Sub-project ID-154

Program Based Research Grant (PBRG)

Sub-project Completion Report
on

Sustainable Development of Indigenous Fisheries in Baors of Southwestern Bangladesh through Multiple-Functions for Ensuring the Food Security

Sub-project Duration
15 October 2019 to 29 December 2022

Coordinating Organization

Fisheries Division
Bangladesh Agricultural Research Council
Farmgate, Dhaka-1215

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

December 2022

Program Based Research Grant (PBRG)

Sub-project Completion Report
on
Sustainable Development of Indigenous Fisheries in *Baors* of Southwestern Bangladesh through Multiple-Functions for Ensuring the Food Security

Implementing Organizations

Department of Fisheries
University of Rajshahi
Rajshahi-6205

Department of Fisheries and Marine Bioscience
Jashore University of Science and Technology
Jashore-7408

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

December 2022

Citation

Islam, M.R., Jasmine, S., Samad, M.A., Hossain, M.Y., Rahman, M.H., Rahman, M. A., Rahman, O., Awal, M.A and Islam, M. M. 2022. Sustainable Development of Indigenous Fisheries in *Baors* of Southwestern Bangladesh through Multiple-Functions for Ensuring the Food Security, *PBRG Sub-project Completion Report*. Fish. Div., BARC. 147 p

Edited by

Project Implementation Unit
National Agricultural Technology Program-Phase II Project (NATP-2)
Bangladesh Agricultural Research Council (BARC)
New Airport Road, Farmgate, Dhaka-1215
Bangladesh

Acknowledgement

The execution of PBRG sub-project has successfully been completed by the Department of Fisheries, University of Rajshahi (RU) and Department of Fisheries and Marine Bioscience, Faculty of Biological Science and Technology, Jashore University of Science and Technology (JUST) using the research fund of WB, IFAD and GoB through Ministry of Agriculture. We would like to acknowledge to the World Bank for arranging the research fund and supervising the PBRGs by BARC. It is worthwhile to mention the cooperation and quick responses of PIU-BARC, NATP-2 in respect of field implementation of the sub-project in multiple sites. Preparing the sub-project completion report required to contact a number of persons for collection of information and processing of research data. Without the help of those persons, the preparation of this document could not be made possible. All of them, who have made it possible, deserve appreciation. Our thanks are due to the Director PIU-BARC, NATP-2 and his team who given their whole hearted support to prepare this document. We hope this publication would be helpful to the agricultural scientists of the country for designing their future research projects in order to technology generation as well as increasing production and productivity for sustainable food and nutrition security in Bangladesh. It would also assist the policy makers of the agricultural sub-sectors for setting their future research directions.

Published in : December 2022

Printed by : **Delight**
67 Noya Paltan, Dhaka-1000
alam.nurey13@gmail.com
01925354414

Abbreviation and Acronyms

%	Percentage	L_m	Size at Sexual Maturity
AFO	Assistant Fisheries Officer	L_{max}	Maximum Length
ANOVA	Analysis of Variance	L_{opt}	Optimum Catchable Length
AnsL	Anus Length	L_r	Length at Recruitment
BARC	Bangladesh Agricultural Research Council	LWR	Length Weight Relationship
BFT	Baor Fiseries Team	MSY	Maximum Sustain Yield
BMG	Baor Management Group	MT	Metric Ton
BW	Body weight	Mw	Natural Mortality
CBFM	Community Based Fisheries Management	NA	Not Applicable
CI	Cross check Interview	NA	Native
CL	Confidence Limit	NATP	National Agricultural Technology Program
cm	Centimeter	NE	Not Evaluated
Co-PI	Co-Principal Investigator	NGO	Non-Government Organization
CPUE	Catch Per Unit Effort	NT	Near Threatened
CR	Critically Endangered	ºC	Degree Celsius
CU	Culture	PCA	Principal Component Analysis
CVA	Canonical Vaiate Analysis	PcL	Pectoral Length
DD	Data Deficient	PCR	Project Completion Report
DFA	Discriminant Function Analysis	PI	Principal Investigator
DFO	District Fisheries Officer	PIU	Project Implementation Unit
E	Exploitation	PoAnL	Post-Anal Length
E_I	Electivity index	PoDL	Post Dorsal Length
EN	Endangered	PRA	Participatory Rural Appraisal
F	Fishing Mortality	PrAnL	Pre-Anal Length
FFG	Fish Farmers Group	PrDL	Pre-Dorsal Length
FGD	Focus Group Discussion	PvL	Pelvic Length
FI	Feeding Intensity	R	Rare
FL	Fork length	RU	University of Rajshahi
FPI	Fishers Personal Interview	SIFS	Small Indigenous Fish Species
F_T	Total Fecundity	SIS	Small Indigenous Species
g	gram	SL	Standard Length
GaSI	Gastro Somatic Index	SM	Small Amount During Monsoon
GDP	Gross Domestic Production	SP	Species
GSI	Gonado-Somatic-Index	SPSS	Statistical Package for the Social Sciences
GW	Gonad Weight	SRS	Self Sustaining Species
HL	Head Length	SUFO	Senior Upazilla Fisheries Officer
IFAD	International Fund for Agricultural Development	TL	Total Length
IMC	Indian Major Carp	t_m	Age at Sexual Maturity
IUCN	International Union For Conversation of Nature	t_{max}	Longevity
JUST	Jashore University of Science and Technology	TO	Training Officer
K	Growth Coefficient	TYL	Throughout the Year in Large Amount
Kg	Kilogram	TYS	Throughout the Year in Small Amount
KII	Key Informant Interview	UFO	Upazilla Fisheries Officer
L_∞	Asymptotic Length	UPGMA	Unweighted Pair Group Method
LC	Least Concern	VR	Very Rare
LFD	Length Frequency Distribution	VU	Vulnerable
LM	Large Amount During Monsoon	Z	Total Mortality

Table of Contents

Sl No	Subject	Page No
Abbreviation and Acronyms		iii
Table of content		iv
List of Table		vi
List of Figure		viii
Executive summary		xi
A	Sub –project description	1
1	Title of the PBRG Sub-Project	1
2	Implementing organizations	1
3	Name and full address with phone, cell and E-mail of Coordinator, Associate Coordinator, PI/Co-PI (s)	1
4	Sub-project budget	2
5	Duration of the sub-project	2
6	Background of the sub-project	2
7	Sub-project general objectives	4
8	Sub-project specific objectives	4
9	Implementing locations	4
10	**Methodology in brief**	5
10.1	Activity implementation approach for the Coordination component	5
10.2	Research methodology of RU component	7
10.2.1	Selection of study sites	7
10.2.2	Baseline survey of fish biodiversity and status of indigenous fish species	8
10.2.3	Causal factor for threatening/ declining of indigenous fish species	10
10.2.4	Fish stocking	11
10.2.5	Data analyses in laboratory	12
10.2.6	Length-frequency distribution	12
10.2.7	Monthly increases length of stocked fishes	13
10.2.8	Size at first sexual maturity, Spawning and Peak-spawning season	13
10.2.9	Fecundity	13
10.2.10	Estimation of growth parameter, length at first recruitment	15
10.2.11	Estimation of mortality, exploitation, biomass and MSY and L_{opt}	15
10.2.12	Data analyses	15
10.3	Component 2 (JUST)	15
10.3.1	Site selection	15
10.3.2	Baseline information about the Baors of Jashore district	15
10.3.3	Fish sampling	18
10.3.4	Stocking of small indigenous fish species (SIFS) and establishment of fish sanctuary	19
10.3.5	Identification of fishes and fish status	20
10.3.6	Biodiversity parameters	20
10.3.7	Livelihood and socio-economic study	21
10.3.8	Market survey	21
10.3.9	Causes of *Baor* fish reduction	21

10.3.10	Study of stock structure analysis	22
10.3.11	Study of reproductive biology	22
10.3.12	Study of feeding habits	23
10.3.13	Identification of co-ownership management problem	23
11	**Results and discussion**	25
11.1	**Component 1 (RU)**	25
11.1.1	Fish biodiversity and status of indigenous fish species	25
11.1.2	Morphometric and meristic characteristics	30
11.1.3	Length-frequency distribution	35
11.1.4	Monthly increases length of stocked fishes	37
11.1.5	Size at sexual maturity (L_m)	39
11.1.6	Spawning season	42
11.1.7	Selection of fishing ban period	45
11.1.8	Fecundity	46
11.1.9	Causes for declining of indigenous fishes from *Baors*	46
11.1.10	Relative abundance	48
11.1.11	Length at first recruitment (L_r)	49
11.1.12	Growth parameters	51
11.1.13	Mortality and exploitation	52
11.1.14	Biomass and maximum sustainable yield (MSY)	53
11.2	**Component 2 (JUST)**	57
11.2.1	Identification of fishes and fish status	57
11.2.2	Fish availability	59
11.2.3	Fishing gears	62
11.2.4	Fish restocking	64
11.2.5	Study of biodiversity parameters	64
12.2.6	Causes of SIFS fish reduction	66
12.2.7	Problems of *Baor* fisherman	67
11.2.8	Livelihood and socio-economic study	68
11.2.9	Effects of Covid-19 on *Baor* fishers community	73
11.2.9.1	Negative effects o Covid -19 on *Baor* fisher's community	73
11.2.9.2	Positive effects of Covid-19 on *Baor* fisheries	77
11.2.10	Impact of marketing	78
11.2.11	Study of stock structure analysis	80
11.2.12	Study of reproductive biology	91
11.2.13	Study of food and feeding habit	96
11.2.14	Identification of co-ownership management problem	107
12	Research highlights	110
12.1	Component 1 (RU)	110
12.2	Component 2 (JUST)	112
B	Implementation status	114
1	Procurement	114
2	Establishment/renovation facilities	116
3	Training/study tour/ seminar/workshop/conference organized	116
C	Financial and physical progress (combined & component wise)	117
D	Achievement of sub-project by objectives (Tangible form):	119

	Technology generated/developed	
E	Information/Knowledge generated/Policy generated	119
F	Materials development/publication made under the sub-project	121
G	Description of generated technology/Knowledge/Policy	123
i	Technology factsheet	123
ii	Effectiveness in policy support (if applicable)	123
H	Technology/Knowledge generation/Policy support (as applied)	124
i	Immediate impact on generated technology	124
ii	Generation of new knowledge that help in developing more technology in future	124
iii	Technology transferred that help increased agricultural productivity and farmers' income	124
iv	Policy support	124
I	Information regarding desk and field monitoring	125124
i	Information on desk monitoring	125124
ii	Information on field monitoring	127
iii	Weather data, flood/salinity/drought level (if applicable) and natural calamities	128
J	Sub-project auditing (covers all types of audit performed)	128
K	Lessons learned	129
L	Challenges	129
M	Suggestions for future planning	130
N	References	130
Annexures		142

List of Tables

Sl No	Title	Page No
1	Body weight, total length and number of stocked brood fishes in the Saganna and Sarjat *Baors*	11
2	List of stocked fish with their total length, body weight, and number in the Bukvora and Khatura *Baor*	20
3	List of indigenous fish species planning to estimation of feeding habits	23
4	List of available fish species in Six *Baor*s in Jhenaidah region, south western Bangladesh	25
5	List of extinct species of several *Baors* in Jhenaidah, Bangladesh	30
6.1	Morphometric measurements of the *Channa punctata* (Bloch, 1793)	31
6.2	Meristic counts of *Channa punctata* (Bloch, 1793)	31
7.1	Morphometric measurements of *Anabas testudineus* (Bloch, 1792)	31
7.2	Meristic counts of *Anabas testudineus* (Bloch, 1792)	32
8.1	Morphometric measurements of the *Heteropneustes fossilis* (Bloch, 1794)	32
8.2	Meristic counts of *Heteropneustes fossilis* (Bloch, 1994)	32
9.1	Morphometric measurements of the *Mystus tengra* (Hamilton, 1822)	33
9.2	Meristic counts of *Mystus tengra* (Hamilton, 1822)	33
10.1	Morphometric measurements of the *Mystus cavasius* (Hamilton, 1822)	33

10.2	Meristic counts of *Mystus cavasius* (Hamilton, 1822)	33
11.1	Morphometric measurements of the of *Mystus vittatus* (Bloch, 1794)	34
11.2	Meristic counts of *Mystus vittatus* (Bloch, 1794)	34
12.1	Morphometric measurements of the *Ompok pabda* (Hamilton, 1822)	34
12.2	Meristic counts of *Ompok pabda* (Hamilton, 1822)	34
13	Size at sexual maturity of stock fishes from study site and other water bodies	42
14	Spawning season of different indigenous species from the study sites & other water bodies	45
15	Fecundity of stocked indigenous fishes from Saganna *Baor* Bangladesh and other water bodies	46
16	Causes for declining of indigeneous fishes from the Saganna and Sarjat *Baors* in Jhenaidah, South western Bangladesh	47
17	Relative abundance of stock fishes from Saganna and Sarjat *Baor*, Bangladesh	49
18	Length at first recruitment for stock species from Saganna and Sarjat *Baor*	49
19	Growth parameters of stock fishes from Saganna and Sarjat *Baor*, Bangladesh	52
20	Mortality and Exploitation rate of stock fishes from Saganna and Sarjat Boar, Bangladesh	53
21	Available fish species from two selected *Baor*s (Bukvora *Baor* and Khatura *Baor*) with local name and Common name	58
22	Available fish species from the two selected *Baor*s with their status according to IUCN Bangladesh (2015) and IUCN global (2021)	59
23	Fishing gears used in the Bukvora *Baor* and Khatura *Baor* for collecting samples	63
24	Fish prices during market survey in Jashore Sadar Upazila, Jashore.	79
25	Calculated size at first sexual maturity of some fishes from the selected two *Baor*s based on maximum length.	92
26	Monthly gut index of the *Pethia ticto* (Hamilton, 1822) individuals in the Bukvora *Baor*, Jashore, Bangladesh	97
27	Ivlev's food preference index/"electivity index" (E) calculated of *Gudusia chapra (*Hamilton, 1822) in the Bukvora *Baor*, Bangladesh	100

List of Figures

Sl No	Title	Page No
1	Location of study sites (Left- Sarjat *Baor* and Right- Saganna *Baor,* Jhenaidah).	8
2	Location of study sites (Left- Bukvora *Baor* and Right- Khatura *Baor*, Jashore).	16
3.1	Length frequency distribution of stocked indigeneous fishes in Saganna *Baor* Jhenaidah Bangladesh	35
3.2	Length frequency distribution of stocked indigenous fishes in Sarjat *Baor* Jhenaidah, Bangladesh	36
4.1	Monthly variation of mean total length of stocked indigenous fishes in Saganna *Baor* Jhenaidah Bangladesh	38
4.2	Monthly variation of mean total length of stocked indigenous fishes in Sarjat *Baor* Jhenaidah, Bangladesh	39
5.1	Estimated size at first sexual maturity of stocked indigenous fishes based on GSI *vs*. TL in Saganna *Baor* Jhenaidah Bangladesh.	40
5.2	Estimated size at first sexual maturity of stocked indigeneous fishes based on GSI vs. TL in Sarjat *Baor* Jhenaidah Bangladesh.	41
6.1	Monthly variation of gonado-somaticindex (GSI) of stocked indigeneous fishes in Saganna *Baor* Jhenaidah Bangladesh.	43
6.2	Monthly variation of gonado-somaticindex (GSI) of stocked indigeneous fishes in Sarjat *Baor* Jhenaidah Bangladesh	44
7	Monthly variation of gonado-somatic index (GSI) of stocked indigenous fishes in Saganna *Baor* Jhenaidah, southwestern Bangladesh	45
8	Causes for declining of indigeneous fishes from the Saganna and Sarjat *Baors* in Jhenaidah, South western Bangladesh	48
9.1	Length at first recruitment for stock species from Saganna *Baor*, Bangladesh	50
9.2	Length at first recruitment for stock species from Sarjat *Baor*, Bangladesh	51
10.1	Biomass for stock species from Sanganna *Baor*, Bangladesh	55
10.2	Biomass for stock species from Sanganna *Baor*, Bangladesh	55
11.1	Biomass for stock species from Sarjat *Baor*, Bangladesh	56
11.2	Biomass for stock species from Sarjat *Baor*, Bangladesh.	57
12	Percentages of four biodiversity indices and eleven families obtained from fish species of Bukvora *Baor*, Jashore.	65
13	Percentages of four biodiversity indices and eleven families obtained from fish species of Khatura *Baor*, Jashore.	65
14	Causes of *Baor* SIFS reduction (a) Bukvora *Baor* (b) Khatura *Baor*	67
15	Problems of *Baor* fishermen	68
16	Educational background of fisher's community of (a) Bukvora *Baor* (b) Khatura *Baor*, Jashore	69
17	Family size of fisher's community of (a) Bukvora *Baor* (b) Khatura *Baor*, Jashore	70
18	Religion of fisher's community of (a) Bukvora *Baor* (b) Khatura *Baor*, Jashore	70
19	Housing condition of fisher's community of (a) Bukvora *Baor* (b)	71

	Khatura *Baor*, Jashore	
20	Drinking water facilities of fisher's community of (a) Bukvora *Baor* (b) Khatura *Baor*, Jashore	71
21	Sanitary condition of fisher's community of (a) Bukvora *Baor* (b) Khatura *Baor*, Jashore	72
22	Health facilities of fisher's community of (a) Bukvora *Baor* (b) Khatura *Baor*, Jashore	72
23	Major negative impacts of *Baor* fisher's communities during Covid-19 situation.	73
24	Major positive (green line) and negative effects (red line) of *Baor* fisher's communities during Covid-19 situation.	78
25	Position of different anatomical landmarks of *Hyporhamphus limbatus* for creating truss networks on fish body (illustrated as a close circle).	80
26	Principal component analysis (PCA) of morphometric data and ratios of *Hyporhamphus limbatus* obtained from different stocks of Bangladesh.	81
27	Dendrogram from truss measurements derived from UPGMA cluster analysis based on the Euclidean distance between the stock centroids.	81
28	Position of different anatomical landmarks of *Ompok bimaculatus* for creating truss networks on fish body (illustrated as a close circle).	82
29	Principal component analysis (PCA) of morphometric data and ratios of *Ompok bimaculatus* obtained from different stocks of Bangladesh.	82
30	Dendrogram from truss measurements derived from UPGMA cluster analysis based on the Euclidean distance between the stock centroids.	83
31	Position of different anatomical landmarks of *Cirrhinus reba* for creating truss networks on fish body (illustrated as a close circle).	83
32	Principal component analysis (PCA) of morphometric data and ratios of *Cirrhinus reba* obtained from different stocks of Bangladesh.	84
33	Dendrogram from truss measurements derived from UPGMA cluster analysis based on the Euclidean distance between the stock centroids.	84
34	Position of different anatomical landmarks of *Lepidocephalichthys annadalei* for creating truss networks on fish body (illustrated as a close circle).	85
35	Principal component analysis (PCA) of morphometric data and ratios of *Lepidocephalichthys annadalei* obtained from different stocks of Bangladesh.	85
36	Dendrogram from truss measurements derived from UPGMA cluster analysis based on the Euclidean distance between the stock centroids.	86
37	Principal component analysis (PCA) of morphometric data and ratios of *Glossogobius giuris* obtained from different stocks of Bangladesh.	86
38	Dendrogram from truss measurements derived from UPGMA cluster analysis based on the Euclidean distance between the stock centroids.	87

39	Position of different anatomical landmarks of *Channa punctata* for creating truss networks on fish body (illustrated as a close circle).	87
40	Principal component analysis (PCA) of morphometric data and ratios of *Channa punctata* obtained from different stocks of Bangladesh.	88
41	Dendrogram from truss measurements derived from UPGMA cluster analysis based on the Euclidean distance between the stock centroids.	88
42	Principal component analysis (PCA) of morphometric data and ratios of *Lepidocephalichthys guntea* obtained from different stocks of Bangladesh.	89
43	Dendrogram from truss measurements derived from UPGMA cluster analysis based on the Euclidean distance between the stock centroids.	89
44	Position of different anatomical landmarks of *Macrognathus pancalus* for creating truss networks on fish body (illustrated as a close circle).	90
45	Principal component analysis (PCA) of morphometric data and ratios of *Macrognathus pancalus* obtained from different stocks of Bangladesh.	90
46	Dendrogram from truss measurements derived from UPGMA cluster analysis based on the Euclidean distance between the stock centroids.	91
47	Monthly variation of GSI of *Gudusia chapra*	92
48	Monthly variation of GSI of *Glossogobius giuris*	93
49	Monthly variation of GSI of *Macrognathus pancalus*	94
50	Monthly variation of GSI of *Heteropneustes fossilis*	94
51	Monthly variation of GSI of *Lepidocephalichthys guntea*	95
52	Monthly variation of GSI of *Anabas testudineus*	96
53	Indexes of the gut content and their percentage for combine sex of *P. ticto* collection from Bukvora *Baor*, Jashore.	96
54	Indexes of the gut content and their percentage for male (a) and female (b) of *P. ticto* collection from Bukvora *Baor*, Jashore.	97
55	Food items of individuals for combined sex of *P. ticto* collected from Bukvora *Baor*, Jashore.	98
56	Food items for male of *P. ticto* collected from Bukvora *Baor*, Jashore	98
57	Degree of fullness (FI) of stomach in *G. chapra* (b) Monthly variations of gastro-somatic index (GaSI) of *G. chapra*	99
58	Indexes of the gut content and their percentage of *H. fossilis* collection from Bukvora *Baor*, Jashore.	100
59	Food items of *H. fossilis* collected from Bukvora *Baor*, Jashore.	101
60	(a) Degree of fullness (FI) of stomach (b) Food items of *A. testudineus* collected from Bukvora *Baor*, Jashore.	102
61	(a) Degree of fullness (FI) of stomach (b) Food items of *M. pancalus* collected from Bukvora *Baor*, Jashore.	103

Executive Summary

Baors are oxbow lakes formed by dead river arms which are the vital inland water assets in the fisheries sector of Bangladesh. Previously, Small indigenous fish species (SIFS) were abundant in *Baors* and SIFS are regarded primarily as a source of food and livelihood, so they are highly valuable economical commodity. The abundance of indigenous fish species and reason behind their extinction from Jhenaidah and Jashore district as well as observed life history features of seven stocked fish species, including population structure, growth, sexual maturity (L_m), spawning season, fecundity, length at first recruitment (L_r), growth parameters, mortality (i.e., total mortality (Z), natural mortality (M_W), and fishing mortality (F)), exploitation (E), maximum sustainable yield (MSY) and optimum catchable length (L_{opt}) with management policies were comprehensively studied from the Saganna and Sarjat *Baor*s, Jhenaidah and Bukvora *Baor* and Khatura *Baor*, Jashore during October 2019 to June 2022. The baseline survey of the fish biodiversity and causes of decline fishes were conducted through Fishers Personal Interview (FPI), Focus Group Discussion (FGD), Key Informant Interview (KII) and categorized them into seven ranks. A total of 7 indigenous fish species including *Anabas testudineus*, *Channa punctata*, *Heteropneustes fossilis*, *Mystus tengra*, *M. vitatus*, *M. cavasius* and *Ompok pabda* were stocked for domestication as a spawner to observe their endure and sustainably through own reproduction and recruitment process. Monthly samples were collected using traditional fishing gears by the hired fishing boats and fishers. Individual lengths (total and standard) were noted up to 0.01 cm by using a measuring board and body weight (BW) was taken by an electric balance with 0.01 g accuracy. Size at sexual maturity (L_m) estimated by TL *vs*. GSI model (GSI % = (GW/BW)*100) (Nikolsky, 1963) and to estimate the spawning season of this species, monthly variation of GSI was assessed. Stock structure of 8 indigenous fishes were analyzed through truss networking. The food and feeding habit of selected 5 SIFS were estimated from Bukvora and Khatura *Baor*. A number of 27 SIFS and 8 cultured species were found from selected *Baor*. Based on survey, about 18 indigenous fish species from Sarjat *Baor*, 3 from Sagana *Baor*, 6 from Fatehpur *Baor*, 1 from Kapashaia *Baor*, 2 from Porapara *Baor*, 3 from Katgora *Baor* have been disappear. These species were extinct before 15 to 25 years ago except Saganna *Baor* (2-3 years ago). Predatory fishes were the major cause for the declining of indigenous fishes in the Saganna *Baor* and introduce of culture species were a key cause for declining in Sarjat *Baor*. In addition, the major causes for the declining of indigenous fish species were over fishing and small mesh sizes of fishing nets in the both Bukvora and Khatura *Baor*. Maximum total length (TL) was noted as 32.80 cm and 32.50 for *O. pabda* from Saganna and Sarjat *Baor*, respectively while minimum TL was noted as 4.50 and 5.10 cm for *M. tengra* from Saganna and Sarjat *Baor,* respectively. Size at sexual maturity was calculated for 7 stocked fishes; the minimum was 7.34 cm for *M. tengra* and maximum was at 17.86 for *O. pabda*. The GSI variations were indicated that the peak spawning season of most SIFS in June-July. Minimum size at first recruitment (L_r) was 5.30 cm for *M. tengra* and maximum was 9.30 cm for *H. fossilis* from Saganna *Baor* while, minimum L_r was 5.30 cm for *M. tengra* and maximum L_r was 9.20 cm for *H. fossilis* from Sarjat *Baor*. Mimimum Z was obtained as 1.36 year^{-1} for *M. cavasius* and maximum as 3.00 year^{-1} for *O. pabda* from Saganna *Baor* and in Sarjat *Baor* minimum Z was 1.53 year^{-1} for *M. vittatus* and largest was 4.79 year^{-1} for *A. testudineus*. Maximum L_{opt} was 21.20 cm for *O. pabda* and minimum was 8.79 cm for *M. tengra* from Saganna *Baor* and maximum L_{opt} was 21.0 cm for *O. pabda* and minimum was 8.79 cm for *M. tengra* from Sarjat *Baor*. From GSI variations, most of the *Baor* fishes spawn in June and July months, so fishing ban period should be established during this time. Thus, these finding would be useful for long term sustainable management policy of small indigenous fish species in the *Baors* of southwestern Bangladesh. Various problems among *Baor* fishers were found through field survey where the major contributor is lack of alternative income sources (36%) and large family size (26%), respectively. The livelihood and socio-economic status of *Baor* fishers were studied for the improvement.

