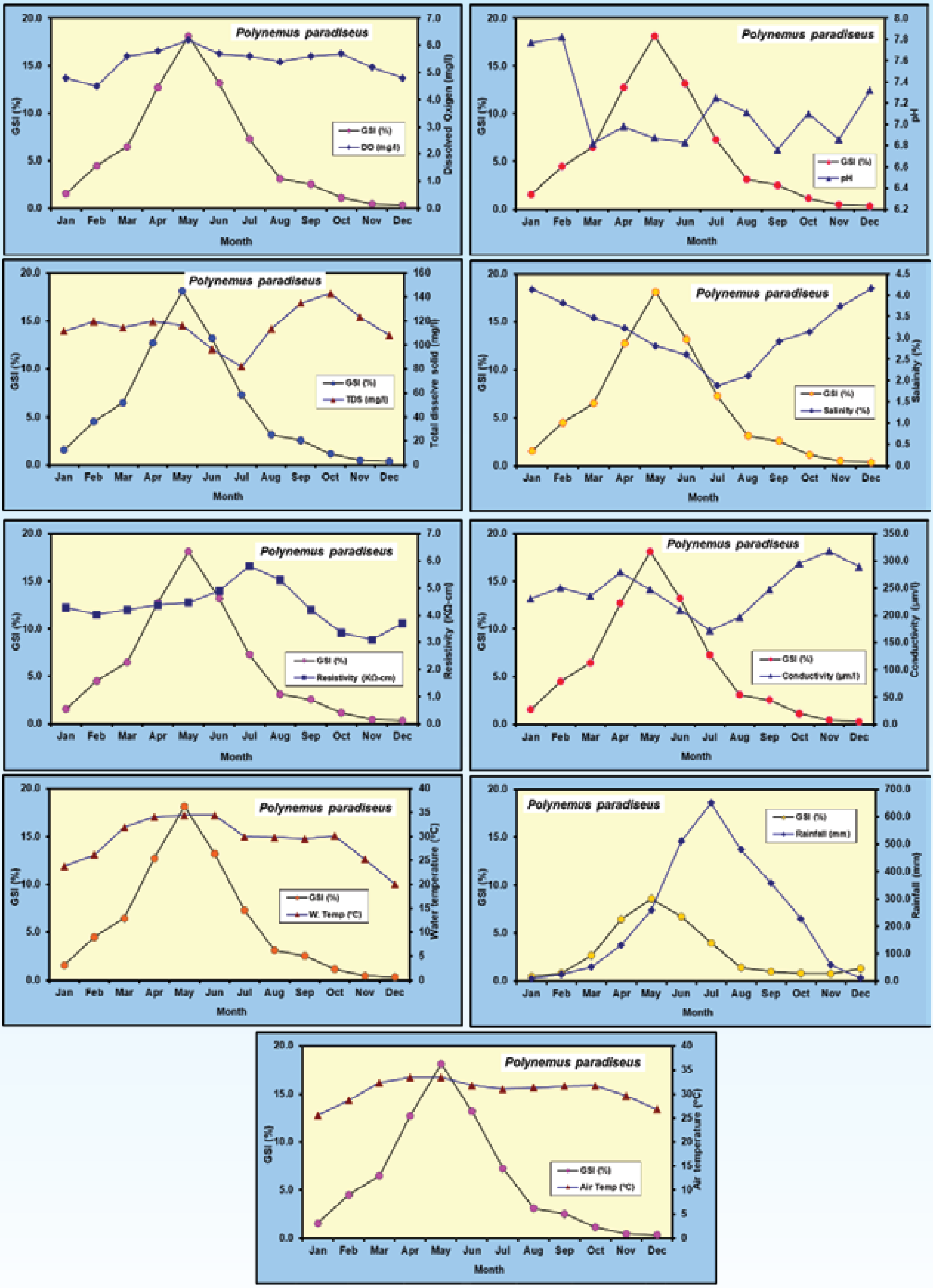
Annexure RU: 3(3)

Relationship between gonadosomatic index (GSI) and environmental factors of female *Harpadon nehereus* in the BoB, Bangladesh



Annexure RU: 3(4)

Relationship between gonadosomatic index (GSI) and environmental factors of female *Polynemus paradiseus* in the BoB, Bangladesh



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