Keywords: *Baors;* Decline cause; L_{opt}, Mortality; Size at sexual maturity; Spawning season

PBRG Sub-project Completion Report (PCR)

A. Sub-project description

1. Title of the PBRG sub-project

Sustainable Development of Indigenous Fisheries in *Baors* of Southwestern Bangladesh through Multiple-Functions for Ensuring the Food Security

2. Implementing organizations: Department of Fisheries, University of Rajshahi, Rajshahi-6205 and Department of Fisheries and Marine Bioscience, Faculty of Biological Science and Technology, Jashore University of Science and Technology Jashore-7408.

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*
Dr. Md. Monirul Islam Member Director Fisheries Division, BARC Farmgate, Dhaka, Phone: 01716-350628 E-mail: md-fisheries@barc.gov.bd	Dr. M. A. Awal Member Director Fisheries Division, BARC Farmgate, Dhaka, Phone: 01716-350628 E-mail: md-fisheries@barc.gov.bd	Dr. Md. Rafiqul Islam Director Nutrition Unit, BARC Farmgate, Dhaka, Phone: 01716-350628 E-mail: dir.nutrition@barc.gov.bd

Principal Investigators

Component-1 (RU)

Dr. Saleha Jasmine
Professor, Department of Fisheries
University of Rajshahi, Rajshahi 6205
Tel: 0721-711117, Cell: +88 01712008433
E-mail: salehajasmine@yahoo.com

Component -2 (JUST)

15 Oct'19 to 15 Mar'21	*16 Mar'21 to 31 Oct'22*
Md. Sarower-E-Mahfuj Asstt. Professor, Dept. of Fisheries and Marine Bioscience Faculty of Biological Science & Technology Jashore Univ. of Science & Technology Jashore-7408 Mobile: +88-01923-396947 E-mail:sa.mahfuz@gmail.com	Md. Abdus Samad Assoc. Professor Dept. of Fisheries and Marine Bioscience Faculty of Biological Science & Technology Jashore Univ. of Science and Technology Jashore-7408 Cell: +88-01750-064350 E-mail: abdussamadjstu@gmail.com

Co-principal Investigators

Component-1 (RU)

Dr. Md. Yeamin Hossain
Professor, Department of Fisheries
University of Rajshahi, Rajshahi 6205
Telephone: 0721-711117
Cell: +88-01751566077
E-mail: hossainyeamin@gmail.com

Component -2 (JUST)

Md. Habibur Rahman
Assistant Professor, Dept. of Fisheries and Marine Bioscience
Faculty of Biological Science and Technology
Jashore University of Science and Technology, Jashore-7408
Cell: +88-01515-640573
E-mail: habib07-fmb@just.edu.bd

4. Sub-project budget (Tk)

4.1	**Total:(in Tk as approved)**	**:Tk. 24000000.00**
i.	Coordination component	:Tk. 2332,000.00
ii.	Component 1 (RU)	: Tk.12556,000.00
iii.	Conponent 2 (JUST)	: Tk. 9112000.00
4.2	**Latest Revised (if any)**	**:Tk. 29118000.00**
i.	Coordination component	: Tk. 3600000.00
ii.	Component 1 (RU)	:Tk. 14906000.00
iii.	Conponent 2 (JUST)	:Tk. 10612000.00

5. Duration of the sub-project

5.1 Start date (Based on LoA signed) : 15 October 2019
5.2 End date : 31 October 2022

6. Background of the sub-project

Baors are oxbow lakes, formed by dead arms of rivers, are situated in the moribund delta of the Ganges in western part of Bangladesh. There are more than 600 *Baor* in south-western Bangladesh, covering an area of 5,488 ha, each ranging from 10 to 500 ha, mostly situated in three greater districts of Jashore, Kustia and Faridpur having many of these concentrations in greater Jashore district. According to DoF (2020), the current production of *Baor* is 5671 MT. There is common property of these water-bodies, which have a high potential of production of fish resources. These *Baors* support many of the 260 freshwater fish species which are in declining trend and produce 7,729 metric ton fish annually (FRSS, 2017). They offer tremendous scope and potential used as an important feeding and spawning ground by many freshwater fish species (Mazid et al., 2005). However, despite relatively small contribution to nationwide fish production 84,000 people are directly and indirectly depend on *Baors,* where majority of them are poor (FRSS, 2017).

About 260 species of freshwater fishes are found in the inland water bodies of Bangladesh. Inland fisheries alone cover an area of 4.3 million hectares of which 94% comprise open-water capture fisheries and only 6% are under close water systems. Recently, most of the *Baors* brought under culture are commonly stocked with exotic carp species. But consumer preferences are now changing from carps to indigenous species gradually. Though few small indigenous species are cultured in pond now-a-days with commercial feed and chemicals, but they are losing consumer liking due to less taste and the probability of health hazards. People are becoming more interested in indigenous species obtained from wild sources. From the available indigenous fishes in *Baors*, the most targeted species are *Botia dario, B. lohachata, Channa orientalis, Esomus danricus*, *Heteropneustes fossilis, Macrognathus pancalus, Nandus nandus*, *Ompok pabda, Pethia phutunio, P. ticto, Trichogaster fasciata, T. lalius etc.* for the small-scale fishers (Mawa et al., 2022). However, currently most of the *Baors* have already lost its fashionable characteristics due to natural as well as human intervention. Due to over exploitation of fish including use of harmful fishing gears and system (fishing by dewatering), degradation and loss of fish habitats, increase agriculture production and road communication, siltation of water bodies by natural process, introduction of a number of alien fish species and water pollution by industry and agrochemicals, the natural inland fish stocks have declined significantly and fish biodiversity have been affected seriously (Ali et al., 2009). Also, due to competition and intervention of aquaculture (e.g., use of fertilizers and feeds) some small indigenous fish species have been locally extinct or threatened in the *Baor*. Moreover, man-made causes together with climate change are responsible for degradation of the *Baor* fisheries.

Population structure provides rudimentary data to evaluate stock structure of fish stocks (Vazzoler, 1996). Knowledge on the growth pattern of fish is crucial to estimate weight from length. Also, the growth pattern is helpful for the researcher to assess the condition and health of fshes (Hasan et al., 2020). The L_m in fish may depend on environmental condition and can assist to defne the minimum catchable size of fshes (Lucifora et al., 1999). The size of sexual maturity variation is a crucial element in determining the infuence of fshing mortality on spawning populations and the best fshery level (Hasan et al., 2020), also used as an indicator of minimumpermissible catchable size (Hasan et al., 2020). Length and age at maturity control, how fast individuals start their reproduction in a certain population and how much they can reproduce, as fecundity, are very often related to size (Khatun et al., 2019).

Determination of the full- and peak-spawning seasons of adult fish is important for conservation the minimum catchable size of fishes (Lucifora et al., 1999; Hasan et al., 2021).

Estimating the spawning period of fshes is crucial for conserving the matured from the excessive fshing stress (Templeman, 1987). In spawning stage assessments, the gonadosomatic index is a pointer of the reproductive process mainly used to estimate the spawning and peak spawning season in fish and determine the gonad maturation stages (Le Cren, 1951). The condition factor is considered as a numerical factor of fish's well-being, representing current feeding conditions and their efect on development, reproduction and survival, towards determining the population success (Le Cren, 1951). To understand the diferences in population levels, fecundity is an integral part of fish biology (Akter et al., 2007). It is very crucial for assessing its life history, stock, culture, and management approach (Doha and Hye, 1970). Variances in fecundity among species frequently reveal different reproductive strategies (Murua and Saborido-Rey, 2003). Recruitment typically refers to a new cohort in the catch due to becoming big or old enough to be vulnerable to the fishery (Sabbir et al., 2021).

Fish mortality is a measure used to account for the loss of fish in a fish stock due to death. Two types of mortality can be distinguished (natural and fishing). Natural mortality refers to the loss of fish from a stock owing to factors other than fishing, such as disease, cannibalism, competition, predation, old age, and pollution, or any other natural condition that causes fish death whereas fishing mortality means the loss of fish from a stock as a result of fishing (Sparre et al., 1989). The term "exploitation" implies the idea of making use of the population, and in fisheries is generally regarded as a process which should be continued indefinitely without destroying the population. The L_{opt} for a given stock is defined as the intermediate length class, where the product of individuals times their average weight reached a maximum (El-Ganainy and Riad, 2008). The biomass of fish is often a major consideration in fisheries management, where in some cases major reproductive capacity could be invested in relatively few, old, large-size individuals that could produce exponentially more eggs than smaller size conspecifics (Bohnsack, 1996). Maximum sustainable yield (MSY) is theoretically, the largest yield (or catch) that can be taken from a species' stock over an indefinite period. The purpose of this sub-project is to sustainable management of indigenous fishes in the *Baors* and to ensure the food security and livelihood of a number of fishers in *Baor* regions of Bangladesh.

7. Sub-project general objectives

- To enlist the fish species with emphasis on indigenous fishes and its stock status in *Baors* of Southwestern Bangladesh.
- To enhance the indigenous fish production and upgrade the livelihoods of fishers' community through sustainable management of *Baor*s fisheries.
- To identify the threats/ factors to *Baors* fisheries resources in Bangladesh.

8. Sub-project specific objectives

Coordination component (BARC)

- 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;
- To coordinate project implementation efforts and integration of activities to generate desired information /technology as per methodology of the sub-projects;
- Identify operational deviations and addressing constraints/problems (if any) under a process of strong and regular monitoring of the project activities;
- To upgrading the level of output of the sub-project through reviewing of yearly technical progress;
- Collect and collate project data, finding and observation and production of compiled Project Completion Report (PCR).

Component-1 (RU)

- To find out the fish diversity with emphasis on indigenous fish species through monthly sampling and later to confirm the size & age-at-sexual maturity, spawning- and peak- season of indigenous fishes in *Baors* of southwestern Bangladesh.
- To identify the major man-made and natural causal factors for declining of indigenous fish species in *Baors* of southwestern Bangladesh.
- To identify the stocks' status with emphasis on relative abundance (CPUE), longevity, size and age-recruitment, exploitation rate, maximum sustainable yield, biomass after and before the ranching of targeted indigenous.

Component-2 (JUST)

- To assess the fish diversity index and causal factors for declining of indigenous fish species in *Baors* of Jashore and later to confirm its spawning and peak season.
- To study the livelihoods of fishers' community in *Baors* of Jashore district.
- To estimate the stock structure delineation and reproductive potentiality and its success of indigenous fishes after and before the ranching programme.

9. Implementing locations

The study areas were located at Saganna and Sarjat *Baor*, Jhenaidah region (23.5450° N, 89.1726° E), southwestern Bangladesh (RU) and at Bukvora *Baor* and Khatura *Baor*, Jashore district (23.1634° N, 89.2182° E), southwestern Bangladesh (location map and sampling sites are shown in Fig 1 & 2 under methodology section).

10. Methodology in brief (componentwise)

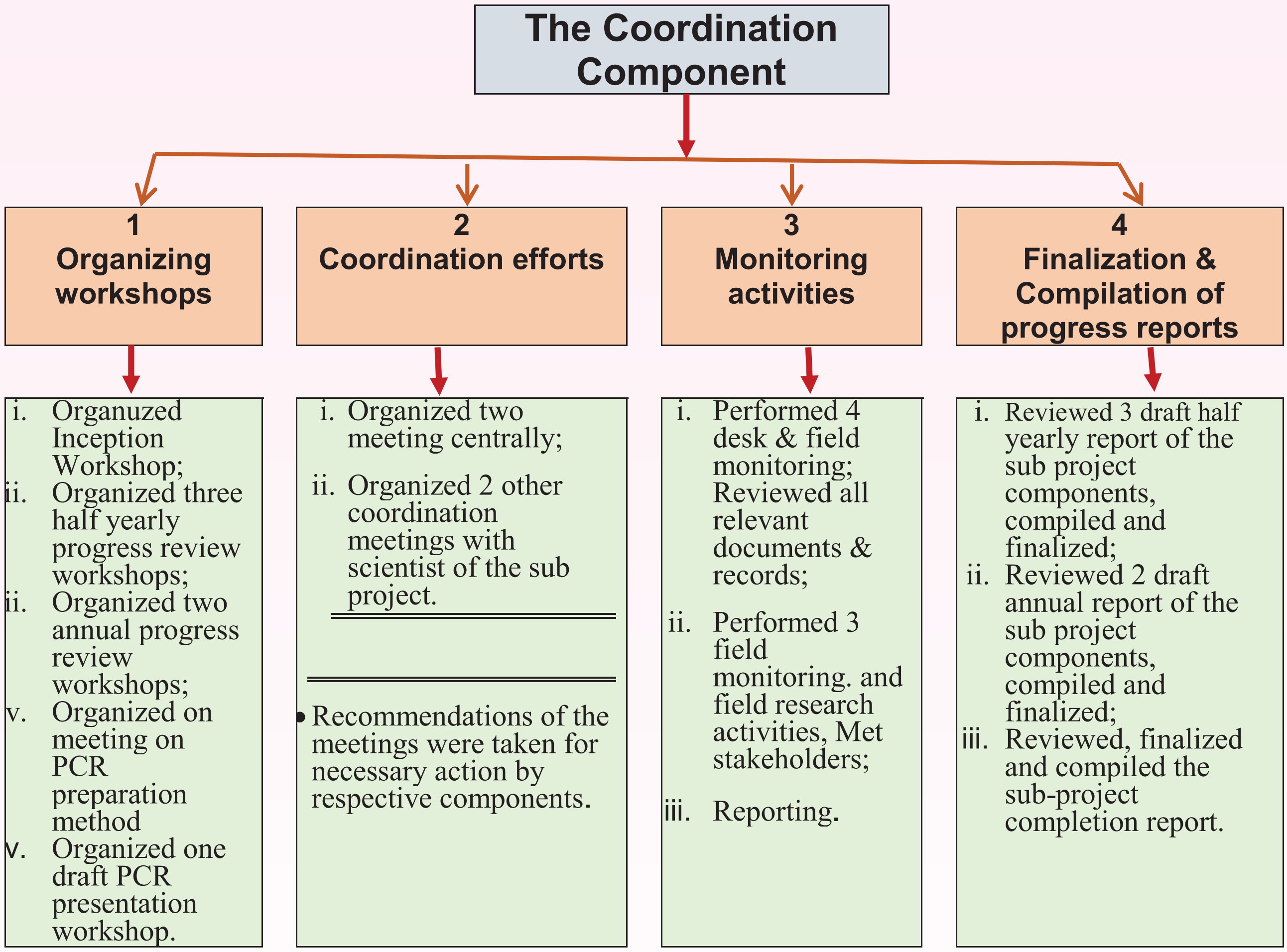
10.1. Activity implementation approach of the Coordination component

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 hereunder in **Annexures: BARC (A – E).**

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

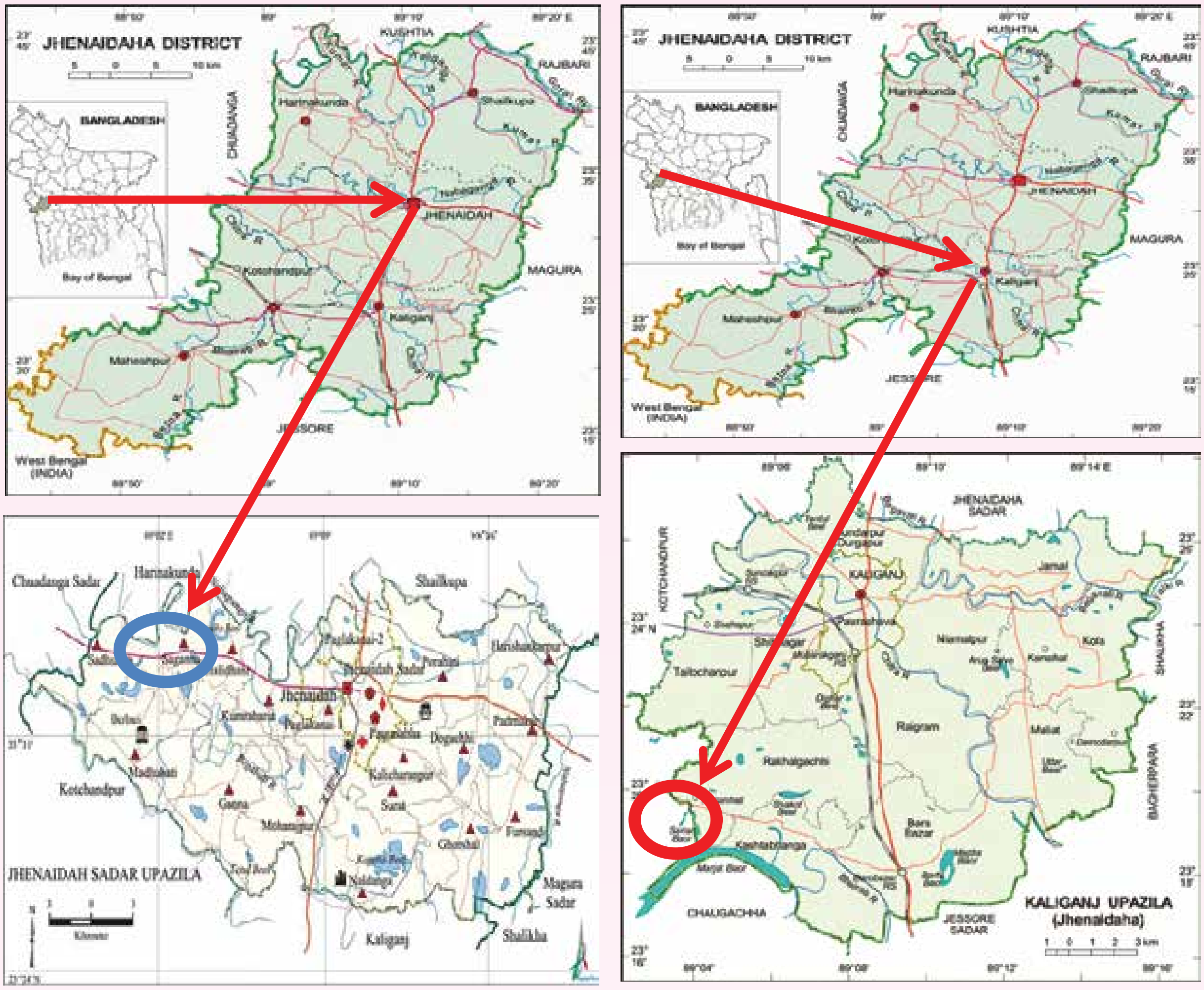
Summary statement of achievements		
Name of activities	**Performance against each component of the sub-project**	**Remark**
Inception workshop	Organized centrally at BARC in November' 2018	Attended all PI, Co-PI & expert members.
Revision of PP	Done as per recommendations of inception workshop	
Half 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	04 *(Two meetings held virtually)*	All coordination meeting held centrally.
Monitoring of field and Lab activities	04 *(RU & JUST)*	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. 90% 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);

Pictorial views of different workshops, coordination meetings and field monitoring activities

10.2. Component 1(RU)

10.2.1. Selection of study sites

The study was conducted in *Baors* of southwestern Bangladesh covering Jhenaidah region (23.5450° N, 89.1726° E) (Fig 1). After field survey on different *Baors,* two *Baors* (Saganna and Sarjat) were selected in Jhenaidah district, southwestern Bangladesh.



O= Saganna *Baor*; O= Sarjat *Baor*

Fig 1. Location of study sites (Left- Sarjat *Baor* and Right- Saganna *Baor,* Jhenaidah).

10.2.2. Baseline survey of fish biodiversity and status of indigenous fish species

The baseline survey of the fish biodiversity was conducted through Personal Interview (PI), Focus Group Discussion (FGD), Key Informant Interview (KII) using questionnaire and checklist. The questionnaire and checklist were pretested before using for field data collection. All fish fauna were catagoried into seven ranks on the basis of more than 35 FGDs, 105 PIs and 15 KIIs. The ranks are categorized as TY (throughout the year), TYS (throughout the year in small amount), TYL (throughout the year in large amount), SM (found in small amount during monsoon), LM (found in large amount during monsoon), R (rare), VR (very rare) and NE (not evaluated). Conservation statuses of fishes were done in Bangladesh and global aspects using IUCN record (2021). We collected information about the extinct fish specie which disappears within 2-25 years ago from five suvey *Baors*. Secondary data was collected from upazila Fisheries Office of Jhenaidah district, journals to cross check and thus authenticate the primary data.

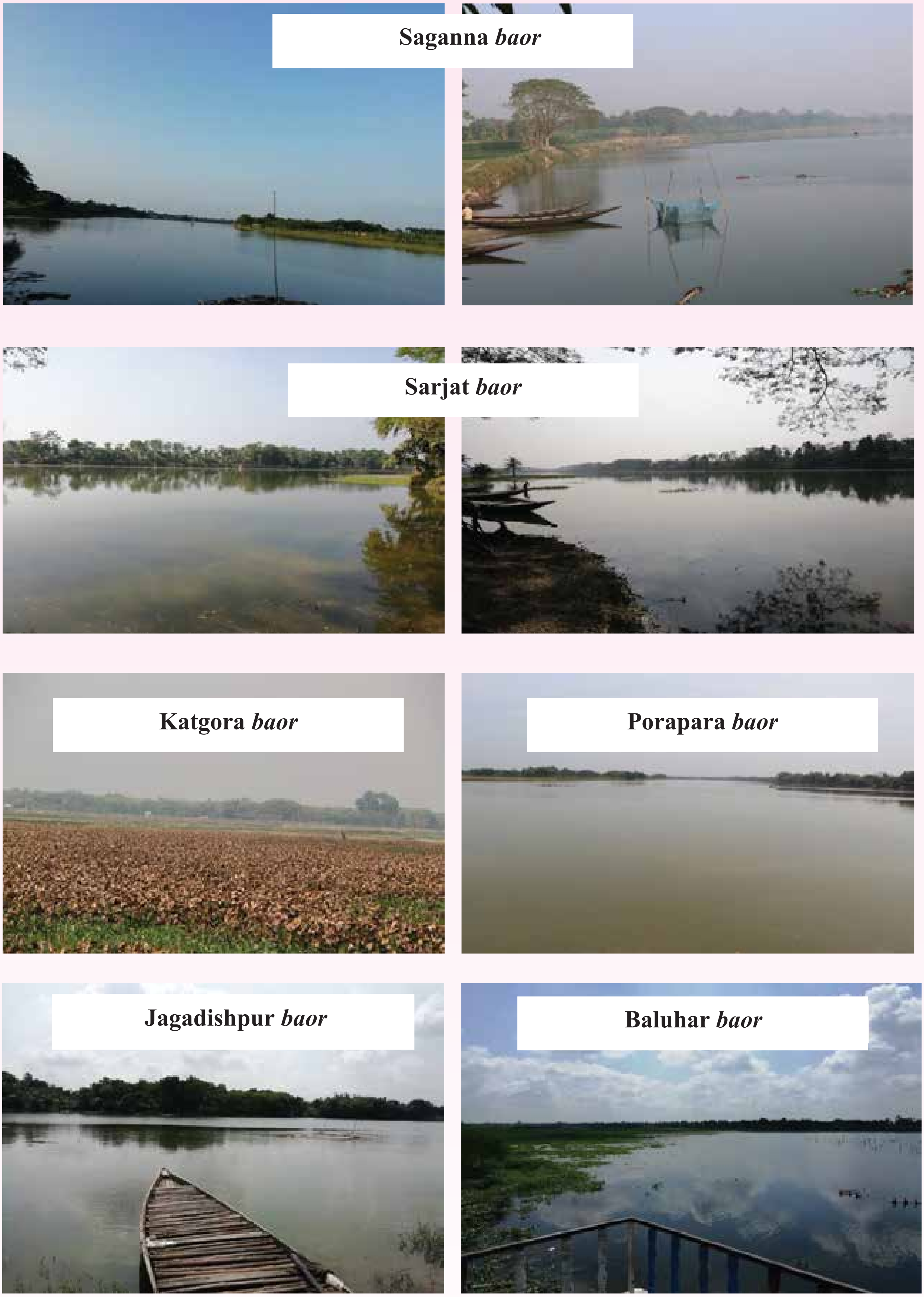


Plate 1. Preliminary survey of *Baors* in Jhenaidah District

Plate 2. Data collection by interview with local fishes, FGD, District Fisheries Officer (DFO), Senior Upazilla Fisheries Officer (SUFO), Upazilla Fisheries Officer (UFO) and Training Officer (TO) and other personnels

10.2.3. Causal factor for threatening/ declining of indigenous fish species

Information about the causal factors which are responsible for the decling of fish population from study areas were done by interview with fishers, fish traders, teachers, students, researchers, government officials (DFO, SUFO) and NGO personnel and experienced persons related to fisheries sectors from journals and publications.

10.2.4. Fish stocking

Indigenous 7 fish species were selected and stocked them after marking and tagging to observe the changes of relative abundance by catch per unit effort and reproductive potentiality through gonadal studies. Selected species were *Anabas testudineus*, *Channa punctata*, *Heteropneustes fossilis*, *Mystus tengra*, *Mystus vitatus*, *Mystus cavasius* and *Ompok pabda* those were collected from local fish hatcheries and live fish traders. Stocking density was maintained as 10-30 individuals /decimal for each species. Total length (TL) was varied within 6.23-14.68 cm and BW was 4.77-37.49 g for 7 stocked. Restocking of high valued indigenous species fishes were also found potentials not only for food and nutrition supply and income generation but also for effective utilization of the *Baor*. The list of stocked brood fishes (adult) with their body weight, total length and stocking number in the Saganna and Sarjat *Baors* are presented in Table 1.

Table 1. Body weight, total length and number of stocked brood fishes in the Saganna and Sarjat *Baors*

Species Name	Local name	Measurement (Mean ± SD)		Stocking number	
		TL	BW	Saganna	Sarjat
Anabas testudineus	Koi	11.85 ± 0.52	35.74 ± 3.24	3000	2800
Channa punctatas	Taki	13.78 ± 0.57	37.79 ± 2.28	2200	2550
Heteropneustes fossilis	Shing	14.68 ± 1.20	11.44 ± 4.34	2300	2200
Mystus tengra	Tengra	7.74 ± 0.35	5.90 ± 0.89	2975	2500
Mystus vitatus	Choto tengra	6.23 ± 0.288	4.77 ± 0.68	2500	2650
Mystus cavasius	Gulsha tengra	11.98 ± 0.30	11.92 ± 2.78	2600	2680
Ompok pabda	Pabda	9.34 ± 1.85	8.07 ± 2.40	3600	3930

TL= Total Length; BW= Body Weight

…

Plate 3. Brood stocking activities in Saganna and Sarjat *Baor* in Jhenaidah region, south western Bangladesh

10.2.5. Data analyses in laboratory

To determine the growth and other physiology status of stock fish laboratory analyses were done. The fresh samples were immediately placed in ice, and then fix in 10% formalin on arrival in the laboratory. The fixed specimens were then taken out one by one later to be weighed, measured and sexed. 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, pre-dorsal, post-dorsal, anal-length were measured to the nearest 0.01 cm and body weight (BW) was being taken with 0.01 g accuracy.

Plate 4. Fish body measurement and dissection were done of Saganna and Sarjat *Baors* in Jhenaidah region, south-western Bangladesh.

10.2.6. Length-frequency distribution (LFD)

Length frequency distribution for each sex was made individually with 1.0 cm intervals of TL.

10.2.7. Monthly increases length of stocked fishes

Monthly increase of stocked fishes observed with the change of total length (TL) and body weight (BW).

10.2.8. Size at first sexual maturity, spawning and peak-spawning season

Size at sexual maturity (L_m) estimated by TL *vs*. GSI model (GSI % = (GW/BW)*100) (Nikolsky, 1963) and to estimate the spawning season of this species, monthly variation of GSI was assessed.

10.2.9. Fecundity

According to Murua et al. (2003), total fecundity (F_T) was estimated by the gravimetric method.

Plate 5. Fish sampling and its morphometric measurements

10.2.10. Estimation of growth parameter, length at first recruitment

Growth parameter such as asymptotic length (L_∞) was calculated based on maximum observed length using the empirical model as: log (L_∞) = 0.044 + 0.9841* log (L_{max}) (Froese and Binohlan, 2000). The another growth parameter, growth co-efficient (K) was calculated by $K = ln(1+L_m/L_\infty)\ t_m$ (Beverton and Holt, 1992). The age at zero length (t_o) of this species was determined by log (-t_0) = (-0.3922 - 0.2752 log L_∞- 1.038 log K) (Pauly, 1980). Length at first recruitment, L_r (mean length of first modal group) was estimated through LFDs of 1.0 cm intervals using Excel-add-in-Solver.

10.2.11. Estimation of mortality, exploitation, biomass, MSY and L_{opt}

Total mortality (Z) was estimated by the length converted catch curve method (Pauly, 1983). 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 (^oC) 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 Beverton and Holt (1966) described yield per recruit model, is the best widely used method for the estimation of yield per recruit model which was expressed as a function of L_c/L_∞, F/K, M/K, and relative fishing mortality F/M. Optimum catchable length calculated by the equation of Beverton (1992) as: $L_{opt}= 3L_\infty(3+MK^{-1})^{-1}$ where L_∞ is the theoretical asymptotic length.

10.2.12. Data analyses

All data and figures were analyzed by using Microsoft® Excel-add-in-solver, GraphPad rison 8.0 and PAST 4.03 software.

10.3. Component 2 (JUST)

10.3.1. Site selection

The pilot survey and transect study was conducted randomly in different *Baor*s of Jashore District, southwestern Bangladesh from October 2019 to June 2022. In the four major *Baor* namely Bukvora *Baor*, Joghati *Baor*, Bahadurpur *Baor*, and Khatura *Baor* under the Jashore district were studied and among them Bukvora *Baor* and Khatura *Baor* were selected. The Bukvora *Baor* and Khatura *Baor* are the major contributors of fish diversity in Bangladesh. Moreover, these aforementioned two boars also serve as the potential ecological niches for indigenous fish spawning and breeding.

10.3.2. Baseline information about the *Baor*s of Jashore districts

Baseline information of the studied four *Baors* namely, 1. Bukvora *Baor 2.* Joghati *Baor 3.* Khatura *Baor and 4.* Bahadur Pur *Baor* are presented in four separate boxex as follows**:**

Baor name: Bukvora *Baor*
Location: Churamonkathi, Halsha, Ichapur, Mohtbari, Arichpur
Union: Doara Model Union
Upazila: Jashore Sadar
District: Jashore
Area: 385 acres
Water Depth: 1.8 to 2.2 meters
Available SIFS: Shing, Chapila, Koi, Bele, Mola, Darkina, Punti, Tengra, Taki, Cheng, Shol, Aor, Veda, Kakila, Chanda.

Box-1

Baor name: Joghati *Baor*
Location: Kamla pur, Jagohati
Union: Churamonkathi
Upazila: Jashore Sadar
District: Jashore
Area: 122 acres
Water Depth: 1.7 to 1.8 meters
Available SIFS: Shing, Koi, Bele, Mola, Darkina, Punti, Tengra, Taki, Cheng, Shol, Veda, Kakila, Chanda

Box-2

Baor name: Khatura *Baor*
Location: Khatura, Modhupur, Boro Chetla, Kola, Muktarpur
Union: Horihor Nagar Union
Upazila: Monirampur
District: Jashore
Area: 290 acres
Water Depth: 2 to 2.5 meters
Available SIFS: Naptani Koi, Gojar, Chapila, Shing, Koi, Bele, Mola, Darkina, Punti, Tengra, Taki, Cheng, Shol, Aor, Veda, Kakila, Chanda.

Box-3

Baor name: Bahadur Pur *Baor*
Location: Shakhari Pota, Bahadur Pur, Benapole,
Union: Benapole
Upazila: Sharsha
District: Jashore
Area: 300 acres
Water Depth: 1.9 to 2.3 meters
Available SIFS: Gojar, Shing, Koi, shorpunti, Napit koi, Bele, Mola, Darkina, Punti, Tengra, Taki, Cheng, Shol, Aor, Veda, Kakila, Chanda

Box-4

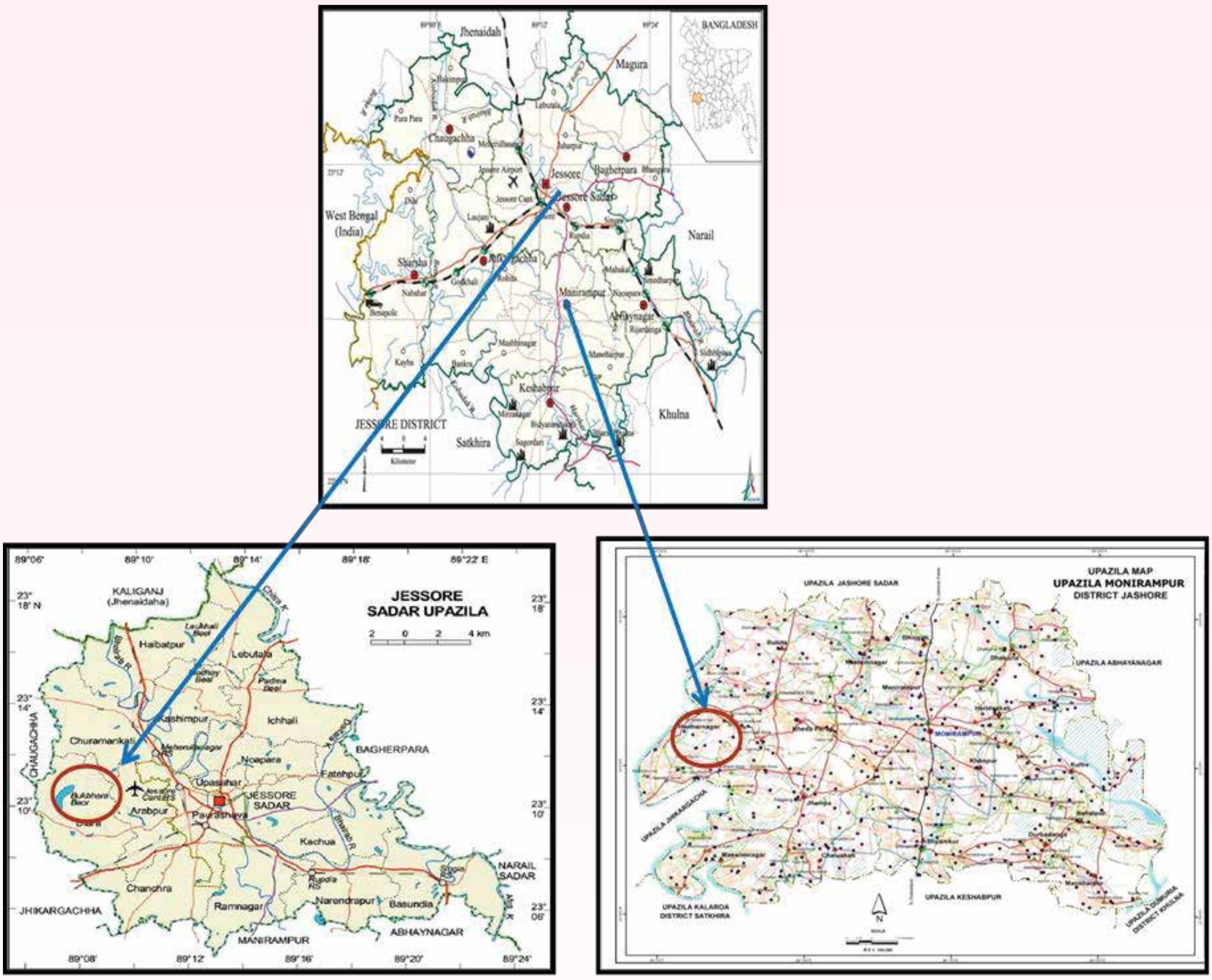


Fig 2. Location of study sites (Left- Bukvora *Baor* and Right- Khatura *Baor,* Jashore).


Ongoing Project

Plate 6. Data collection by interview with local fishes, FGD, District Fisheries Officer (DFO), Senior Upazilla Fisheries Officer (SUFO) and other personnels

10.3.3. Fish sampling

Fish sampling was done monthly with the help of traditional fishing nets *viz*. cast nets, gill nets, lift nets and fishing traps. All these fishing gears were operated at the same spot within 0.5 km area to ensure harvesting of maximum species of study site in the catch. Immediately after harvesting, the fishes were counted on the spot. However, on the spot if seem difficult to identify those species was preserved in 7 to 10% buffered formalin solution and transported to the Laboratory of the Department of Fisheries, Jashore University of Science and Technology (JUST) for identification and further study.

Plate 7. Laboratory activities of measuring morphometric parameters of fish samples for studying the population parameters.

10.3.4. Stocking of small indigenous fish species (SIFS) and establishment of fish sanctuary

Selected indigenous fishes were stocked after marking and tagging with Flurochrome Dyes to observe the changes of relative abundance by catch per unit effort and reproductive potentiality through gonadal studies**.** Fish sanctuary was established for facilitating fish breeding and conservation. In Bangladesh, to date about 20 indigenous fish species have been domesticated and their culture protocols have been developed (Hossain and Wahab, 2009). Around 50% of the domesticated fishes are cypriniforms and now under nation-wide aquaculture. Koi (*Anabas testudineas*), Taki (*Channa punctata*), Magur (*Clarius batrachus*), Shingee (*Heteropneustes fossilis*), tengra (*Mystus cavasius*) etc. are considered as the major groups of fishes in *Baor* of Bangladesh which have high demand as well as high price. Stocking density was maintained as 10-30 individuals /decimal for each adult species. Restocking of high valued indigenous species fishes is also found potentials not only for food and nutrition supply and income generation but also for effective utilization of the *Baor*. During the study period we stocked mostly larger sizes of small indigenous fish species.

Plate 8. Restocking of SIFS in Bukvora Baor co-operation with the Baor Fishers and Upazila Fisheries Officer

Table 2: List of stocked fish with their total length, body weight, and number in the Bukvora and Khatura *Baor*

Fish Species	Common name	Measurement (Mean ± SD)		Name of *Baor*	
		Total length (Cm)	Body weight (g)	Bukvora *Baor* (n)	Khatura *Baor* (n)
Anabas testudineus	Climbing Perch	12.20±0.55	36.54±3.10	2200	2000
Channa Punctatas	Spotted snakehead	13.90± 0.60	39.45±2.34	1600	1400
Clarius batrachus	Philippine catfish	27.50±2.10	155.23±32.3	750	550
Heteropneustes fossilis	Stinging catfish	15.20±1.50	12.12±4.45	2200	2000
Mystus tengra	Tengara catfish	7.80±0.37	6.43±0.92	2400	2350
Mystus vitatus	Gangetic mystus	7.20±0.33	5.04±0.70	1550	1450
Mystus cavasius	Gangetic mystus	12.20±0.31	12.34±2.80	2600	2400
Ompok pabda	Butter catfish	9.76±1.76	8.34±2.38	3200	3000

10.3.5. Identification of fishes and fish status

Fish fauna was harvested from the study area and simultaneously identified based on their morphometric and meristics characters following Rahman (1989, 2005) and Talwar and Jhingran (1991). After identification, fish species was systematically classified according to Nelson (2006). Availability of fish species with emphasis on indigenous fish species was determined on the basis of their abundance during sampling and through interviewing of fishermen with questionnaire. Fish availability was categorized as TY (throughout the year), TYS (throughout the year in small amount), TYL (throughout the year in large amount), SM (found in small amount during monsoon), LM (found in large amount during monsoon), R (rare), VR (very rare) and NE (not evaluated). The relationship between the maximum total lengths (TL) attained by a species and the number of species attaining that TL (i.e., numbers expressed as cumulative percentage) was estimated during this study. Collected fishes were categorized based IUCN list.

10.3.6. Biodiversity parameters

To estimate the seasonal diversity of fishes in the study area, month-wise data were collected. Evenness and richness indices were calculated for understanding the status of diversity using the following formulas:

Shannon-Weaver diversity index, $H = -\Sigma \text{Pi} \ln \text{Pi}$ (Shannon and Weaver, 1949)

Margalef's richness index, $D = (S-1)/\ln N$ (Margalef, 1968)

Evenness index, $e = H/\ln S$ (Pielou, 1966)

Where, *H* is the diversity index, *Pi* is the relative abundance (s/N), *s* is the number of individuals for each species, *N* is total number of individuals, *D* is the richness index, *S* is the total number of species, *e* is the similarity or evenness index and *ln* is the natural logarithm.

10.3.7. Livelihood and socio-economic study

The livelihood and socio-economic study were conducted based on primary and secondary data. To complete the proposed study, survey method was used to collect primary data. The entire social and economic parameters were categorized according to the status reviewed from Paul et al. (2018). Assessment of socioeconomic status information was collected by research student about household activity, education, health, land ownership, sanitation, income, credits, savings etc. Well-designed questionnaire was formed including many socio-economic parameters with daily activities and survival strategies (Henry, 1990). Random sampling method was followed (Das et al., 2015) for questionnaire interviews. As sample, random 60 fishermen were selected from the study area. Fishermen were interviewed at the river sides and at their houses according to their availableness. Each fisherman was interviewed for half an hour. During present study, PRA (Participatory Rural Appraisal) tool (i.e. FGD (Focus Group Discussion) was arranged with fishermen (Ahmed, 1996). FGD was used to get some collective issues such as local fishing systems, social and economic status of fishermen with relative challenges etc. Cross-cheek Interviews (CI) was organized with key personals such as UFO (Upazila Fisheries Officer), AFO (Assistant Fisheries Officer) and related NGOs employers. Summary of all collected data was sorted carefully before the actual record. The arranged data was transferred to a calculation sheet from which segregated tables was prepared to describe the findings of the study. All collected data was categorized into three different capitals (i.e. human, physical and social with financial capitals) (Paul et al., 2018).

10.3.8. Market survey

Market survey was conducted based on Focus group discussion (FGD) in two selected *Baor*s.The major and important data was collected through questioning to the necessary respondent of the fish market during the study period. Necessary photograph for conducting this study was collected by digital camera during the study time. Summary of all data was sorted carefully before the actual record. The arranged data was transferred to a calculation sheet from which segregated tables was prepared to describe the findings of the study.

10.3.9. Causes of *Baor* fish reduction

All crucial data and information for underlying threats to biodiversity and management implementation was assessed survey on local fishers, fish farmers, fish businessman, researchers, NGO personnel's, government stake holder as well as highly experienced persons related to fisheries and aqua culturists and literatures. Additionally, data of agro-climatic condition was collected and evaluated from previous researches, books, webs and meteorological offices. Finally, several trainings were organized for local fish farmers to teach about the ecological maintenance, ecological threats, proper management system of *Baors* and indigenous fish species biology and its life cycle.

10.3.10. Study of stock structure analysis

Firstly the samples were washed in running fresh water. After washing, the water was sucked finely by using soft tissue paper from the body surface of fish. Then the fish was placed on a white paper as a background, which was used for capturing the digital image. Each individual was labeled with a specific code of identification. A cyber shoot DSC-W 300 digital camera (Sony, China) was used to capture the digital images, which provide a complete archive of body shape and allowed a repeat of the measurement when necessary (Cadrin and Friedland, 1999).

Approximately, eight to 10 landmarks delineating 16-25distances was measured on the fish body from left to right side by one person, therefore avoided the biasness. The landmark and truss measurements were varied according to the phenotype of fish. Truss distances from the digital images of specimens were extracted by using a linear combination of tpsDig2v2.1 (Rohlf, 2006). A box truss of 16-25 lines connecting these landmarks was generated for each fish species to represent the basic shape of the fish (Strauss and Bookstein, 1982). Then all measurements were transferred to a Microsoft Office Excel spreadsheet software, 2007 and SPSS 21 version software for subsequent analysis.

During the analysis, the size effect was eliminated from the data set. The variations were attributed to body shape differences and not to the relative sizes of the fish. Size dependent variation was corrected by adapting an allometric method as suggested by Elliot et al. (1995)

$$M_{adj} = M(L_s / L_o)^b$$

Where M is the original measurement, M_{adj} is the size adjusted measurement, L_o is the TL of the fish and L_s is the overall mean of the TL for all fish from all samples. Parameter *b* was calculated for each character from the observed data as the slope of the regression of log M on log Lo, using all fish in all stocks. The transformed data was checked for efficiency by testing the significance of the correlation between the transformed variable and the TL. The degree of similarity between the samples in overall analysis and the relative importance of each measurement was evaluated by using discriminant function analysis (DFA) with cross-validation. A dendrogram of the stocks based on the morphometric and landmark distance data was drawn by the unweighted pair group (UPGMA) and cluster analysis. A univariate analysis of variance (ANOVA) was carried out to test the significance of morphological differences. All statistical analyses were done using SPSS 21 (SPSS, Chicago, IL, USA).

10.3.11. Study of reproductive biology

Approximately 100 mature females of available indigenous fish species were collected randomly from two *Baor*s in Jashore district. All the samples were immediately transported to the laboratory analysis. Total length (TL) and standard length (SL) from each individual of specific species, and body weight (BW) and ovaries weight were weighed by electronic balance.

Gonadosomatic index (GSI) was calculated according to the formula as follows:
GSI = (gonad mass / somatic mass of the individual × 100%).
Size ($L_{m50\%}$) at first sexual maturity for fish was estimated by (i) relationship between TL *vs.* GSI (Khatun et al., 2018) (ii) maximum length-based equation (Binohlan and Froese, 2009).

10.3.12. Study of feeding habits

For feeding habit analysis, 5 live available fish species were collected from the same location (Table 3). All the samples were immediately transported to the laboratory analysis. Fishes were dissected and the stomach was carefully cut from the rest of the digestive tract. The condition of feed was assessed by the degree of distension of the stomach and expressed as full, 3/4 full, 1/2 full, ¼ full, tress and empty. These were known to as index of stomach fullness. The volume of stomach content was estimated by observation and was recorded on absolute scale. The largest volume was observed in preliminary study and finally allocated 100 points, and each of the stomachs was examined and then rated in one of the following categories 0, 3, 6, 12, 25, 50 and100 points, according to the volume of food present. The stomach contents were emptied into a Petri dish and examined under a binocular microscope with the help of Sedgewick Rafter Counting Cell Slide. Occurrence method was used for the qualitative analysis of food contents. Ecological niches and relation with the feeding behavior was studied during the study period.

Table 3. List of indigenous fish species used for the estimation of feeding habits.

Fish Species	Common name
Anabas testudineus	Climbing Perch
Gudusia chapra	Indian River Shad
Heteropneustes fossilis	Stinging catfish
Macrognathus pancalus	Barred spiny eel
Pethia ticto	Ticto barb

10.3.13. Identification of co-ownership management problem

Existing co-ownership management problem was investigated by using survey method to collect primary data. There are *Baor* fisheries teams (BFT) and fish farmers group (FFG) at the primary operational level and at the collective level in *Baor* management group (BMG). BTF/FFG is involved with the operation of *Baor* Fishery within *Baor* Boundary while BMG is the control body, this looks after the interest of all member fishers in the lake in general. This data was collected from local fisherman group. All collected data was analyzed for the findings of the study.

Plate 9. Monitoring of sub-project activities by different officials (DFO, SUFO, TO)

11. Results and discussions

11.1. Component 1(RU)

11.1.1 Fish biodiversity and status of indigenous fish species

During our study, total 25 species of indegeus fishes belonging to 12 families and 4 orders were identified from Saganna, Sarjat, Fatehpur, Kapashatia, Kathgora and Porapara *Baor* of Jhenaidah district. A total of 58 species were recorded from Dogger *Beel* in Hajigonj Upazila (Siddiq et al., 2013) which was much higher comparing with present study. List of available fish species with their scientific name, English name, local name, cultural status, conservation status in Bangladesh and global aspect are presented in Table 4. Also listed the extinct species which disappeared from different *Baors* were noted that about 18 species (*sp*.) were extinct from Sarjat *Baor* among them 10 *sp*. extinct about 15-29 years ago, 5 *sp*. about 20-25 years and 3 *sp*. about 5-6 years ago in Jhenaidah. In addition, 3 species were disappeared from Saganna, Fatehpur and Kathgora *Baor*s among them species of Saganna *Baor* extint about 2-3 years before, Fatehpur and Kathgora *Baors* species were extint around 15-20 years and 20-25 years ago, respectively. 1 and 2 species were extinct from Kaspashatia and Porapara *Baor*s almost 15-20 years back, respectively. The possible reason for the extinction fish species from the *Baors* was due to different natural and man-made causes. List of extinct fish species with their scientific name, English name, local name and year of extinction are documented in Table 5.

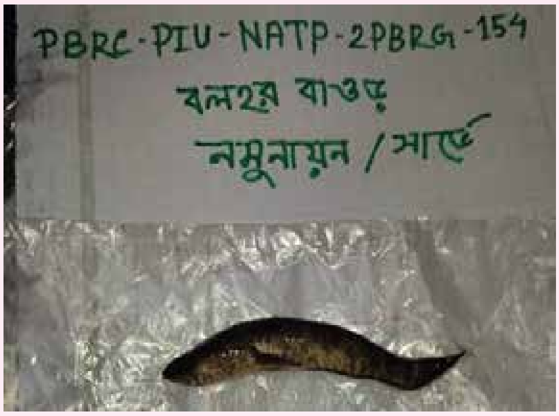
Table 4. List of available fish species in six *Baors* in Jhenaidah region, south-western Bangladesh

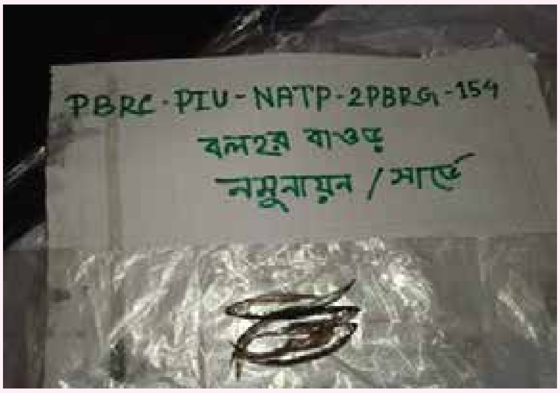
Baor	Species name	Common name	Local name	Na /Cul	Availa bility	IUCN B-desh	IUCN (Global) status
Saganna	*Amblypharyngodon mola*	Mola carplet	Mola	Na	R	LC	LC
	Anabas testudineus	Climbing perch	Koi	Na	TYS	LC	DD
	Channa orientalis	Walking snakehead	Cheng	Na	TYS	LC	LC
	Channa striatus	Striped snakehead	Shol	Na	VR	LC	LC
	Glossogobius giuris	Tank goby	Bele	Na	TYS	LC	LC
	Heteropneustes fossilis	Stinging catfish	Shing	Na	TYS	LC	LC
	Mastacembelus armatus	Zig-zag eel	Sal baim	Na	VR	EN	NE
	Mystus tengara	Tengara catfish	Tengra	Na	TYS	LC	LC
	Puntius sophore	Pool barb	Jatputi	Na	TYL	LC	LC
	Salmostoma bacaila	Large razor belly minnow	Chela	Na	VR	LC	LC
	Cirrhinus cirrhosus	Mrigal carp	Mirka	Cul		NT	VU
	Cyprinus carpio var.communis	Common carp	Japani rui	Cul			CR
	Gibelion catla	Katla	Katol	Cul		LC	LC
	Hypophthalmichthys molitrix	Silver carp	Silver carp	Cul			NT
	Labeo rohita	Roho labeo	Rui	Cul		LC	LC
Sarjat	*Channa marulius*	Great snakehead	Gozar	Na	R	EN	LC
	Channa striatus	Striped snakehead	Shol	Na	TYS	LC	LC
	Chanda nama	Elongate glass-perchlet	Chanda	Na	TYL	LC	LC
	Glossogobius	Tank goby	Bele	Na	TYL	LC	LC

	giuris						
	Gudusia chapra	Indian River Shad	Chapila	Na	TYL	VU	LC
	Mastacembelus armatus	Zig-zag eel	Sal baim	Na	VR	EN	NE
	Puntius sophore	Pool barb	Jatputi	Na	TYS	LC	LC
	Salmostoma bacaila	Large razor belly minnow	Chela	Na	TYL	LC	LC
	Sperata aor	Long-whiskered catfish	Ayre	Na	TYS	VU	LC
	Cirrhinus cirrhosus	Mrigal carp	Mirka	Cul		NT	VU
	Ctenopharyngodon idella	Grass carp	Glass carp	Cul			NE
	Cyprinus carpio var.communis	Common carp	Japani rui	Cul			CR
	Gibelion catla	Katla	Katol	Cul		LC	LC
	Hypophthalmichthys nobilis	Bighed carp	Brekap	Cul			DD
	Hypophthalmichthys molitrix	Silver carp	Silver carp	Cul			NT
	Labeo rohita	Roho labeo	Rui	Cul		LC	LC
Fatehpur	*Anabas testudineus*	Climbing perch	Koi	Na	TYS	LC	DD
	Channa marulius	Great snakehead	Gozar	Na	R	EN	LC
	Channa punctatus	Spotted snakehead	Taki	Na	TYL	LC	LC
	Channa striatus	Striped snakehead	Shol	Na	TYS	LC	LC
	Glossogobius giuris	Tank goby	Bele	Na	TYL	LC	LC
	Gudusia chapra	Indian River Shad	Chapila	Na	TYS	VU	LC
	Pethia ticto	Ticto barb	Titputi	Na	LM	VU	LC
	Cirrhinus cirrhosus	Mrigal carp	Mirka	Cul		NT	VU
	Ctenopharyngodon idella	Grass carp	Glass carp	Cul			NE
	Cyprinus carpio var.communis	Common carp	Japani rui	Cul			CR
	Cyprinus carpio var.specularis	Mirror carp	Mirror carp	Cul			CR
	Gibelion catla	Katla	Katol	Cul		LC	LC
	Hypophthalmichthys molitrix	Silver carp	Silver carp	Cul			NT
	Labeo rohita	Roho labeo	Rui	Cul		LC	LC
Kapashatia	*Amblypharyngodon mola*	Mola carplet	Moa	Na	TYS	LC	LC
	Anabas testudineus	Climbing perch	Koi	Na	TYS	LC	DD
	Channa orientalis	Walking snakehead	Cheng	Na	TYS	LC	LC
	Chanda nama	Elongate glass-perchlet	Chanda	Na	TYS	LC	LC
	Channa striatus	Striped snakehead	Shol	Na	TYS	LC	LC
	Glossogobius giuris	Tank goby	Bele	Na	TYS	LC	LC
	Heteropneustes fossilis	Stinging catfish	Shing	Na	TYS	LC	LC
	Mystus tengara	Tengra catfish	Tengra	Na	TYS	LC	LC
	Nandus nandus	Gangetic leaffish	Bheda	Na	TYS	NT	LC
	Notopterus notopterus	Bronze featherback	Foloi	Na	TYS	VU	LC
	Puntius sophore	Pool barb	Jatputi		TYS		LC

	Salmostoma bacaila	Large razor belly minnow	Chela	Na	TYS	LC	LC
	Sperata aor	Long-whiskered catfish	Ayre	Na	VR	VU	LC
	Cirrhinus cirrhosus	Mrigal carp	Mirka	Cul		NT	VU
	Gibelion catla	Katla	Katol	Cul		LC	LC
	Hypophthalmichthys nobilis	Bighed carp	Brekap	Cul			DD
	Hypophthalmichthys molitrix	Silver carp	Silver carp	Cul			NT
	Labeo rohita	Roho labeo	Rui	Cul		LC	LC
Kathgora	*Channa marulius*	Great snakehead	Gozar	Na	R	EN	LC
	Channa punctatus	Spotted snakehead	Taki	Na	TYL	LC	LC
	Channa striatus	Striped snakehead	Shol	Na	TYS	LC	LC
	Chanda nama	Elongate glass-perchlet	Chanda	Na	TYL	LC	LC
	Clarias batrachus	Walking catfish	Magur	Na	R	LC	LC
	Gudusia chapra	Indian River Shad	Chapila	Na	LM	VU	LC
	Heteropneustes fossilis	Stinging catfish	Shing	Na	TYS	LC	LC
	Macrognathus aculeatus	Lesser spiny eel	Tara baim		R	NT	NE
	Macrognathus pancalus	Barred spiny eel	Guchi		TYS	LC	LC
	Mystus tengara	Tengra catfish	Tengra	Na	TYL	LC	LC
	Nandus nandus	Gangetic leaffish	Bheda	Na	DR	NT	LC
	Ompok pabda	Pabda catfish	Pabda	Na	R	EN	NT
	Puntius sophore	Pool barb	Puti	Na	TYS	LC	LC
	Sperata aor	Long-whiskered catfish	Ayre	Na	R	VU	LC
	Xenentodon cancila	Freshwater garfish	Kakila	Na	TYL	LC	NE
	Hypophthalmichthys molitrix	Silver carp	Silver carp	Cul			NT
	Gibelion catla	Katla	Katol	Cul		LC	LC
	Labeo rohita	Roho labeo	Rui	Cul		LC	LC
Porapara	*Channa marulius*	Great snakehead	Gozar	Na	TYL	EN	LC
	Channa punctatus	Spotted snakehead	Taki	Na	TYS	LC	LC
	Channa orientalis	Walking snakehead	Cheng	Na	TYS	LC	LC
	Channa striatus	Striped snakehead	Shol	Na	TYS	LC	LC
	Clarias batrachus	Walking catfish	Magur	Na	R	LC	LC
	Gudusia chapra	Indian River Shad	Chapila	Na	TYL	VU	LC
	Heteropneustes fossilis	Stinging catfish	Shing	Na	TYS	LC	LC
	Mastacembelus armatus	Zig-zag eel	Sal baim	Na	TYS	EN	NE
	Mystus tengara	Tengra catfish	Tengra	Na	TYL	LC	LC
	Ompok pabda	Pabdah catfish	Pabda	Na	TYL	EN	NT
	Puntius sophore	Pool barb	Mourullah	Na	TYS	LC	LC
	Salmostoma bacaila	Large razor belly minnow	Chela	Na	TYL	LC	LC

	Sperata aor	Long-whiskered catfish	Ayre	Na	TYL	VU	LC
	Labeo rohita	Roho labeo	Rui	Cul		LC	LC
	Hypophthalmichthys molitrix	Silver carp	Silver carp	Cul			NT
	Cirrhinus cirrhosus	Mrigal carp	Mirka	Cul		NT	VU
	Oreochromis niloticus	Nile tilapia	Nilontica	Cul			LC





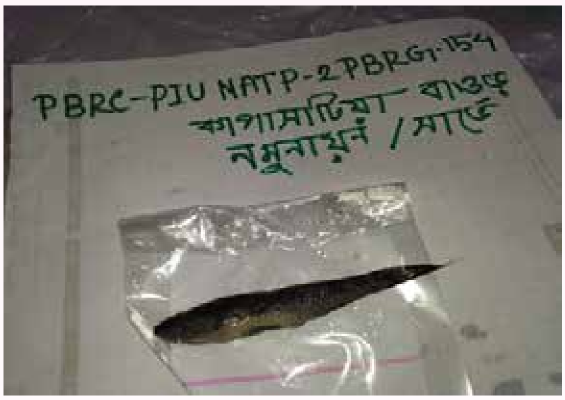



Plate 10. Collection of monthly fish samples

Table 5. List of extinct fish species of six *Baors* in Jhenaidah, Bangladesh

Baor Name	Species Name	Common Name	Local Name	Year of Extinction
Sarjjat	*Anabas testudineus*	Climbing perch	Koi	15-20 yrs
	Heteropneustes fossilis	Stinging catfish	Shing	20-25 yrs
	Mystus cavasius	Gangetic mystus	Gulsa	5-6 yrs
	Mystus tengara	Tengara catfish	Tengra	5-6 yrs
	Ompok pabo	Pabdah catfish	Pabda	20-25 yrs
	Clarias batrachus	Walking catfish	Magur	20-25 yrs
	Amblypharyngodon mola	Mola carplet	Mola	20-25 yrs
	Macrognathus pancalus	Barred spiny eel	Guchi	5-6 yrs
	Nandus nandus	Gangetic leaffish	Bheda	20-25 yrs
	Notopterus chitala	Indian featherback	Chital	15-20 yrs
	Lepidocephalichthys guntea	Guntea loach	Gutum	15-20 yrs
	Macrognathus pancalus	Barred spiny eel	Guchi	15-20 yrs
	Notopterus notopterus	Bronze featherback	Foloi	15-20 yrs
	Cyprinus calbasu	Black rohu	Kalibaus	15-20 yrs
	Macrobrachium rosenbergii	Giant freshwater prawn	Chigri	15-20 yrs
	Dermogenys pusilla	Wrestling halfbeak	Ekthota	15-20 yrs
	Trichogaster fasciata	Giant gourami	Kholisa	15-20 yrs
	Wallago attu	Helicopter catfish	Boal	15-20 yrs
Fatehpur	*Heteropneustes fossilis*	Stinging catfish	Shing	15-20 yrs
	Clarias batrachus	Walking catfish	Magur	15-20 yrs
	Mystus tengara	Tengara catfish	Tengra	15-20 yrs
	Trichogaster fasciata	Giant gourami	Kholisa	15-20 yrs
	Xenentodon cancila	Freshwater needlefish	Kakila	15-20 yrs
	Nandus nandus	Gangetic leaffish	Bheda	15-20 yrs
Kathgora	*Wallago attu*	Helicopter catfish	Boal	20-25 yrs
	Puntius sarana	Olive barb	Sorputi	20-25 yrs
	Channa marulius	Great snakehead	Gojar	20-25 yrs
Kapashatia	*Channa marulius*	Great snakehead	Gozar	15-20 yrs
Porapara	*Nandus nandus*	Gangetic leaffish	Bheda	15-20 yrs
	Macrobrachium rosenbergii	Giant freshwater prawn	Chigri	15-20 yrs
Saganna	*Ompok pabo*	Pabdah catfish	Pabda	2-3 yrs
	Nandus nandus	Gangetic leaffish	Bheda	2-3 yrs
	Macrognathus aculeatus	Lesser spiny eel	Tara baim	2-3 yrso

11.1.2. Morphometric and meristic characteristics

Fish length is often considered more significant than fish age, as many ecological and physiological factors depend more on the length than the age (Erzini et al., 1997). Morphometric and meristic characteristics of fish species from different surveyed *Baors* are given in Table 6.1 – 12.2. Meristics and morphometrics features have been used to identify stocks of fish, differentiate the species taxonomically, and distinct various morpho types. Morphometric characters are less heritable than meristic characters that are why morphometric features were the more preferred method to identifying intraspecific deviation within a stock (Mawa et al. 2021).

Table 6.1. Morphometric measurements of the *Channa punctata* (Bloch, 1793)

Measurements	Min (cm)	Max (cm)	Mode (cm)	Mean ± SD (cm)	95% CL (cm)	%TL
TL (Total length)	5.80	23.0	15.00	14.28±3.17	13.92 - 14.63	100
SL (Standard length)	4.50	18.60	12.00	11.78±2.62	11.48 - 12.07	80.86
PrDL (Pre-dorsal length)	2.00	6.90	4.50	4.30±0.93	4.19 - 4.40	30.00
PoDL(Post-dorsal length)	4.40	17.10	11.50	10.72±2.38	10.5 - 10.99	74.34
PcL (Pectoral length)	1.90	6.50	3.80	4.06±0.91	3.95 - 4.16	28.26
PrAnL (Pre-anal length)	2.90	9.70	6.00	6.30±1.35	6.15 - 6.46	42.17
PoAnL (Post-anal length)	4.10	16.60	11.00	10.56±2.36	10.29 - 10.83	72.17
BW (Body weight)*	1.96	126.90	6.39	36.25±23.31	33.63 - 38.88	-

Min, minimum; Max, maximum; SD, standard deviation; CL, confidence limit for mean value; *, weight in g

Table 6.2. Meristic counts of *Channa punctata* (Bloch, 1793)

Meristic data	Numbers	(Un-branched / Branched)
Dorsal fin rays	30-32	
Pectoral fin rays	15-17	
Pelvic fin rays	5	
Anal fin rays	19-14	
Caudal fin rays	14-16	(ii-iv/12-14)

Unbranched, single fin ray; branched, upper portion of fin is divided into several rays; spine, upper portion of unbranched fin ray is pointed.

Table 7.1. Morphometric measurements of *Anabas testudineus* (Bloch, 1792)

Measurements	Min (cm)	Max (cm)	Mode (cm)	Mean ±SD	95% CL (cm)	% TL
TL (Total length)	7.4	14.5	9.8	10.88±1.39	10.70 - 11.05	100
SL (Standard length)	6.1	11.9	8	8.6 ±1.11	8.52 - 8.80	82.07
HL (Head length)	1.7	3.6	2.9	2.73±0.34	2.69 - 2.78	24.83
PrDL (Pre-dorsal length)	1.9	4.3	3.1	2.99±0.42	2.94 - 3.04	29.66
PoDL (Post-dorsal length)	5.2	10.4	8.1	7.81±1.02	7.68 -7.94	71.72
PcL (Pectoral length)	2.1	4	3	2.98±0.33	2.94 - 3.02	27.59
PvL (Pelvic length)	2.3	4.6	3.2	3.28±0.43	3.23 - 3.34	31.72
AnsL (Anus length)	3.1	6.5	4.6	4.65±0.62	4.58 - 4.73	44.83
PrAnL (Pre-anal length)	3.2	6.6	4.7	4.81±0.64	4.73 - 4.89	45.52
PoAnL (Post-anal length)	5.7	11	8.2	8.13±1.07	7.996 - 8.6	75.86
BW (Body weight)*	7.89	64	13.14	26.52±10.68	25.18 - 27.87	-

Table 7.2. Meristic counts of *Anabas testudineus* (Bloch, 1792)

Meristic data	Nmbrs	Spine	Unbranched	Branched
Dorsal fin rays	26–28	XVI–XVIII	1–2	7–10
Pectoral fin rays	13–15	-	1–2	11–14
Pelvic fin rays	6	I	-	5
Anal fin rays	18–21	VIII–XI	1–2	8–10
Caudal fin rays	15–17	-	2	13 – 15
1st lateral line scale	14 – 17			
2nd lateral line scale	10 – 13			
Scale above the lateral line to dorsal fin base	3 – 4			
Scale below the lateral line to pelvic fin base	6 – 7			

Table 8.1. Morphometric measurements of the *Heteropneustes fossilis* (Bloch, 1794)

Measurements	Min (cm)	Max (cm)	Mode (cm)	Mean ± SD (cm)	95% CI (cm)	%TL
TL (Total length)	6.7	26.80	13.0	14.40±2.97	14.08 - 14.72	100
SL (Standard length)	6.0	24.50	10.5	12.95±2.73	12.66 - 13.24	91.41
PrDL (Pre-dorsal length)	2.0	7.80	3.2	3.99±0.88	3.89 - 4.08	29.100
PcL (Pre pectoral length)	0.7	3.70	1.9	1.81±0.42	1.77 - 1.86	13.80
PvL (Pre pelvic length)	1.9	8.10	3.5	4.17±0.94	4.07- 4.27	30.22
PrAnL (Pre-anal length)	2.5	9.80	4.5	5.10±1.12	4.97 - 5.22	33.95
PoAnL (Post-anal length)	6.0	24.10	11.0	12.74±2.72	12.44 - 13.03	89.92
BW (Body weight)	3.5	105.23	12.1	18.22±12.82	16.84 - 19.60	-

Table 8.2. Meristic counts of *Heteropneustes fossilis* (Bloch, 1994)

Meristic data	Numbers
Dorsal fin rays	6
Pectoral fin rays	7 – 8
Pelvic fin rays	6
Anal fin rays	64 – 69

Table 9.1. Morphometric measurements of the *Mystus tengra* (Hamilton, 1822)

Measurements	Min (cm)	Max (cm)	Mode (cm)	Mean ± SD (cm)	95% CL (cm)	%TL
TL (Total length)	5.91	17.6	15.00	13.12±2.59	12.80 - 13.45	100
FL (Forked length)	4.84	13.90	10.2	11.02 ± 7.67	10.31 - 10.80	81.89
SL (Standard length)	4.54	13.20	9.40	9.70 ± 1.84	9.48 - 9.94	76.81
PrDL (Pre-dorsal length)	2.50	3.20	2.50	2.84 ± 0.29	2.64 - 3.04	42.30
PoDL (Post-dorsal length)	3.40	4.20	4.10	3.84 ± 0.32	3.62 - 4.06	57.52
PcL (Pectoral length)	1.40	1.70	1.60	1.55 ± 0.10	1.48 - 1.62	23.68
PvL (Pelvic length)	3.30	4.40	4.10	3.83 ± 0.40	3.56 - 4.10	55.83
PrAnL (Pre-anal length)	5.00	6.40	6.30	5.72 ± 0.51	5.38 - 6.06	84.60
PoAnL (Post-anal length)	5.50	7.00	7.00	6.40 ± 0.54	6.03 - 6.76	93.06
BW (Body weight)*	1.36	40.18	24	19.15±8.45	18.10 - 20.20	551.73

Table 9.2. Meristic counts of *Mystus tengra* (Hamilton, 1822)

Meristic data	Numbers	Spine	Un-branched	Branched
Dorsal fin rays	6 - 8	I	-	7
Pectoral fin rays	7-9	I	-	8
Pelvic fin rays	4-6	-	1	5
Anal fin rays	8-13	-	2-3	9-10
Caudal fin rays	17-19	-	-	19

Table 10.1. Morphometric measurements of the *Mystus cavasius* (Hamilton, 1822)

Measurements	Min (cm)	Max (cm)	Mode (cm)	Mean ± SD (cm)	95% CI (cm)	%TL
TL (Total length)	4.50	18.80	8.20	9.58 ± 2.63	9.24 -9.92	100
FL (Forked length)	4.00	17.10	6.90	7.83 ± 2.65	9.00- 9.25	88.88
SL (Standard length)	3.50	16.50	6.00	7.73 ± 2.45	7.41 – 8.05	77.77
BW (Body weight)	0.97	55.50	5.50	11.48 ± 9.00	10.31 – 12.65	-

Table 10.2. Meristic counts of *Mystus cavasius* (Hamilton, 1822)

Meristic data	Numbers	Spine	Un-branched	Branched
Dorsal fin rays	6-8	I	-	7
Pectoral fin rays	7-9	I	-	8
Pelvic fin rays	5-7	-	1	5
Anal fin rays	8-10	-	4	7-9

Table 11.1. Morphometric measurements of the of *Mystus vittatus* (Bloch, 1794)

Measurements	Min (cm)	Max (cm)	Mode (cm)	Mean ± SD (cm)	95% CL (cm)	%TL
TL (Total length)	4.20	12.70	5.00	5.69 ± 1.29	5.50 - 5.87	100
FL (Forked length)	3.60	10.7	4.50	4.89 ± 1.06	4.74 - 5.04	85.71
SL (Standard length)	1.90	9.80	4.00	4.43 ± 0.99	4.28 - 4.57	45.23
PrDL (Pre-dorsal length)	1.20	4.00	1.50	1.82 ± 0.45	1.74 - 1.90	28.57
PoDL (Post-dorsal length)	1.60	5.50	2.00	2.43 ± 0.63	2.32 - 2.5	38.09
PcL (Pectoral length)	0.40	2.20	0.60	0.90 ± 0.32	0.84 - 0.96	9.52
PvL (Pelvic length)	1.50	5.40	1.90	2.40 ± 0.64	2.28 - 2.51	35.71
PrAnL (Pre-anal length)	2.20	7.00	2.70	3.34 ±0.88	3.18 - 3.50	52.38
PoAnL (Post-anal length)	2.20	8.20	3.40	3.86 ± 1.04	3.67 - 4.04	52.38
BW (Body weight)*	0.67	20.02	1.30	2.06 ± 1.90	1.79 - 2.33	-

Table 11.2. Meristic counts of *Mystus vittatus* (Bloch, 1794)

Meristic data	Number	Spine	Unbranshed	Branched
Dorsal fin rays	7-9	I	-	8
Pectoral fin rays	8-10	I	-	9
Pelvic fin rays	5-7	-	1	5
Anal fin rays	10-12	-	3-4	8-9

Table 12.1. Morphometric measurements of the *Ompok pabda* (Hamilton, 1822)

Measurements	Min (cm)	Max (cm)	Mode (cm)	Mean ± SD (cm)	95% CI (cm)	%TL
TL (Total length)	8.20	22.30	11.50	14.49±3.17	14.08 -14.89	100
FL (Forked length)	7.20	20.00	14.40	13.24 ± 2.79	12.89 – 13.60	87.80
SL (Standard length)	7.00	19.00	13.40	12.45 ± 2.61	12.12 – 12.79	85.36
BW (Body weight)	3.68	63.70	15.76	19.54 ± 12.33	17.97 – 21.11	-

Table 12.2. Meristic counts of *Ompok pabda* (Hamilton, 1822)

Meristic data	Number	Spine	Unbranched	Branched
Dorsal fin rays	4-6	-	-	4-5
Pectoral fin rays	10-12	I	-	11-13
Pelvic fin rays	6-8		1	6-7
Anal fin rays	54-56	-	2	48-54

11.1.3. Length-frequency distribution

Length-frequency distribution (LFD) is an important biometric index to assess the dynamic rates of recruitment, growth, mortality, yields and stock biomass in a particular ecosystem through dynamic mathematical models (Sabbir et al., 2021). Length frequency distributions of 7 indigenous fish species were calculated from Saganna and Sarjat *Baor* (Fig. 3.1 & 3.2). We observed that The TL ranged from 8.20 to 32.80 cm for *O. pabda*, 6.20 to 24.30 for *H. fossilis*, 6.50 to 24.70 cm for *C. punctata*, 7.20 to 17.40 cm for *A. testudineus*, 5.91 to 27.10 cm for *M. cavasius*, 4.50 to 13.90 cm for *M. tengra* and 6.00 to 18.90 cm for *M. vittatus* in Saganna *Baor*, Jhenaidah, Bangladesh (Fig. 3.1). In Sarjat *Baor,* the TL ranged from 7.50 to 32.50 cm for *O. pabda*, 7.20 to 27.30 for *H. fossilis*, 5.5 to 23.70 cm for *C. punctata*, 8.20 to 16.40 cm for *A. testudineus*, 6.91 to 26.40 cm for *M. cavasius*, 5.10 to 12.80 cm for *M. tengra* and 5.50 to 18.70 cm for *M. vittatus* (Fig. 3.2). To compare our findings with other works we found that Mawa et al. (2022) estimate total length of *M. vittatus* was 6.53 to 18.80 cm in the Ganges River and 7.50 to 16.40 cm TL for *A. testudineus* from Gajner *Beel*, Bangladesh. Hasan et al. (2022) reported, 6.70 to 24.10 cm TL for *H. fossilis* from Gajner *Beel*. These differences in TL perhaps depend on water temperatures and other environmental conditions which affect the fish growth (Mawa et al., 2022).

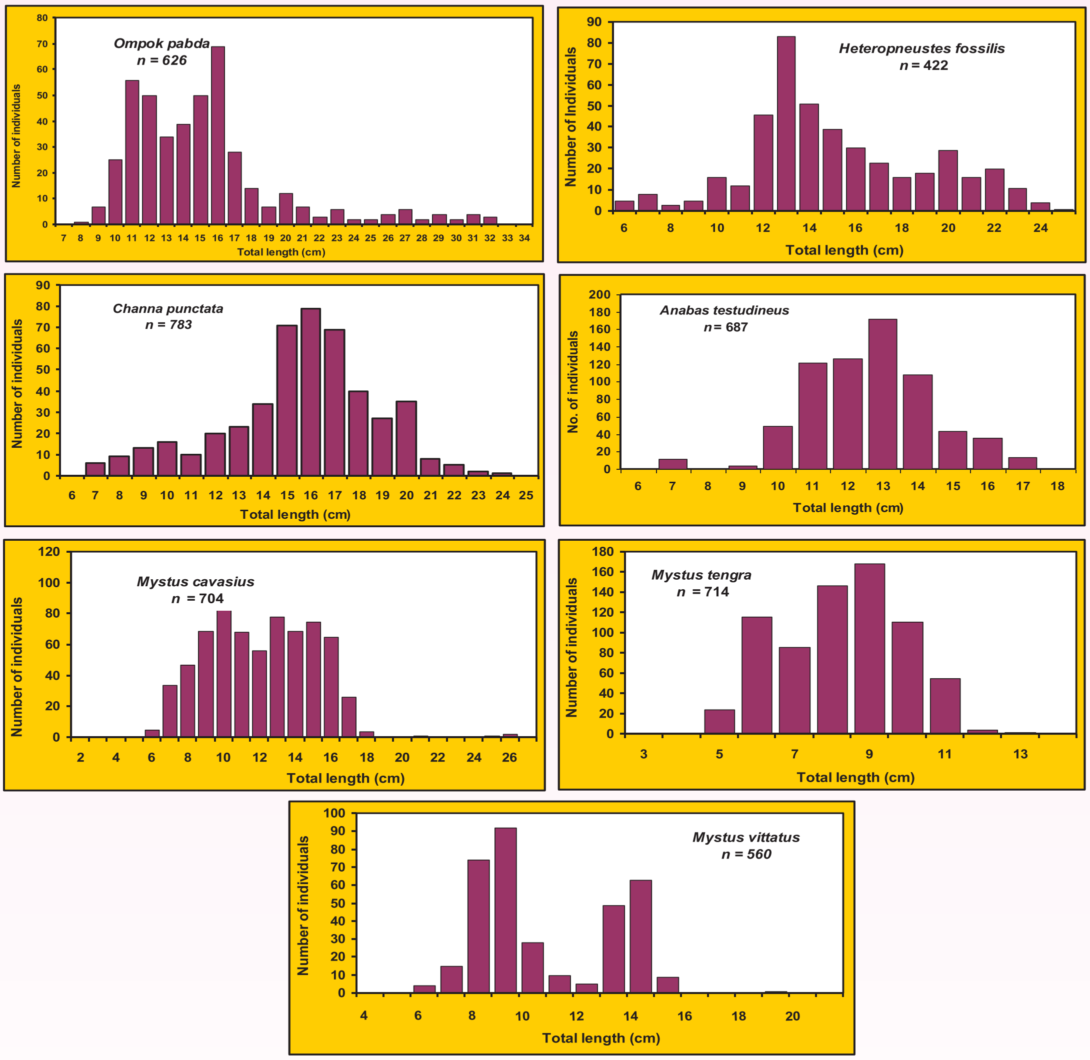


Fig 3.1. Length frequency distribution of stocked indigeneous fishes in Saganna *Baor*, Jhenaidah, Bangladesh

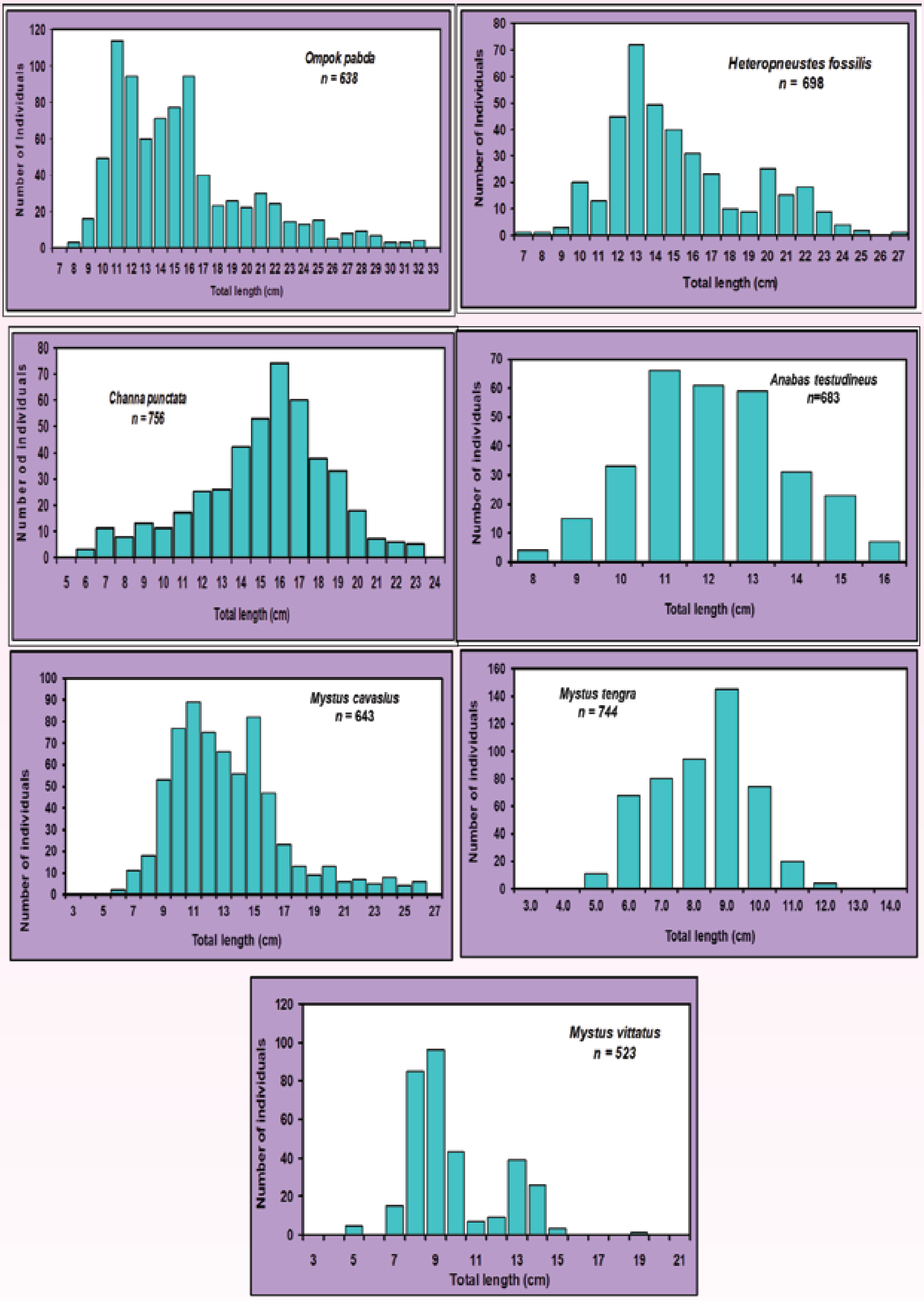
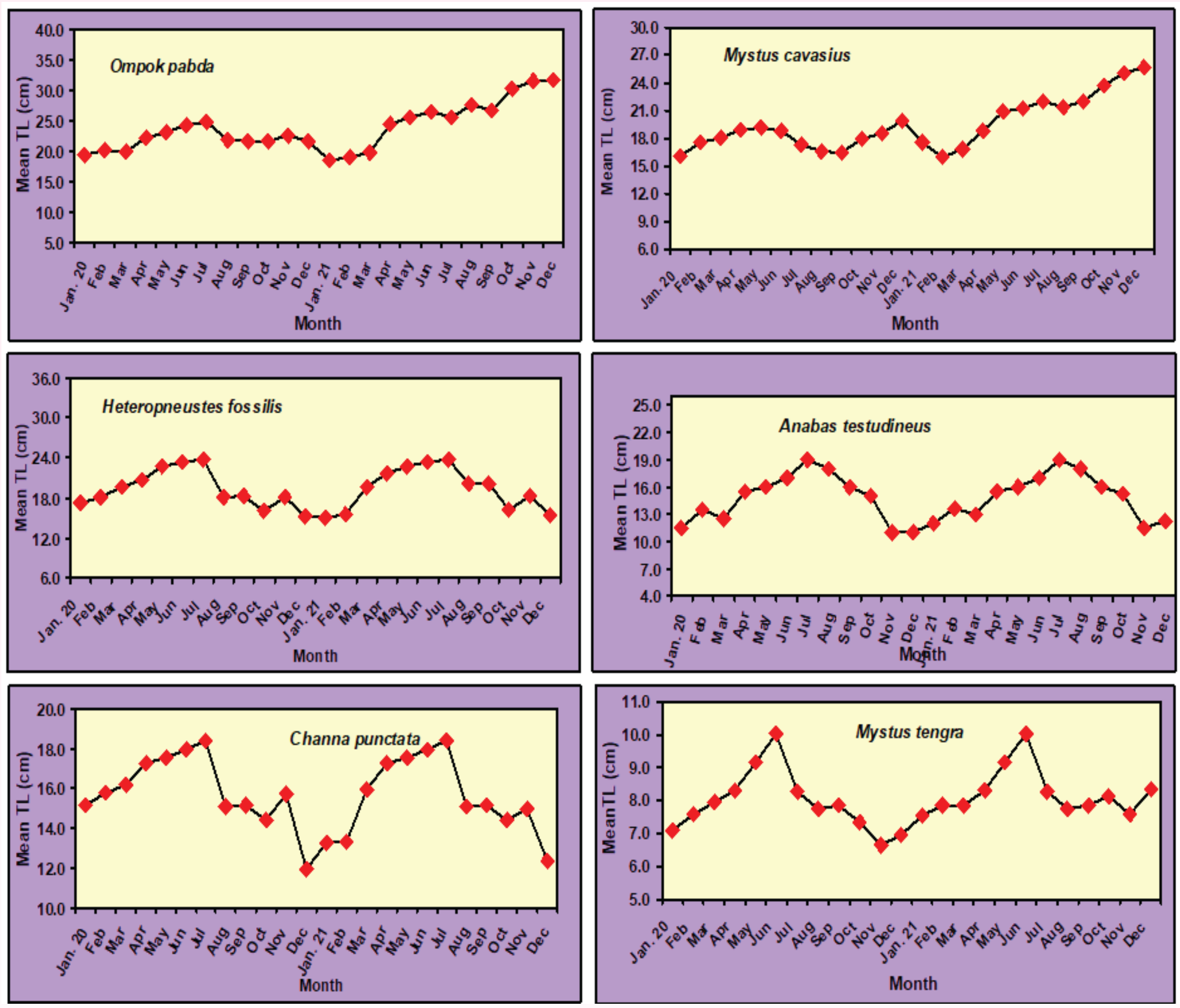


Fig 3.2. Length frequency distribution of stocked indigenous fishes in Sarjat *Baor*, Jhenaidah, Bangladesh

11.1.4. Monthly increases length of stocked fishes

In our study, we observed the monthly variation of mean total length (size) of 7 stocked fish species from Saganna and Sarjat *Baor* (Fig. 4.1 & 4.2). We recorded the hightest mean length (TL) for *O. pabda* as 31.80 cm in the month of December 2021, the second hightest length was recorded for *M. cavasius* as 25.70 cm in the same month of 2021 for Saganna *Baor*. In case of Sarjat *Baor,* the hightest mean length for *O. pabda* as 31.50 cm in the month of December 2021, the second hightest length was recorded for *M. cavasius* as 25.40 cm in the same month of 2021. In the month of January-February 2022, we even recorded individuls weight was around 350 g for *O. pabda* and 170 g for *M. cavasius*. Fast growth rate of fish is advantageous in many ways. Rapid growth rate of fish not only gives the fish immunity from predators but also allows carrying large numbers of eggs with higher chances of larval survival (Hossain et al., 2017). In addition, growth and recruitment have remarkable effects on the maintenance of maximum sustainable yield of a wild stock (Ahmed et al., 2012).



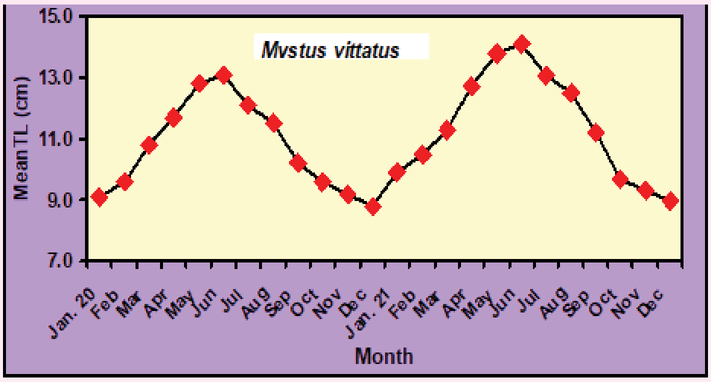
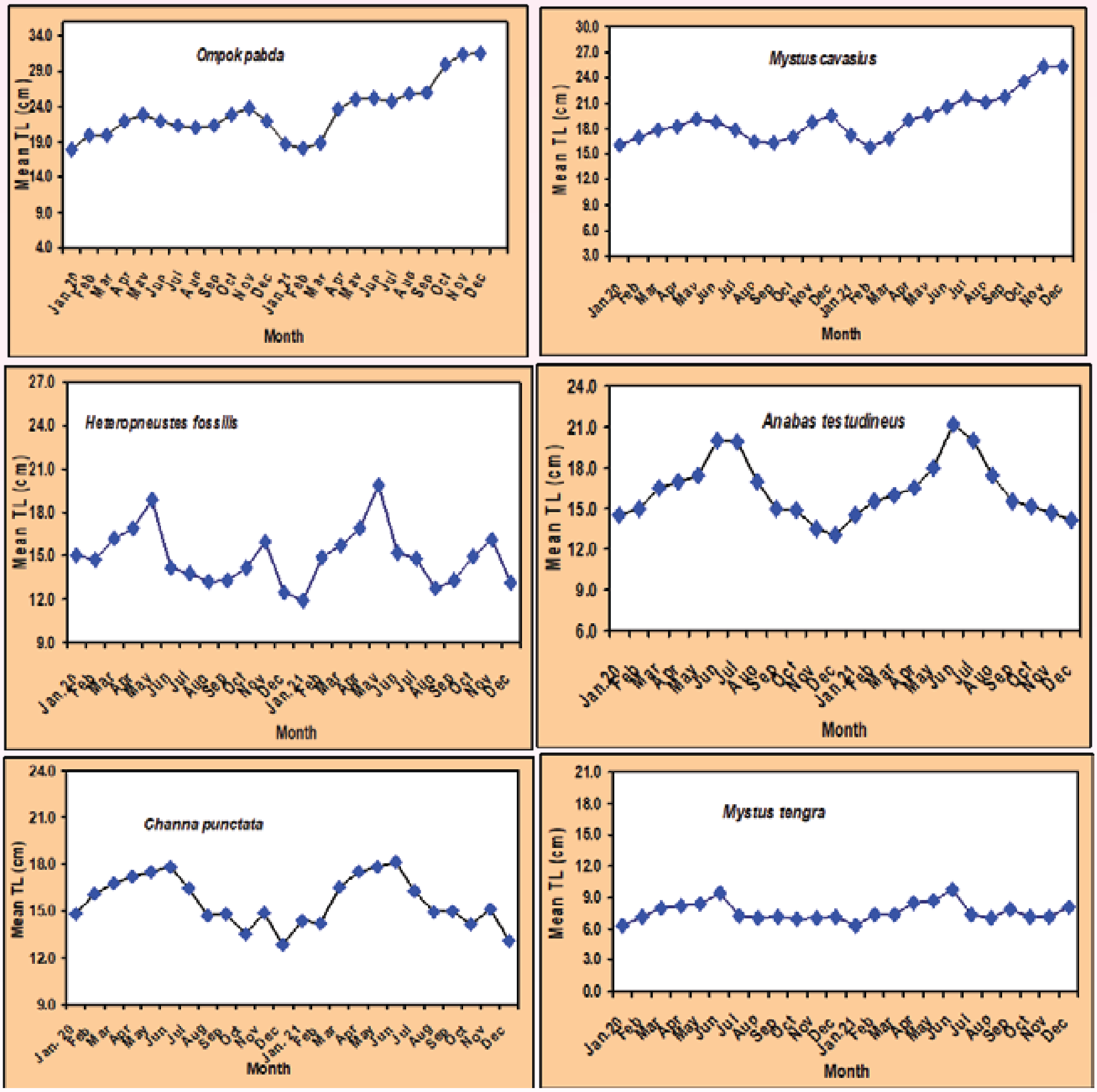


Fig 4.1 Monthly variation of mean total length of stocked indigenous fishes in Saganna *Baor*, Jhenaidah, Bangladesh



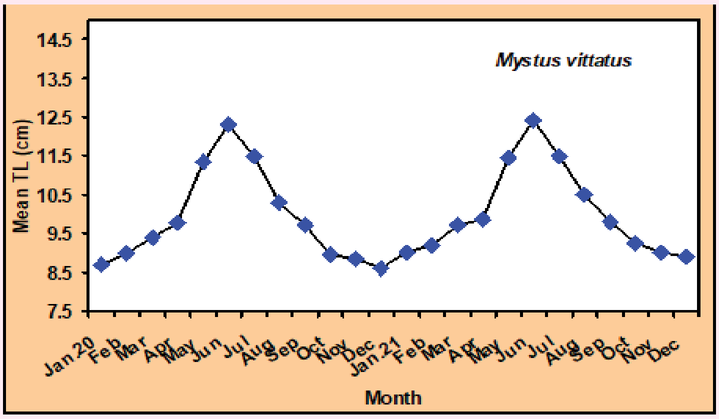


Fig 4.2. Monthly variation of mean total length of stocked indigenous fishes in Sarjat *Baor* from Jhenaidah, Bangladesh

11.1.5. Size at sexual maturity (L_m)

The maturity size (L_m) of fishes can be used (a) to estimate minimum catchable size and (b) for stock evaluation. It is also used for differentiating among different populations of a single species and to assess the impacts due to fishing stress, etc. (Mawa et al., 2022). In our study we estimated the size at sexual maturity of 7 stocked species from two study areas and among them the lowest L_m 7.50 cm for *M. tengra* and highest was 13.10 cm for *C. punctata* in the Saganna *Baor*. In case of Sarjat *Baor*, we found 7.80 cm for *M. tengra* and highest were 13.80 cm for *C. punctata* (Fig. 5.1 & 5.2). We also calculated size at sexual maturity of some others SIFS based on their L_{max}; the L_m was 5.25 cm for *Chanda nama,* 11.10 cm for *Mastacembalus puncalus*, 7.38 cm for *Tricogaster fasciata*, 7.38 cm for *Puntius sophore*, 7.08 cm for *Gudusia chapra*, 8.25 cm for *Glossogobius giuris*, 10.74 cm for *Dermogeny spusilla* and 5.64 cm for *Salmostoma bacaila* from Saganna *Baor* and in case of Sarjat *Baor* L_m was 4.12 cm for *Chanda nama*, 10.74 cm for *Mastacembalus puncalus*, 5.13 cm for *Tricogaster fasciata*, 6.79 cm for *Puntius sophore*, 11.37 cm for *Gudusia chapra*, 8.62 cm for *Glossogobius giuris*, 6.20 cm for *Dermogeny spusilla* and 7.83 cm for *Salmostoma bacaila* from Sarjat *Baor*. Mawa et al. (2022) estimated L_m of *M. vittatus* was 9.60 cm in the Ganges River and 11.50 cm for *A. testudineus* from Gajner *Beel*, Bangladesh. Hasan et al. (2022) reported, L_m was13.50 cm for *H. fossilis* from Gajner *Beel*. Prasad et al. (2011) found out the *C. punctata* got its sexual maturity at 12.0 cm TL from Ganges River, India.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 (Sabbir et al., 2021; Mawa et al., 2022).

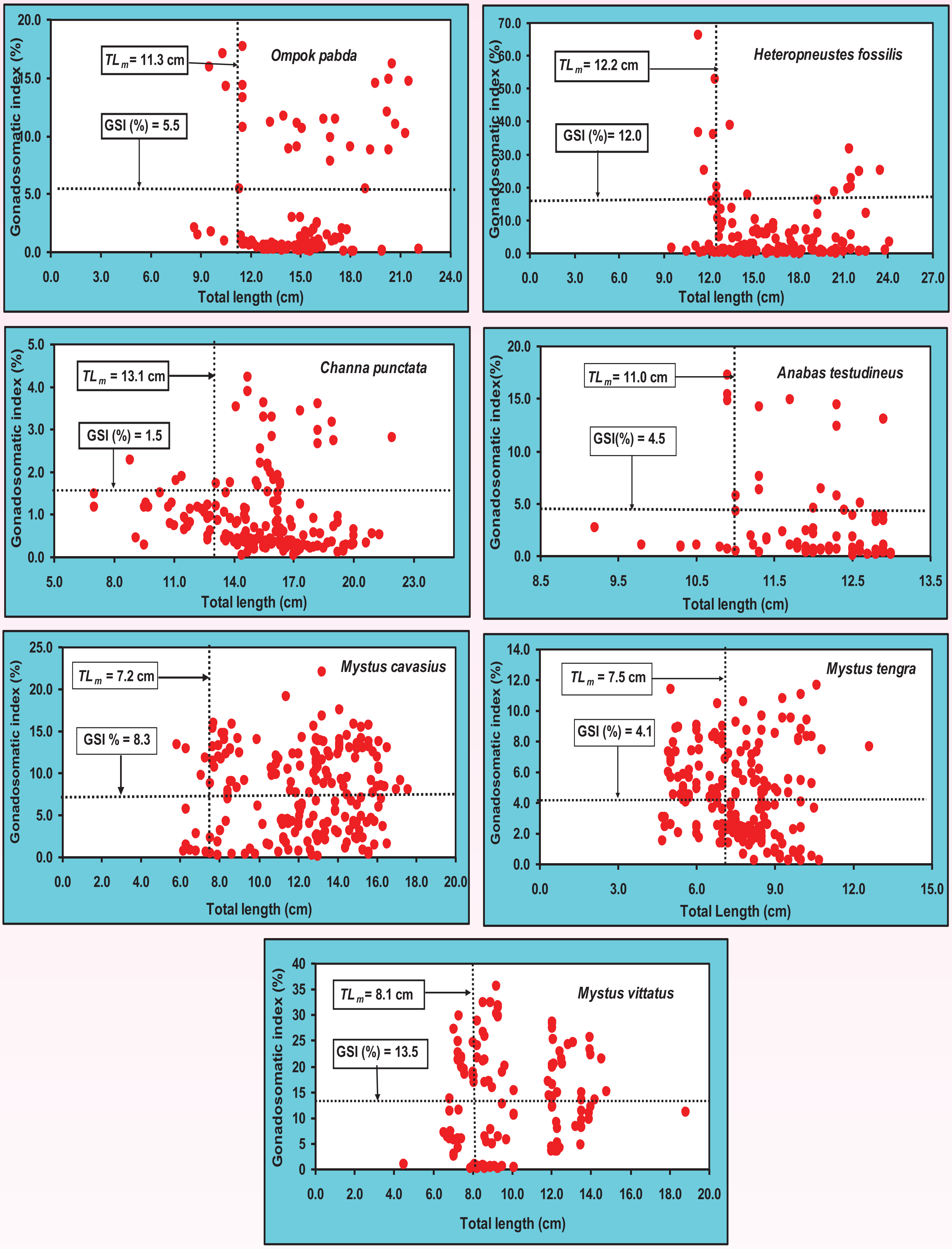


Fig 5.1. Size at first sexual maturity of stocked indigenous fishes based on GSI *vs*. TL in Saganna *Baor* from Jhenaidah, Bangladesh.

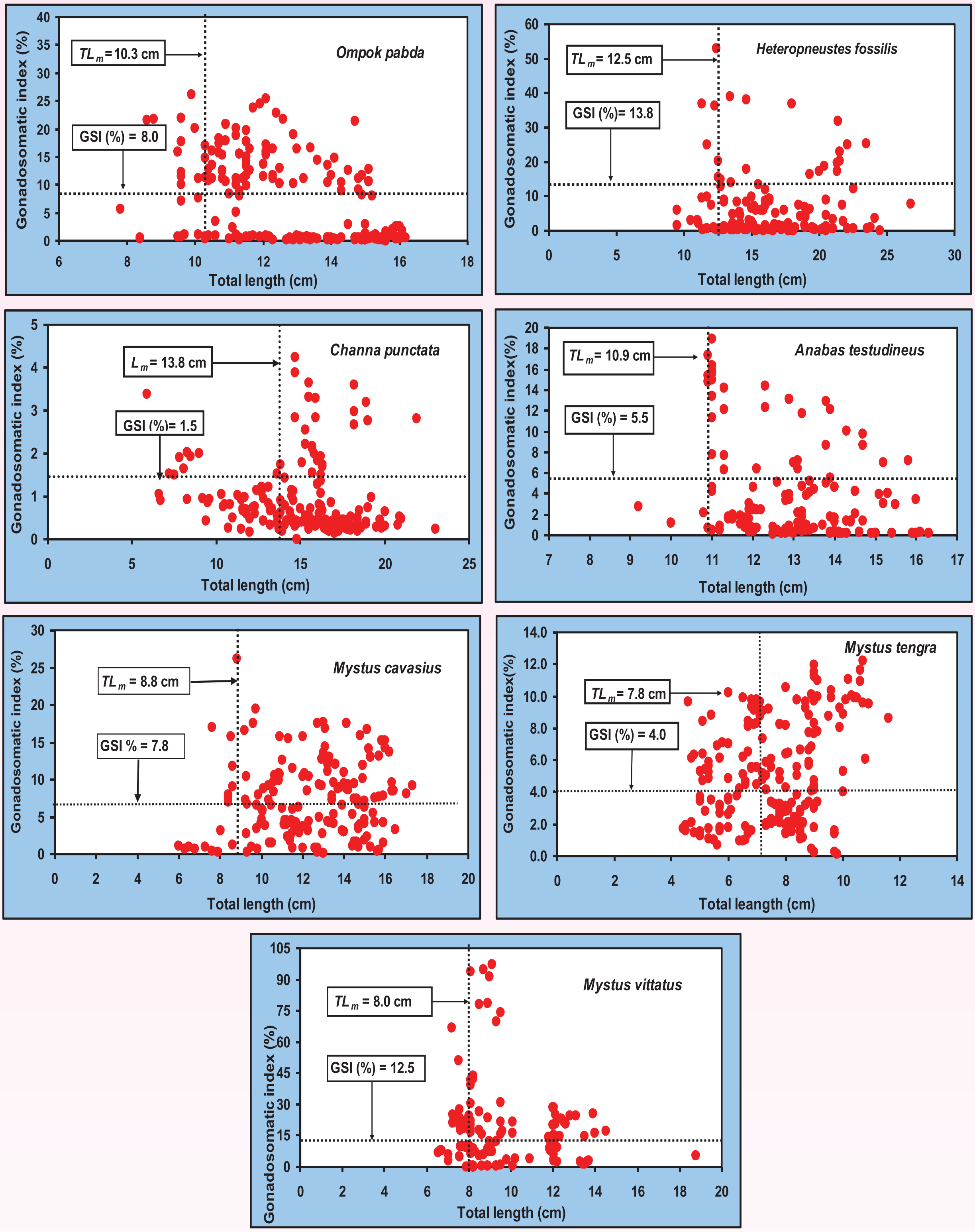


Fig. 5.2. Size at first sexual maturity of stocked indigeneous fishes based on GSI *vs.* TL in Sarjat *Baor*, Jhenaidah, Bangladesh.

Table 13. Size at sexual maturity of stocked fishes from study site and other water bodies

Baors	Species	L_m(cm) (GSI based)	Available Literatures		Species	L_m(cm) (L_{max} based)	Available Literatures	
			L_m(cm)	References			L_m(cm)	References
Saganna	*Anabas testudineus*	11.00	8.41	Khatun et al. (2019)	*Chanda nama*	5.25	4.23	Hasan et al. (2021)
	Channa punctata	13.10	11.65	Hasan et al. (2021)	*Mastacembalus puncalus*	11.10		-
	Clarius batrachus	-	-	-	*Tricogaster fasciata*	7.38	5.91	Parvin et al. (2021)
	Heteropneustes fossilis	12.20	14.02	Hasan et al. (2022)	*Puntius sophore*	7.38	4.2	Ahamed et al. (2015)
	Mystus tengra	7.50	-	-	*Gudusia chapra*	7.08	7.0	Hasan et al. (2021)
	Mystus vitatus	8.10	9.37	Mawa et al. (2022)	*Glossogobius giuris*	8.25	8.49	Hasan et al. (2021)
	Mystus cavasius	7.20	9.88	Hasan et al. (2021)	Dermogenyspusilla	10.74	9.70	Hossen et al. (2019)
	Ompok pabda	11.30	10.22	Hasan et al. (2021)	*Salmostoma bacaila*	5.64	7.34	Sarmin et al. (2021)
Sarjat	*Anabas testudineus*	10.90			*Chanda nama*	4.12		
	Channa punctatas	13.80			*Mastacembalus puncalus*	10.74		
	Clarius batrachus	-			*Tricogaster fasciata*	5.13		
	Heteropneustes fossilis	12.50			*Puntius sophore*	6.79		
	Mystus tengra	7.80			*Gudusia chapra*	11.37		
	Mystus vitatus	8.00			*Glossogobius giuris*	8.62		
	Mystus cavasius	8.80			Dermogenyspusilla	6.90		
	Ompok pabda	10.30			*Salmostoma bacaila*	7.83		

11.1.6. Spawning season

Spawning period is very important for the immigration of fshes for spawning purposes (Wilding et al., 2000). Monthly changes of GSI of seven (7) indigenous fish species had been analyzed and shown in Fig. 6.1 & 6.2. In case of *A. testudineus* spawning season ranged from May to August, May to September for *C. punctata*, May to August for *M. tengra*, May to August for *H. fossilis*, May to August for *M. vittatus*, March to July for *M. cavasius* and April to September for *O. pabda* from Saganna *Baor*. On the other hand, in Sarjat *Baor* we observed spawning season ranged from May to September for *A. testudineus*, April to August for *C. punctata*, April to July for *M. tengra*, May to August for *H. fossilis*, April to July for *M. vittatus*, April to July for *M. cavasius* and May to August for *O. pabda*. Hasan et al. (2022) observed spawning season for *H. fosssilis* ranged from April to August from Gajner *Beel*. Chakraborti et al. (2010) noticed *O. pabda* spawn during May to July from Mymensingh, Bangladesh (Table 14). On the other hand, Mawa et al. (2022) calculated the spawning season for *A. testudineus* ranged from May to July and for *M. vittatus* it was April to September from Gajner *Beel* and Ganges River, respectively. Spawning season of *A. testudineus* was documented from June to July in the Padma river of Rajshahi (Islam and Hossain, 1983), April to July in several water bodies of Bangladesh (Rahman, 2005), and July to October in the Sylhet region of Bangladesh (Uddin et al. 2017). Prasad et al. (2011) reported the spawning season was ranged from September to October for *C. punctata* from Ganges River, India. The documented variations in the spawning season are probably linked to environmental parameters, mostly water temperature and precipitation, population density, and food availability (Mitu, 2017; Khatun et al., 2019).

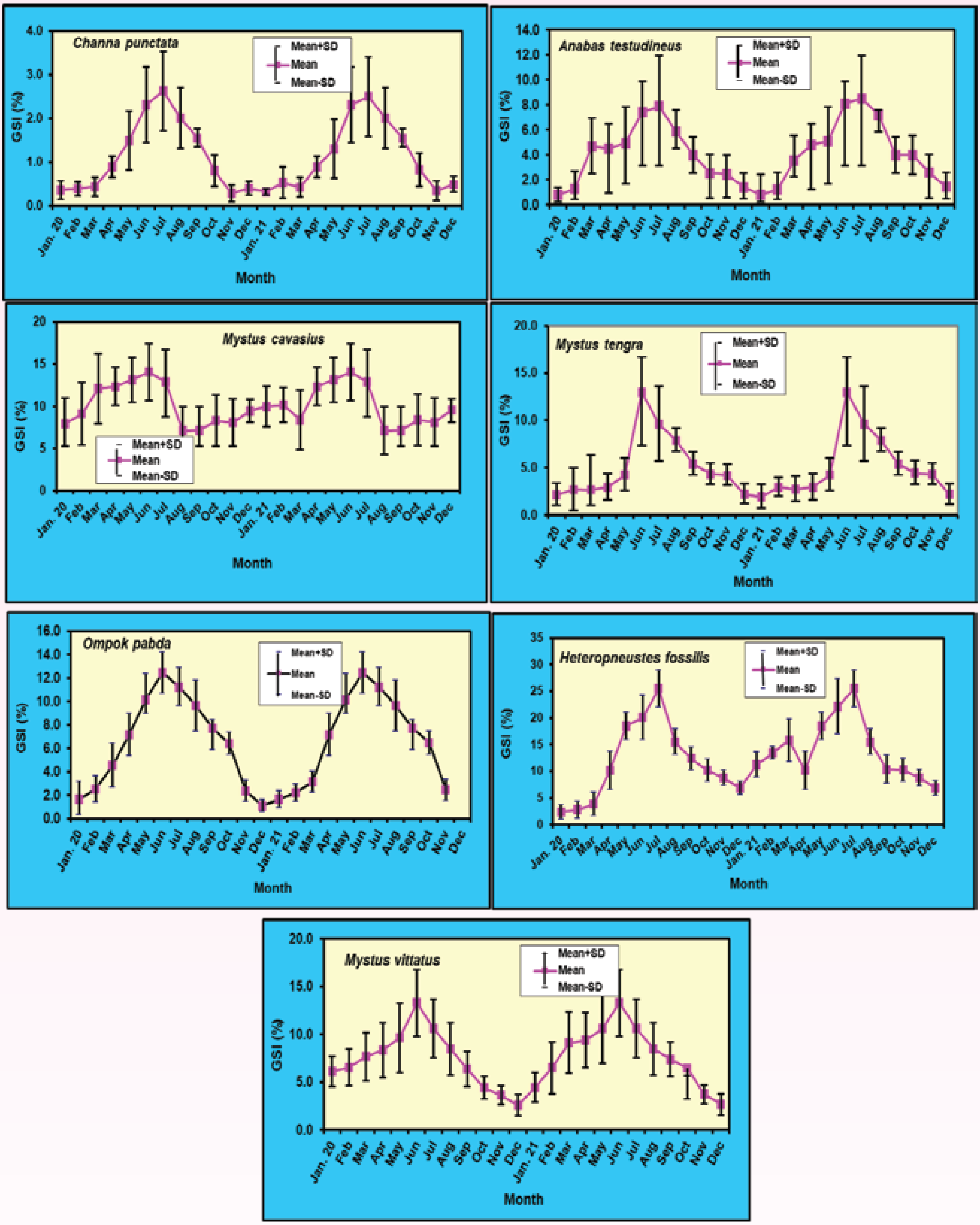


Fig 6.1. Monthly variation of gonado-somaticindex (GSI) of stocked indigeneous fishes in Saganna *Baor*, Jhenaidah, Bangladesh.

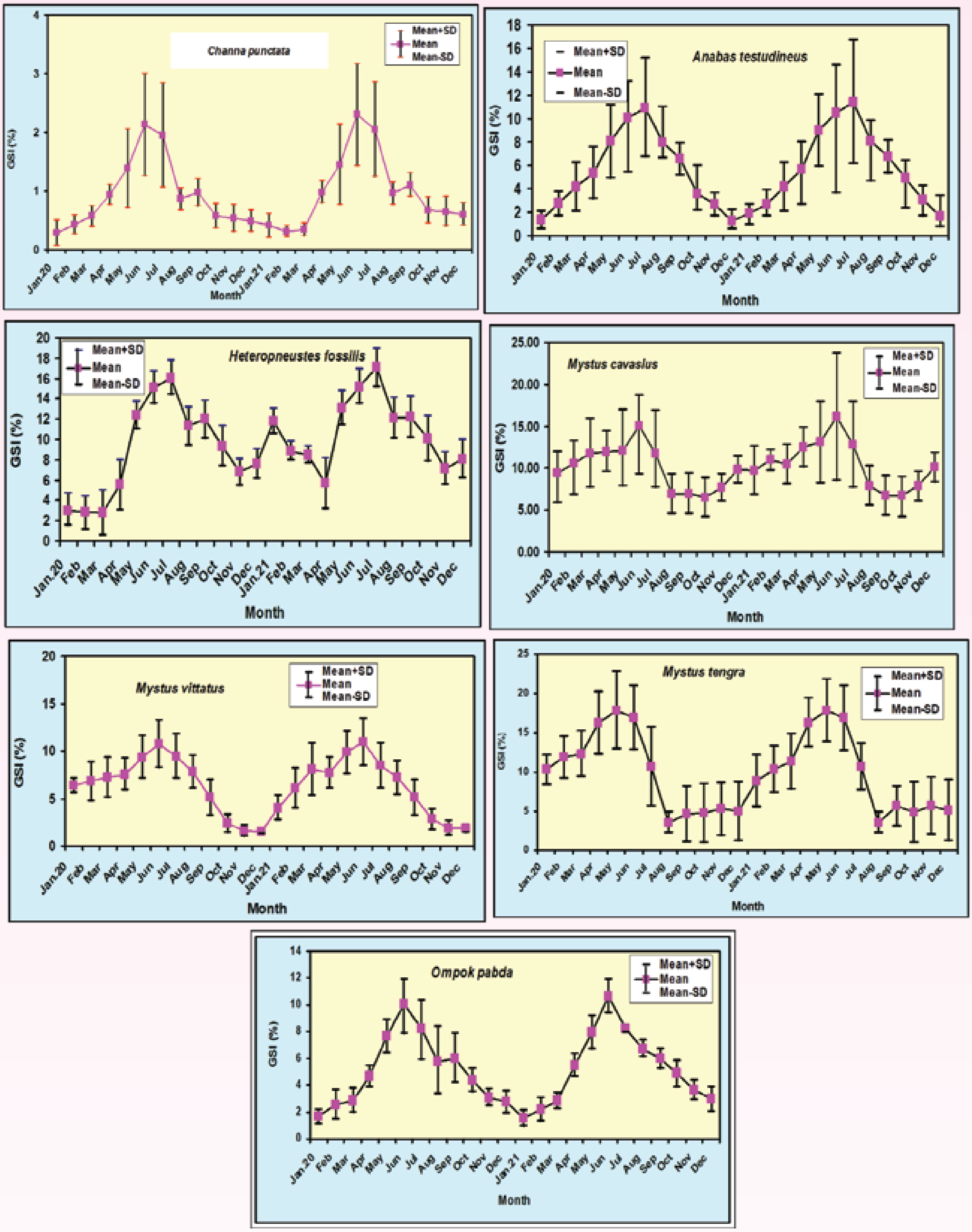


Fig 6.2. Monthly variation of gonado-somaticindex (GSI) of stocked indigeneous fishes in Sarjat *Baor,* Jhenaidah, Bangladesh.

Table 14. Spawning season of different indigenous species from the study sites & other water

Species Name	Saganna *Baor*		Sarjat *Baor*		Available literature			
	Spanwning season	Peak spawning season	Spawning season	Peak spawning season	Spawning season	Peak spawning season	Water body	References
Anabas testudineus	May to August	June to July	May to September	June to July	May to August	June to July	Gajner *beel*	Mawa et.al. (2022)
Channa puctaata	May to September	June to July	April to August	June to July	June to October.	August	Varuna River (Tributary of Gange)	Prasad et. al (2011)
Mystus tengra	May to August	June to July	April to July	May to June	May to September	July	West Bengal, India	Sandipan Gupta; 2013
Heteropneustes fossilis	May to August	June to July	May to August	June to July	March to August	May to June.	Ganges River	Parvin et.al (2022)
Mystus vittatus	May to August	June to July	April to August	May to July	April to September	May to July	Ganges River	Mawa et.al. (2022)
Mystus cavasius	March to July	May to July	April to July	June to July	April to July	May and June	Padma River	Naser et. Al (2014)
Ompok pabda	April to September	June to July	May to August	June to July	September	June	Brahmaputtro River	Tumpa et al. (2020)

11.1.7. Selection of fishing ban period

After observing the spawning season of all the stock species and from the available literature for othe species, we found that most of the SIFS from *Baor* spawn (peak spawning season) during June to July (Fig 7). Thus, we recommended to impose the fishing ban period of SIFS in *Baors* during this peak spawning season for the protection the brood fishes and ensuring their spawning smoothly.

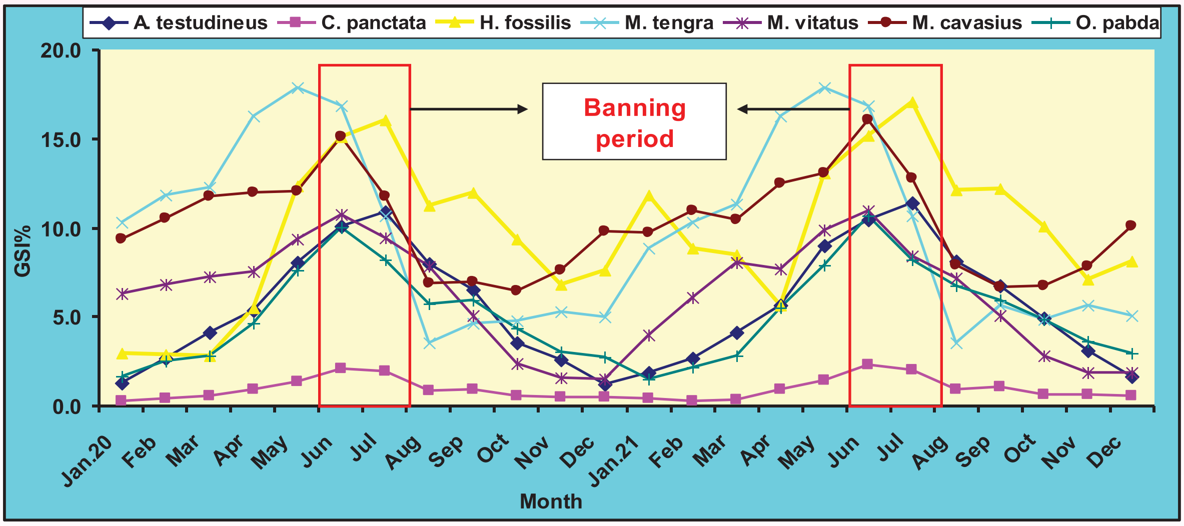


Fig 7. Monthly variation of gonado-somatic index (GSI) of stocked indigenous fishes in Saganna *Baor* from Jhenaidah, south-western Bangladesh

11.1.8. Fecundity

The estimation of fecundity and description of reproductive strategies are essential topics for fish population dynamics, physiology, and other biological studies (Mawa et al. 2022). In our study, we recorded minimum fecundity was 1285 for *M. tengra* and maximum was 5356 for *A. testudineus*. Mawa et al. (2022) found 5722 for *A. testudineus* and 4942 for *M. vittatus* from Gajner *Beel* and Ganges River, respectively (Table 15). Other authors (Alam et al. 2011; Rahman et al. 2018 and Parvin et al. 2022) reported fecundity 3917 for *C. punctata,* 1488 for *P. sophore,* 2059 for *H. fossilis* from Hilna Beel, Rajshahi and Ganges river, respectively. On the other hand, Hussain (2010), Khan et al. (1992), Islam and Das (2006) and Roy et al. (2021) observed fecundity was 2,340 for *C. batrachus,* 720 for *M tengra,* 2198 for *M cavasius* and 3675 for *O pabda* from research ponds of BFRI and Brahmaputra river, respectively. Such differences probably occurred due to fish living under different nutrional conditions (Ruzzante et al. 1998), methodological techniques used for the fecundity estimation (Alonso-Fernández et al., 2009).

Table 15. Fecundity of stocked indigenous fishes from Saganna *Baor* in Bangladesh and other water-bodies

Fish Species	**Mean Fecundity**	**Available literature**		
		Mean fecundity	**Study Site**	**References**
Anabas testudineus	5356	5722	Gajner Beel	Mawa et al. (2022)
Channa punctatus	4567	3917.8	Hilna Beel, Rajshahi	Alam et al. (2011)
Mystus vittatus	3457	4942	Gajner Beel, Pabna	Mawa et al. (2022)
Puntius sophore	1547	1488	Padma River	Rahman et al. (2018)
Heteropneustes fossilis	3456	2059	Ganges River	Parvin et al. (2022)
	1578	1730	Gajner Beel, Pabna	Hasan et al. (2022)
Clarias batrachus	2876	2,340	BFRI Research Pond	Hussain (2010)
Mystus tengra	1285	720	Bangladesh	Khan et al. (1992)
Mystus cavasius	2187	2198	Brahmaputra River	Islam and Das (2006)
Ompok pabda	3076	3675	Old Brahmaputra River	Roy et al. (2021)

11.1.9. Causes for declining of indigenous fishes from *Baors*

According to respondent fishers and *Baor* management people, availability of fish in the Saganna and Sarjat *Baor* has been decling due to various man-made and natural causes those are reflected in Table 16 & Fig. 8. However, based on survey findings a list of total causes of declining fish diversity in Baor waters are summarized as follows:

- The presence of a large number of predatory fish in Baors is responsible for a decrease in biodiversity and fish production in the research region due to reduction of prey species.
- The addition of cultural fish species is another significant factor in the reduction of fish diversity in the research region as a result of competition for food and habitat.
- Floods reduce fish populations because the offspring are isolated by the retreating waters following the flood.

- During the breeding season, fishers catch brood fish and fish fry without discrimination, diminishing biodiversity.
- Use of distructive fishing gears *i.e*. fine seine net (*ber jal*) and currunt *jal* are responsible for destroying SIS fishes.
- Killing fish by poison is done in winter and early monsoon season, which destroys all organisms in the water bodies.
- Pesticides and other chemicals used in agriculture are dangerous not just to fish but also to aquatic species. Pesticides and chemicals enter the river through canals and kill a large number of fish, including eggs.
- Water quality degradation caused by jute decomposition has had a negative impact on fish populations.
- Roads, dams, and other infrastructure construction disrupts fish spawning grounds, limiting fish productivity.

Therefore, proper management measures should be taken to protect SIFS wild stock in the *Baor*s. It must, however, be noted that a reduction of fishing pressure can be effective if it is preceded by community education. It is an urgent need to set up an effective fisheries management plan to protect and conserve this species including other species that have commercial values. From an investigation along with 400 fishermen, it is clear that over fishing, climate change, habitat degradation, using of illegal fishing gear, small mesh size of fishing gears, destroy of fry and fingerlings are the principal causes for declining of SIFS in the *Baor*s. To save the fish habitat and fishes in the *Baor*s, government and non-government organization should come forward. Rahman et al. (2012) state that the main factors contributing to the decline in fish biodiversity are overfishing, environmental degradation, pesticides and aquatic pollution, disease transmission, unrestricted introduction of exotic fish, destruction of breeding grounds, excessive water abstraction, siltation, various ecological changes in the fish's natural habits, and improper management leading to the withdrawal of water from the Baors, which is almost similar with with the present findings.

Table 16. Causes for declining of indigeneous fishes from the Saganna and Sarjat *Baors* in Jhenaidah, south western Bangladesh

Causal factors	Respondent (%)
Saganna	
Predatory fish	30
Addition of culture species	15
Use of destructive fishing gears	13
Indiscriminate fishing	12
Water from jute decomposition	10
Pesticides	8
Destruction of spawning ground	5
Poisoning	3
Poaching	2
Sarjat	
Addition of culture species	35
Flooding	20
Over fishing	15
Insecticides and Pesticides	10
Use of destructive fishing gears	8
Poisoning and Poaching	7
Destruction of spawning ground	5

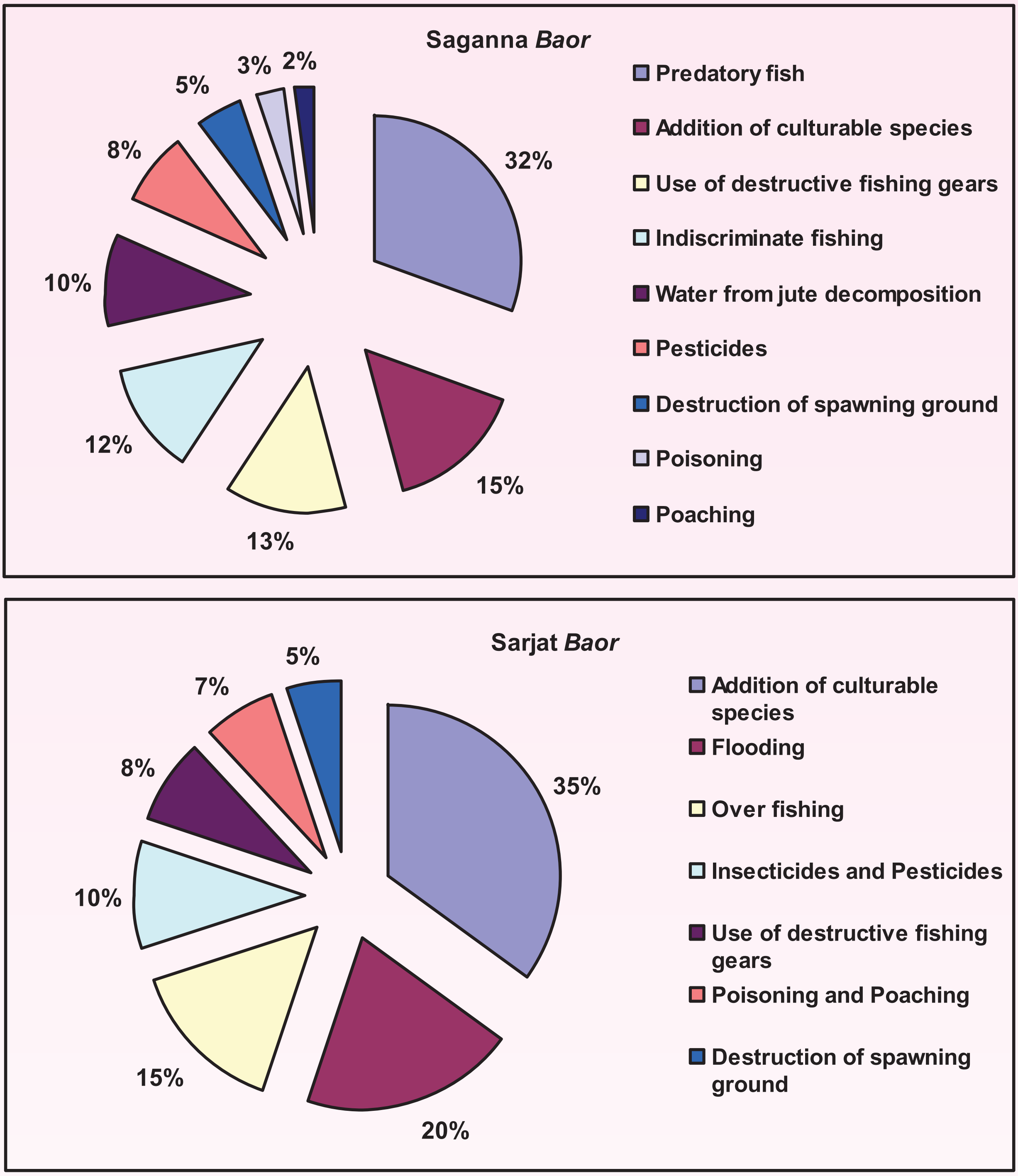


Fig 8. Causes of declining indigeneous fishes from the Saganna and Sarjat *Baors* in Jhenaidah, south-western Bangladesh.

11.1.10. Relative abundance

Fish abundance relates positively with the closeness of ambient environmental conditions to those of its niche (Hayes et al., 2006). In our study, we estimate the relative abundance of 7 stocked species by maintaining the CPUE and after fishing for 2 hours. Calculated abundance is shown in Table 17.

Table 17. Relative abundance of stocked fishes from Saganna and Sarjat *Baor*, Bangladesh

Baor	Species	June, 2020	June, 2021	April, 2022
Saganna	*Anabas testudineus*	92	168	198
	Channa punctatas	87	150	200
	Clarius batrachus	-	-	-
	Heteropneustes fossilis	105	178	245
	Mystus tengra	101	178	225
	Mystus vitatus	95	155	198
	Mystus cavasius	110	201	278
	Ompok pabda	125	220	335
Sarjat	*Anabas testudineus*	95	178	201
	Channa punctatas	88	150	189
	Clarius batrachus	-	-	-
	Heteropneustes fossilis	95	145	202
	Mystus tengra	98	182	215
	Mystus vitatus	101	183	205
	Mystus cavasius	115	203	301
	Ompok pabda	120	210	325

11.1.11. Length at first recruitment (L_r)

Recruitment typically refers to a new cohort in the catch due to becoming big or old enough to be vulnerable to the fishery (Sabbir et al., 2021). In our study, length at first recruitment was estimated for the 7 stock species; 7.9 cm for *A. testudineus*, 7.2 cm for *C. punctata*, 9.3 cm for *H. fossilis*, 5.4 cm *M. tengra*, 5.3 cm for *M. vittatus*, 6.3 cm for *M. cavasius*, 9.2 cm for *O.pabda* from Saganna *Baor*. In case of Sarjat *Baor*, 7.1 cm for *A. testudineus*, 7.3 cm for *C. punctata*, 9.2 cm for *H. fossilis*, 5.3 cm for *M. tengra*, 5.8 cm *M. vittatus*, 6.9 cm for *M. cavasius* and 9.0 cm for *O. pabda* (Table 18; Fig. 9.1 & 9.2).

Table 18. Length at first recruitment for stocked species from Saganna and Sarjat *Baor*

Baor	Species	Length at first recruitment (L_r) cm
Saganna	*Anabas testudineus*	7.9
	Channa punctata	7.2
	Clarius batrachus	-
	Heteropneustes fossilis	9.3
	Mystus tengra	5.4
	Mystus vitatus	5.3
	Mystus cavasius	6.3
	Ompok pabda	9.2
Sarjat	*Anabas testudineus*	7.1
	Channa punctata	7.3
	Clarius batrachus	-
	Heteropneustes fossilis	9.2
	Mystus tengra	5.3
	Mystus vitatus	5.8
	Mystus cavasius	6.9
	Ompok pabda	9.0

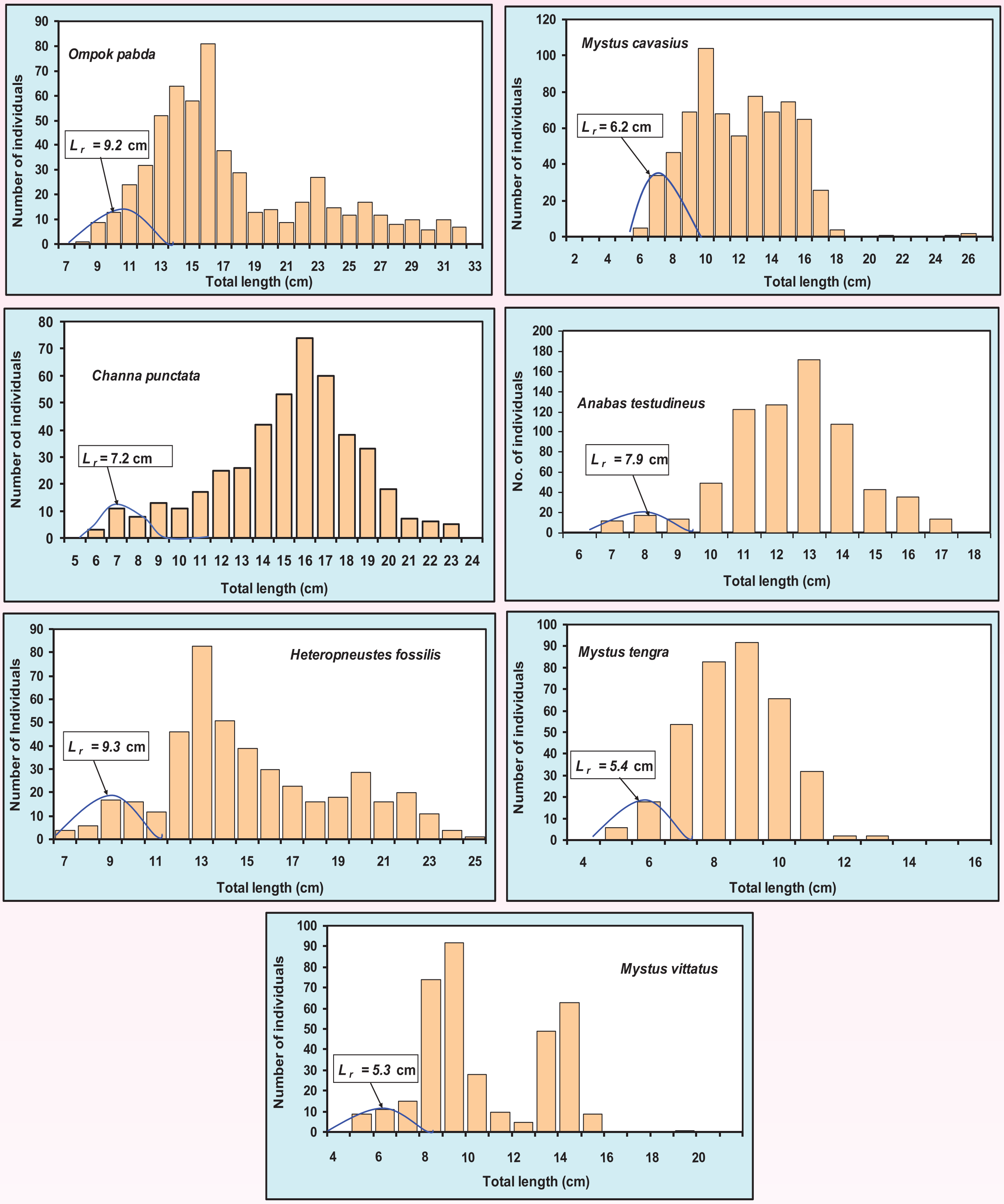


Fig 9.1. Length at first recruitment for stocked species from Saganna *Baor*, Bangladesh.

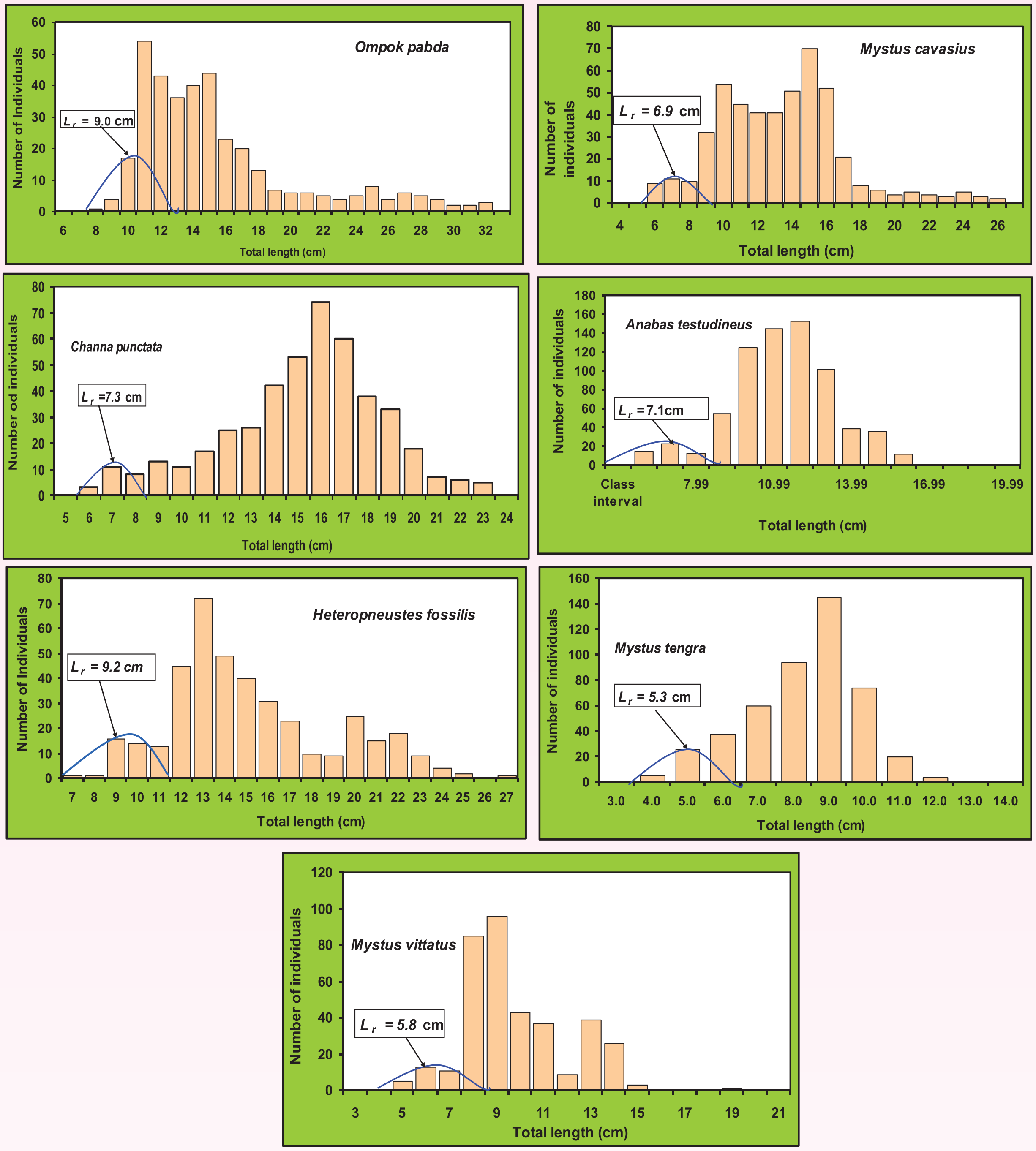


Fig 9.2. Length at first recruitment for stocked species from Sarjat *Baor*, Bangladesh.

11.1.12. Growth parameters

It is crucial to determine the growth parameters for predicting future yields and stock biomass from a particular aquatic ecosystem (Sabbir et al. 2021). Growth parameters of 7 stock species were calculated from Saganna and Sarjat Baor (Table 19). We observed maximum L_∞ was 34.34 cm for *O. pabda* and minimum 14.75 cm for *M. tengra*. L_∞ was recorded as 34.03 for *O. pabda* and 13.60 cm for M. tengra. We also estimated K, t_0, t_m and t_{max} of the stocked fishes; among them maximum K was 1.08 and minimum was 0.97 for *O. pabda* and *H. fossilis* from Saganna *Baor*, respectively. In Sarjat Baor Maximum K was was 1.03 for *H. fossilis* and minimum was 0.98 for *M. tengra*. Maximum longivity (t_{max}) recorded for H. *fossilis* (3.10 year) and minimum for *O. pabda* (2.79 year) from Sanganna *Baor* where, In Sarjat Baor maximum t_{max} recoerded for *M. tengra* (3.07 year) and minimum for *O. pabda* (2.79 year).

Optimum catchable length (L_{opt}) was recorded for 7 stocked specices among them maximum was 21.20 cm and minimum was 8.79 cm for *O. pabda* and *M. tengra*, respectively from Saganna *Baor*. And maximum L_{opt} was 21.0 cm for *O. pabda* and minimum was 8.79 cm for *M. tengra* from Sarjat *Baor*. To compare our findings with other works we found that Mawa et al. (2022) estimated optimum catchable length for *M. vittatus* was 11.14 cm from the Ganges River, Bangladesh. In case of capture the fishes, optimum catchable length should be maintained to obtain the maximum possible yield and to maintain the sustainability of the species (El-Ganainy and Riad 2008). L_{opt} helps to select mesh sizes of gear and avoid the catch of fishes below this catchable size for the target fishes and we strongly recommended catching fishes from this size for maintaining the existence of fishes year after year by protecting the maximum brood species (Mawa et al., 2021).

Table 19. Growth parameters of stocked fishes from Saganna and Sarjat *Baor*, Bangladesh

Baors	Species	L_{max} (cm)	L_{∞} (cm)	*K* (year^{-1})	ϕ	t_0 (year)	t_m (year)	t_{max} (year)	L_{opt} (cm)
Saganna	*Anabas testudineus*	17.40	18.40	1.01	2.53	0.016	0.83	2.97	11.06
	Channa punctatas	24.70	25.97	0.97	2.82	0.016	0.87	3.10	15.84
	Clarius batrachus	-	-	-	-	-	-	-	-
	Heteropneustes fossilis	24.30	25.56	0.97	2.80	0.016	0.87	3.10	15.58
	Mystus tengra	13.90	14.75	0.99	2.33	0.018	0.85	3.03	8.79
	Mystus vitatus	18.90	19.96	1.01	2.60	0.016	0.83	2.97	12.04
	Mystus cavasius	27.10	28.46	1.05	2.93	0.013	0.80	2.86	17.43
	Ompok pabda	32.80	34.34	1.08	3.11	0.012	0.78	2.79	21.20
Sarjat	*Anabas testudineus*	16.40	17.36	1.00	2.48	0.017	0.84	3.00	10.41
	Channa punctatas	23.70	24.94	1.03	2.81	0.014	0.81	2.90	15.19
	Clarius batrachus	-	-	-	-	-	-	-	-
	Heteropneustes fossilis	27.30	28.66	1.06	2.94	0.013	0.79	2.83	17.56
	Mystus tengra	12.80	13.60	0.98	2.26	0.019	0.86	3.07	8.07
	Mystus vitatus	18.70	19.75	1.01	2.60	0.016	0.83	2.97	11.91
	Mystus cavasius	26.40	27.73	1.05	2.91	0.013	0.80	2.86	16.96
	Ompok pabda	32.50	34.03	1.08	3.10	0.012	0.78	2.79	21.0

11.1.13. Mortality and exploitation

Assessment of the mortality rate is crucial for evaluating the abundance of a fish stock which helps to set harvest limits to obtain maximum benefit for the stakeholders of the resource (Sabbir et al., 2021). Mortality and exploitation rate of 7 stocked species were calculated from Saganna and Sarjat *Baor* (Table 20). In this study, we estimated mortality (total, natural and fishing) of 7 SIFS species from two *Baors*; among them, the mimimum *Z* was obtained as 1.36 year^{-1} for *M. cavasius* and maximum as 3.00 year^{-1} for *O. pabda* from Saganna *Baor* and in Sarjat *Baor* minimum *Z* was 1.53 year^{-1} for *M. vittatus* and largest was 4.79 year^{-1} for *A.*

testudineus. The minimum *M* was 1.45 $year^{-1}$ for *M. cavasius* and maximum was 1.61 $year^{-1}$ for *H. fossilis* from Saganna *Baor* and in case of Sarjat *Baor*, minimum *M* was 1.47 $year^{-1}$ for *C. puntata* and the largest was 1.66 $year^{-1}$ for *O. pabda*. Minimum fishing mortality (F) was 0.20 $year^{-1}$ for *M. cavasius* and maximum was 1.53 $year^{-1}$ for *O. pabda* from Saganna *Baor*. In case of Sarjat *Baor*, Minimum *F* was 0.01 $year^{-1}$ for *M. tengra* and maximum was 3.22 $year^{-1}$ for *A. testudineus*. Maximum exploitation was observed for *M. vittatus* (0.45) and minimum for *H. fossilis* (0.10) from Saganna *Baor*. From Sarjat *Baor*, maximum *E* was recorded for *A. testudineus* (0.67) and minimum for *M. cavasius* (0.10). Mawa et al. (2022) found, Z was 1.80 $year^{-1}$, M_w was 0.97 $year^{-1}$, and *F* was 0.83 $year^{-1}$ for *M. vittatus* from Ganges River, Bangladesh. Khatun et al (2019) recorded M was 1.60 $year^{-1}$ for *A. testudineus* from Gajner *Beel*, Bangladesh. This difference depends on some factors like disease, competition, pollution, environmental factors, and any other natural/manmade factors (Mawa et al., 2022).

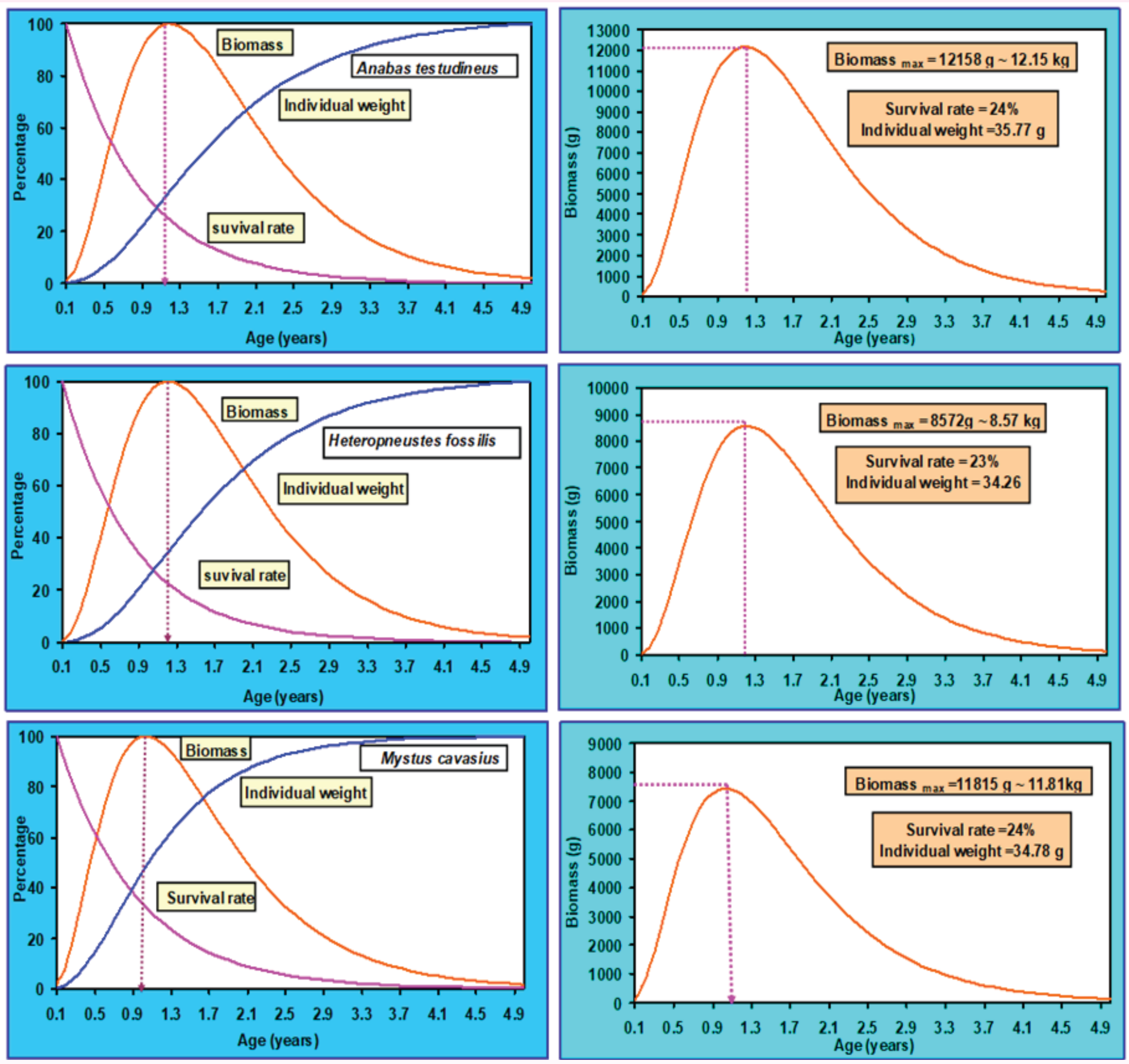
Table 20. Mortality and exploitation rate of stocked fishes from Saganna and Sarjat Boar, Bangladesh

Sl. No.	Species	Z ($year^{-1}$)	M ($year^{-1}$)	F ($year^{-1}$)	E
Saganna	*Anabas testudineus*	1.80	1.55	0.25	0.18
	Channa punctata	1.96	1.58	0.38	0.19
	Clarius batrachus	-	-	-	-
	Heteropneustes fossilis	2.05	1.61	0.44	0.10
	Mystus tengra	2.05	1.58	0.47	0.23
	Mystus vitatus	2.45	1.55	1.90	0.45
	Mystus cavasius	1.36	1.45	0.20	0.14
	Ompok pabda	3.00	1.47	1.53	0.32
Sorjat	*Anabas testudineus*	4.79	1.57	3.22	0.67
	Channa punctata	2.22	1.47	0.75	0.34
	Clarius batrachus	-	-	-	-
	Heteropneustes fossilis	2.89	1.61	1.28	0.44
	Mystus tengra	1.69	1.49	0.20	0.20
	Mystus vitatus	1.53	1.52	0.01	0.35
	Mystus cavasius	1.73	1.55	0.18	0.10
	Ompok pabda	2.59	1.66	0.93	0.36

11.1.14. Biomass and maximum sustainable yield (MSY)

This study is estimated the effect on growth and mortality on biomass of stocked species from two *Baor* (Fig. 10.1, 10.2, 11.1 & 11.2). We found that with time individual's weight were increasing and survival rate was decreasing but when the biomass reached its maximum level then the biomass was gradually decreasing. It was assumed that if 1000 fishes were recruiting. From that we can calculate the total biomass. MSY was to catch fishes about 50% from the total Biomass. In our study, we estimated 7 stock species from the two *Baors*; stocked 2600 individuals of *M. cavasius* in 2020. In 2022 we got around 1087170 ind/ 8082 kg, we can catch 50% from the stock (MSY= 4041 kg) and income was (4041*600) = 24, 24,600 TK, for *O. pabda*, in 2020 stocked amount was 3600 ind, and in 2022 we got biomass around 1053450 ind /5818 kg. MSY was 50% (2909 kg) and income was (2909*700) = 20,36,300 TK. For *A. testudineus* we stocked 3000 individuals in 2020 and in 2022 we got 67020 ind/6702 kg and MSY (3351 kg) and income (3351*550) =18, 43,050 Tk. For *M. vittatus* , we stocked 2500 in 2020, in 2022 we got 136928 ind/6224 kg and MSY (3112kg) so income was

(31112*400)=12,44800TK, for *M. tengra*, stocked 2975 in 2020 and in 2022 we got 118280 ind/6312 kg, MSY was 3156kg and income was (3156*420)=13520 TK, for *C. punctata* , we stocked 2200 in 2020, in 2022 we got 56936ind/ 4745 kg, MSY was 2372 kg and income was (2372*400)=948800 TK and for *H. fossilis*, we stocked 2300 in 2020, in 2022 we got 43560/4840 kg, MSY was 2420kg and income was (2420*600)=1452000 Tk. Fish biomass provides an important protein source for many people, particularly in the developing world. These results suggest that management to sustain SIFS diversity which will promote total fish biomass as well as increase the socioeconomic condition of *Baor* fisher's community and higher resilience of that ecosystem.



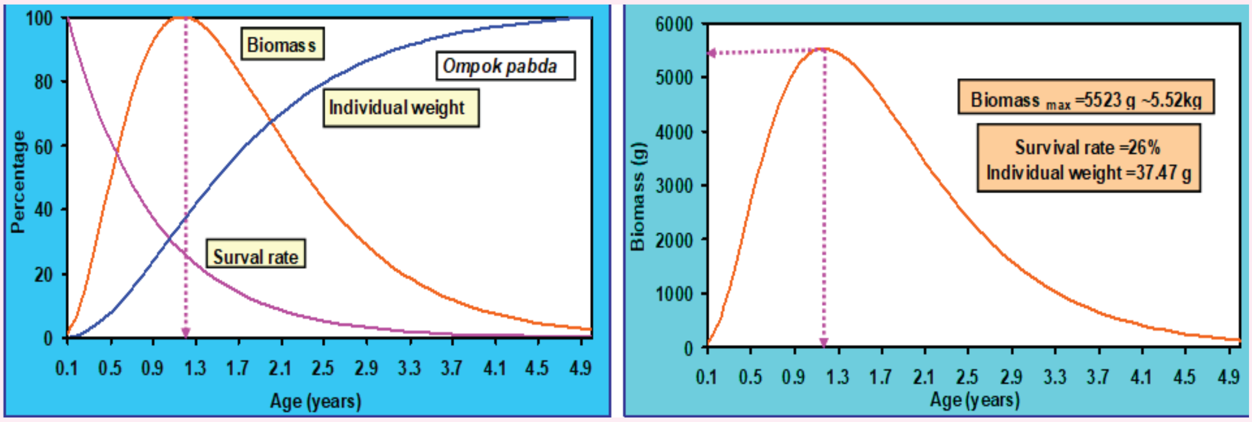


Fig 10.1. Biomass for stocked species from Sanganna *Baor*, Bangladesh.

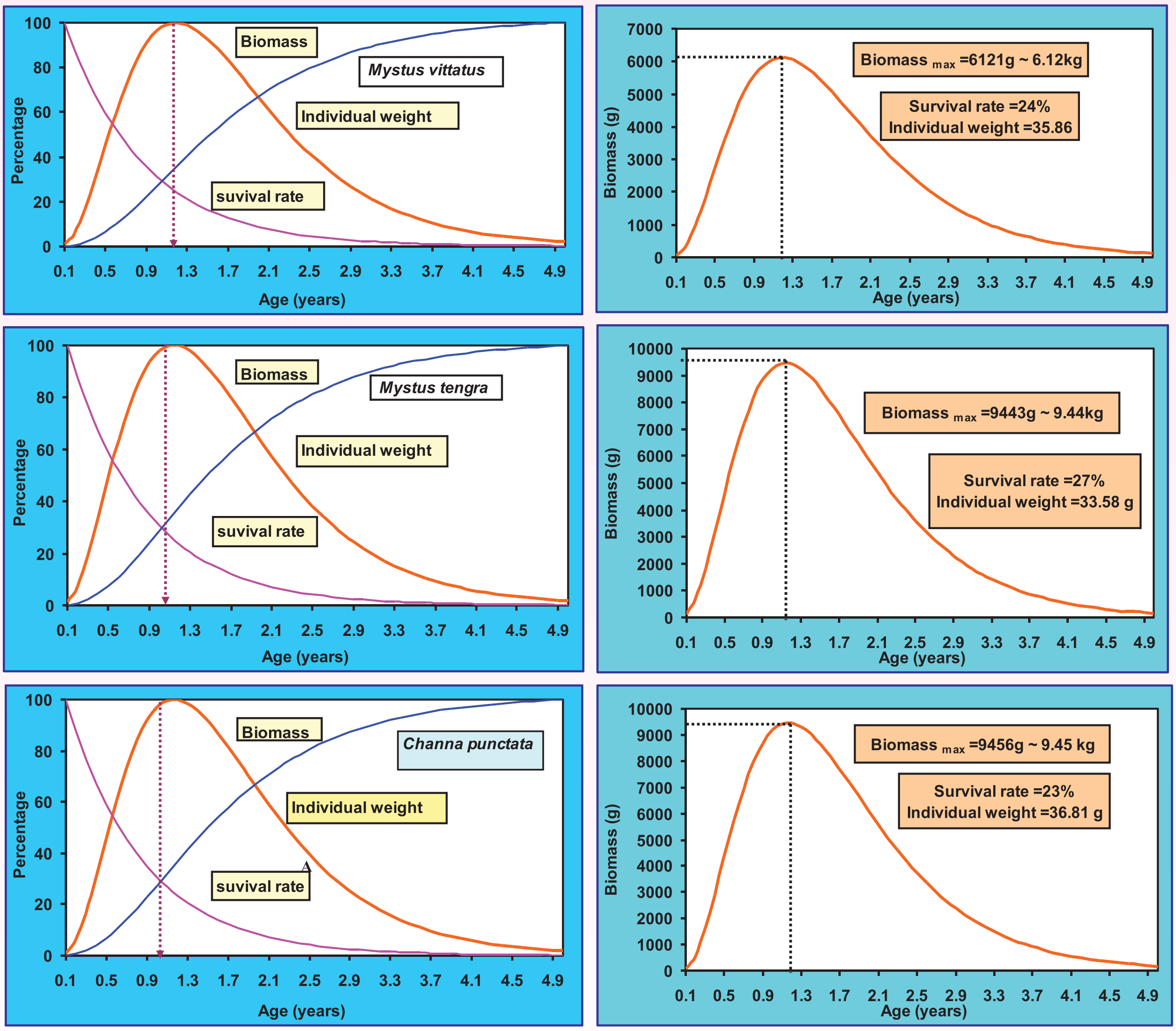


Fig 10.2. Biomass for stocked species from Sanganna *Baor*, Bangladesh.

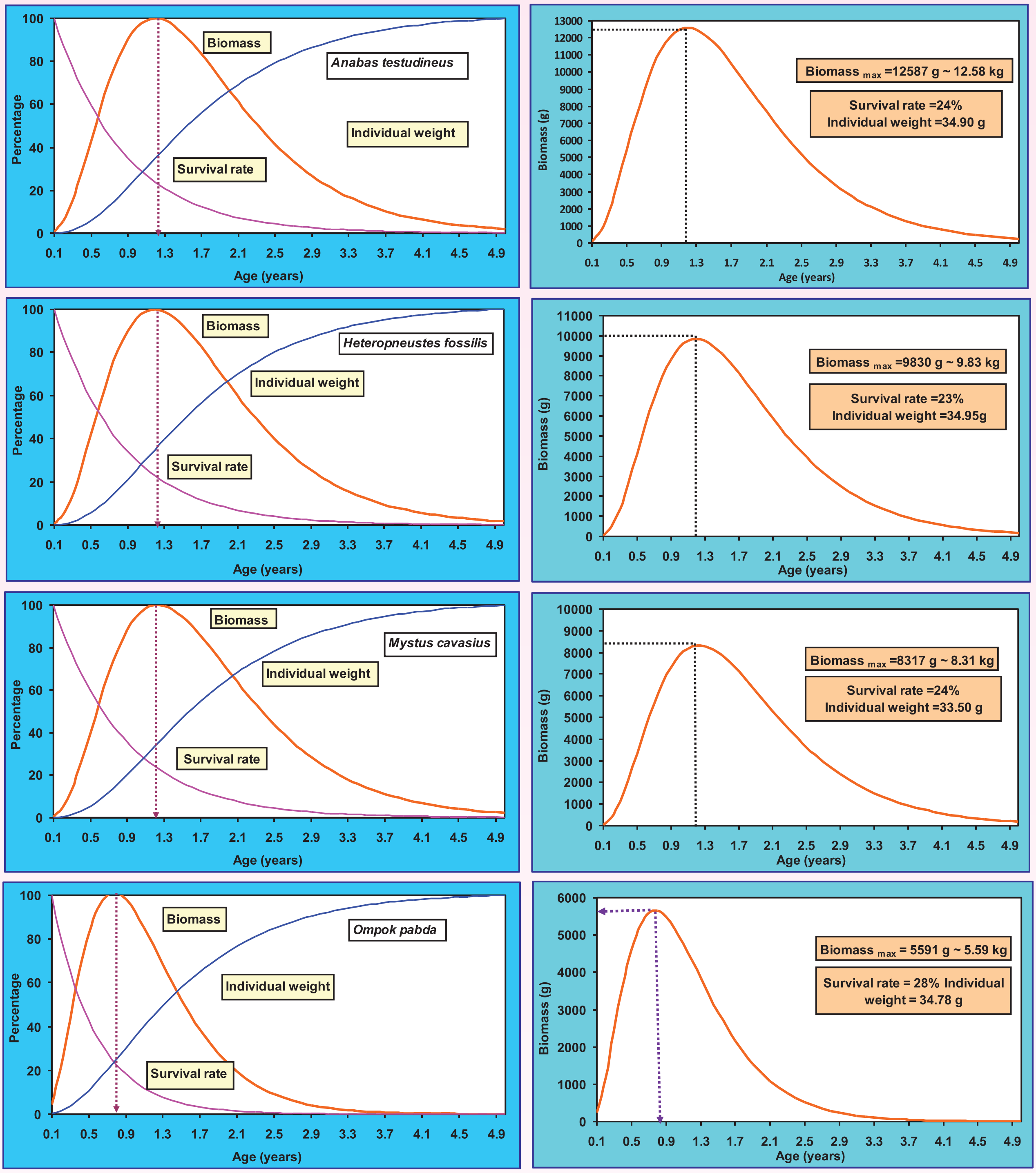


Fig 11.1. Biomass for stocked species from Sarjat *Baor*, Bangladesh.

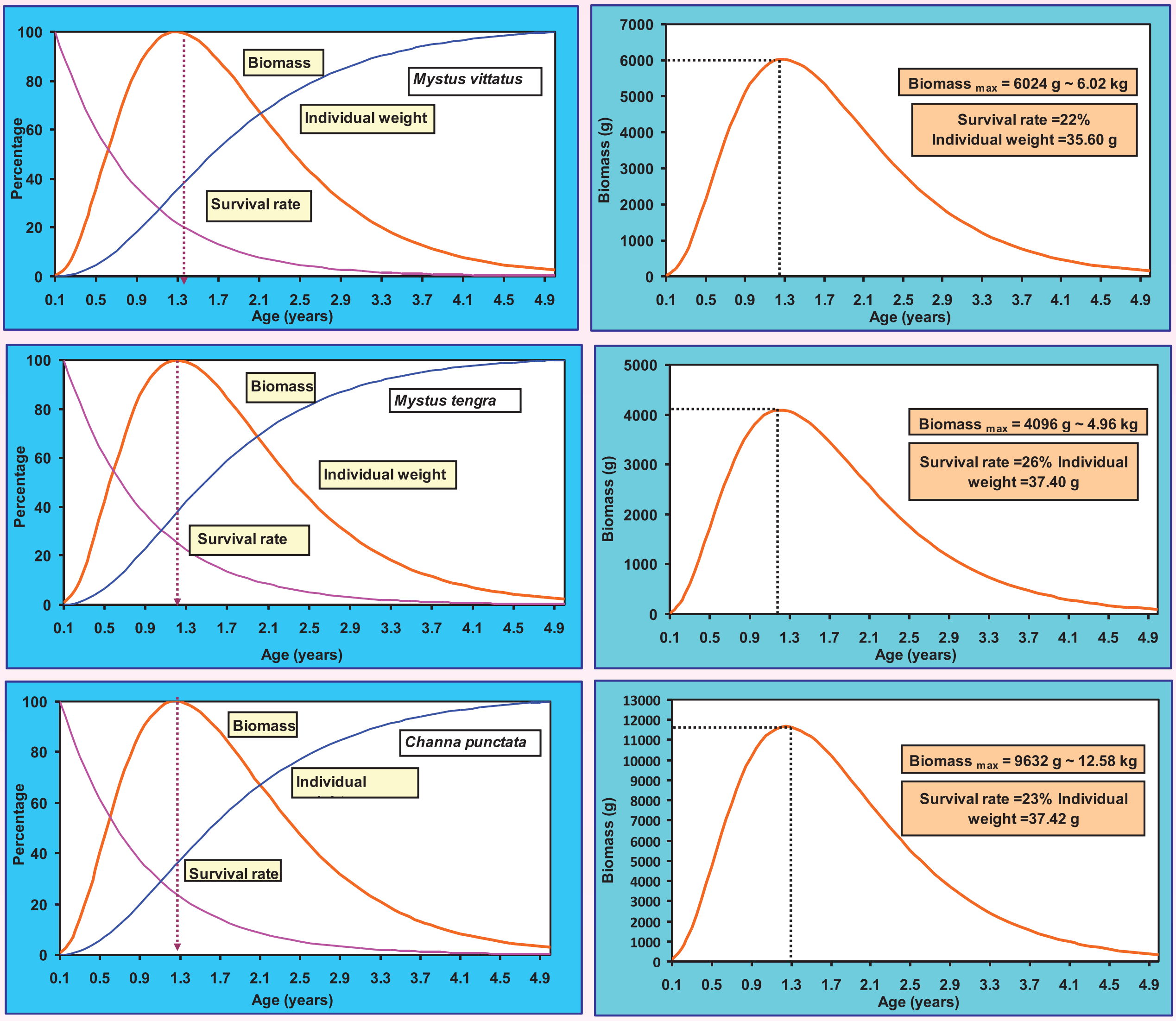


Fig 11.2. Biomass for stocked species from Sarjat *Baor*, Bangladesh.

11.2. Component-2 (JUST)

11.2.1. Identification of fishes and fish status

A number of 27 small indigenous fish species (SIFS) and 6 culture species (Table 21) with their IUCN global status were found from two selected *Baor*s (Table 22). Bangladesh is unique in terms of valuable wetland ecosystems and associated aquatic biodiversity, ranking third in Asia with roughly 260 indigenous fresh water species (Rahman, 2005). A total of 68 fish species have been recorded in Itna and Kishoregonj water bodies (Sakawat, 2002). A total of 54 fish species have been recorded in Kafrikhal beel water bodies (Halim et al., 2017). Similarly, 52 species were discovered in Shorupdah beel, Manirumpur, Jessore (Majumder et al., 2017) and 55 species were discovered in Mymensingh's Old Brahmaputra River (Raushon et al., 2017). So far, 70 fish species have been identified from the Gharia *beel* (Chakraborty and Mirza 2007). A total of 40 fish species, including three exotic species from Chanda *beel* were identified (Ehshan et al., 2000). Chalan *beel* has 105 recorded fish species (Ahsan, 2008).

Table 21. Available fish species from two selected *Baor*s of Jashore district (Bukvora *Baor* and Khatura *Baor*) with local name and common name

SL No.	Species name	Local name	Common name
1	*Amblypharyngodon mola*	Mola	Mola carplet
2	*Anabas testudineus*	Koi	Climbing perch
3	*Badis badis*	Napit koi	Badis
4	*Chanda nama*	Chanda	Elongate glass-perchlet
5	*Channa orientalis*	Cheng	Walking snakehead
6	*Channa punctatus*	Taki	Spotted snakehead
7	*Channa striatus*	Shol	Striped snakehead
8	*Esomus danrica*	Darkina	Flying barb
9	*Glossogobius giuris*	Bele	Tank goby
10	*Gudusia chapra*	Chapila	Indian River Shad
11	*Heteropneustes fossilis*	Shing	Stinging catfish
12	*Lepidocephalichthys guntea*	Gutum	Guntea loach
13	*Macrognathus aculeatus*	Tara baim	Lesser spiny eel
14	*Macrognathus pancalus*	Guchi	Barred spiny eel
15	*Mastacembelus armatus*	Sal baim	Zig-zag eel
16	*Mystus cavasius*	Golsha-tengra	Gangetic mystus
17	*Mystus tengara*	Choto tengra	Tengara catfish
18	*Nandus nandus*	Bheda	Gangetic leaffish
19	*Ompok pabda*	Madhu pabda	Pabdah catfish
20	*Parambassis ranga*	Lal chanda	Indian glassy fish
21	*Pethia ticto*	Titputi	Ticto barb
22	*Puntius sophore*	Jatputi	Pool barb
23	*Salmostoma bacaila*	Chela	Large razorbelly minnow
24	*Tetraodon cutcutia*	Potka	Ocellated pufferfish
25	*Trichogaster fasciata*	Kholisha	Banded gourami
26	*Trichogaster lalius*	Lal kholisha	Dwarf gourami
27	*Xenentodon cancila*	Kakila	Freshwater garfish
Cultured fish			
1	*Cirrhinus cirrhosus*	Mrigal	Mrigal carp
2	*Cirrhinus reba*	Raik	Reba carp
3	*Labeo bata*	Bata	Bata
4	*Labeo calbasu*	Kal baush	Orange fin labeo
5	*Labeo rohita*	Rui	Roho labeo
6	*Aristichthys nobilis*	Bighead	Bighead carp
7	*Gibelion catla*	Catla	Catla

Table 22. Available fish species with their status according to IUCN Bangladesh (2015) and IUCN global (2021) from the two selected *Baor*s, Jashore region, south-western Bangladesh

SL No.	Species name	Availability in the *Baor*	IUCN Bangladesh Status	IUCN (Global)
1	*Amblypharyngodon mola*	TYL	LC	LC
2	*Anabas testudineus*	LM	LC	LC
3	*Badis badis*	SM	NT	LC
4	*Chanda nama*	TYL	LC	LC
5	*Channa orientalis*	TYS	LC	LC
6	*Channa marulius*	SM	EN	LC
7	*Channa punctatus*	TYL	LC	LC
8	*Channa striatus*	SM	LC	LC
9	*Esomus danrica*	TYS	LC	LC
10	*Glossogobius giuris*	TYL	LC	LC
11	*Gudusia chapra*	TYL	VU	LC
12	*Heteropneustes fossilis*	SM	LC	LC
13	*Lepidocephalichthys guntea*	LM	LC	LC
14	*Macrognathus aculeatus*	SM	NT	NE
15	*Macrognathus pancalus*	TYS	LC	LC
16	*Mastacembelus armatus*	SM	EN	NE
17	*Mystus cavasius*	LM	LC	VU
18	*Mystus tengara*	TYS	LC	LC
19	*Nandus nandus*	SM	LC	LC
20	*Ompok pabda*	SM	EN	NT
21	*Parambassis ranga*	TYL	LC	NE
22	*Puntius sophore*	TYL	LC	LC
23	*Salmostoma bacaila*	TYL	LC	LC
24	*Tetraodon cutcutia*	SM	LC	LC
25	*Trichogaster fasciata*	TYL	LC	LC
26	*Trichogaster lalius*	TYS	LC	LC
27	*Xenentodon cancila*	TYS	LC	NE
Culture fish				
1	*Cirrhinus cirrhosus*	TYL	NT	VU
2	*Cirrhinus reba*	TYL	NT	LC
3	*Labeo bata*	TYL	LC	LC
4	*Labeo calbasu*	TYL	LC	LC
5	*Labeo rohita*	TYL	LC	LC
6	*Aristichthys nobilis*	TYL	LC	DD
7	*Gibelion catla*	TYL	LC	LC

Note: LC-Least concern, VU-Vulnerable, EN-Endangered, CR- Critically endangered, NT-Near threatened, DD- Data deficient, NE- Not evaluated, TYS (throughout the year in small amount), TYL (throughout the year in large amount), SM (found in small amount during monsoon), LM (found in large amount during monsoon), and NE (not evaluated).

11.2.2. Fish availability

According to the *Baor* fishers (40%), Small indigenous fish species (SIFS), and Indian major carps (IMCs) were abundant fish in the *Baor* areas throughout the period of time (Table 22).

Available SIFS in *Baors*

Glossogobius giuris

Channa stariata

Channa orientalis

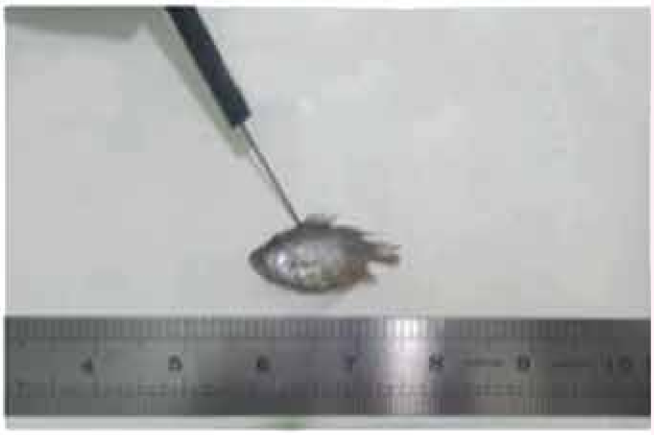
Channa punctata

Puntius sophore

Nandus nandus

Heteropneustis fossilis

Puntius ticto



Chanda nama

Trichogaster fasciata

Parambasis ranga

Badies badies

western Bangladesh

11.2.3. Fishing gears

Survey study revealed that, out of the several fishing gears used to collect samples, the seine net (Ber jal) was the most commonly used one (Table 23) followed by square lift net and cast net those are also used widely. In addition, many sorts of traps were utilized to catch fish in the Bukvora and Khatura *Baor.* According to Biswas et al., (2021), different types of fishing gear were used for fishing in Kannayadaha baor, Jashore, Bangladesh. Among them, Khepla jal, Bhasal jal, Ber jal and Fash jal were highly used. Rubel et al., (2014) was reported using different gears like jhaki jal, Behundi jal, Thella jal, Moia jal in Lohalia River and different types of fishing gear are used in different period in Lohalia river.

Plate 12. Fishing gears used by fishers in Bukvora *Baor* and Khatura *Baor*, Jashore, south-western Bangladesh

Table 23. Fishing gears used in the Bukvora *Baor* and Khatura *Baor*

Sl No.	English name	Local name	Mesh Size(cm)
1	Gill net	Fas-jal	1.5-2.5
2	Kholson	Kholsun	
3	Hook	Borshi	
4	Seine net	Ber jal	1.0-2.0
5	Mosquito net	Moshari jal	0.5-1.0
6	Box trap	Dohair	
7	Fence	Bana	
8	Fyke net	Ghuni	1.0-2.5
9	Cast net	Jhaki jal	1.0-2.0
10	Lave net	Thela jal	1.5-2.5

11.2.4. Fish restocking

Selected indigenous fishes (Koi (*Anabas testudineas*), Taki (*Channa punctata*), Magur (*Clarius batrachus*), Shingee (*Heteropneustes fossilis*), tengra (*Mystus cavasius*), etc.) were stocked after being marked and tagged with Flurochrome Dyes to observe changes in relative abundance by Catch per unit effort and reproductive potentiality through gonadal studies. The brood fish were collected from local hatchery and live fish traders. Fish sanctuary was established for facilitating fish breeding and conservation

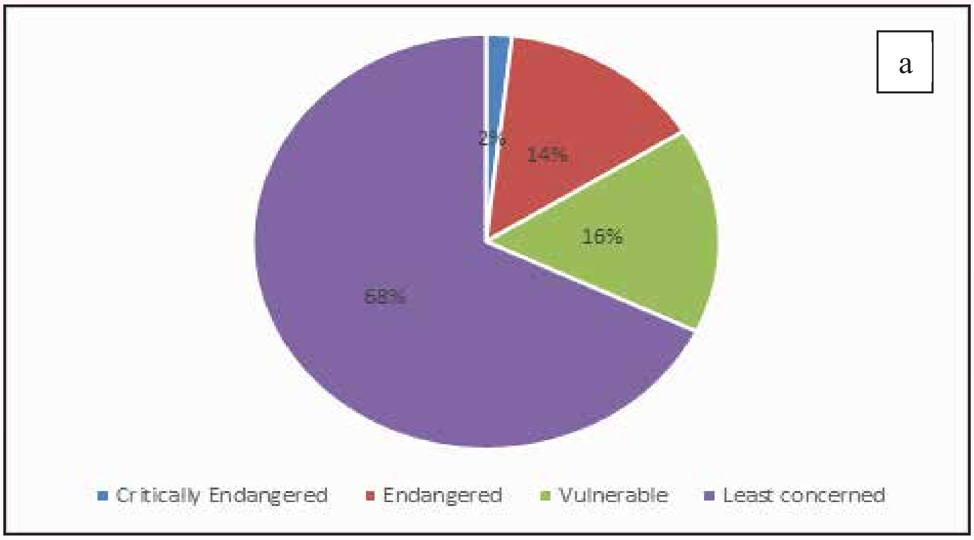
11.2.5. Study of biodiversity parameters

Study area and sampling

The study area was divided into three zones at the Bukvora *Baor*. All data were collected at fortnightly intervals for fish sampling. Based on similarity; August, September and October as autumn; November, December and January as winter seasons; February, March and April are considered as summer; May, June and July as monsoon.

Identification of the fish

Fish specimens were caught by five different gill nets (100 meters long, 1.5 meter height, mesh size 8, 12, 16, 20 mm mesh sizes) and five traditional bamboo made traps operating at the same time and spot within 0.7 km area for 6 h (7:00 – 13:00). A total of 39,324 specimens were caught, where unknown species were kept in 10% formalin and transported to laboratory. The species were identified and sorted species-wise based on their external morphology (Rahman, 2005). The sampled specimens were categorized as four groups by using biodiversity indices according to IUCN (2015). The following indices were found: least concerned (68%), vulnerable (2%), endangered (14%) and critically endangered (2%). Moreover, 39,324 specimen's total eleven families were recorded. The following ratios of fish species were categorized as follows: Cyprinidae (36%), Mastacembelidae (5%), Clupeidae (5%), Cobitidae (3%), Notopteridae (3%), Bagridae (9%), Synbranchidae (2%), Ambassidae (3%), Nandidae (2%), Belonidae (2%), Hemiramphidae (2%), Engraulidae (2%), Channidae (6%), Centropomidae (3%), Osphronemidae (5%), Heteropneustidae (3%), Gobiidae (2%), Ailiidae (3%), Anabantidae (2%) and Siluridae (6%) in Bukvora *Baor* (Fig. 12 a & b).



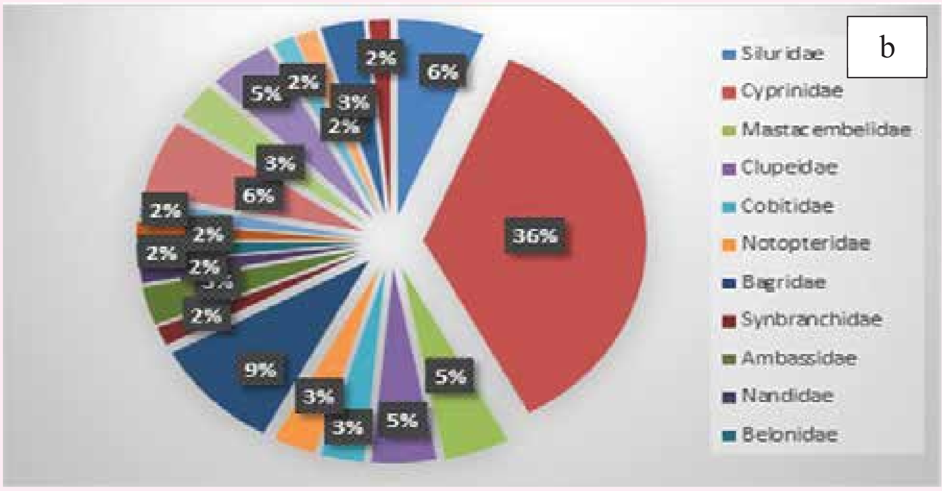


Fig 12. (a) Percentages of four biodiversity indices **(b)** Fish species under eleven families obtained from of Bukvora *Baor*, Jashore.

The following indices were found: least concerned (65%), vulnerable (7%), endangered (15%), critically endangered (7%) and near threatened (6) (Khatura *Baor*). Moreover, 39,324 specimen's total eleven families were recorded. The following ratios of fish species were categorized as follows: Cyprinidae (37%), Mastacembelidae (10%), Clupeidae (7%), Cobitidae (9%), Notopteridae (8%), Nandidae (8%), Bagridae (9%), Synbranchidae (9%), Ambassidae (7%), and Siluridae (5%) in Khatura *Baor* (Fig.13 a & b).

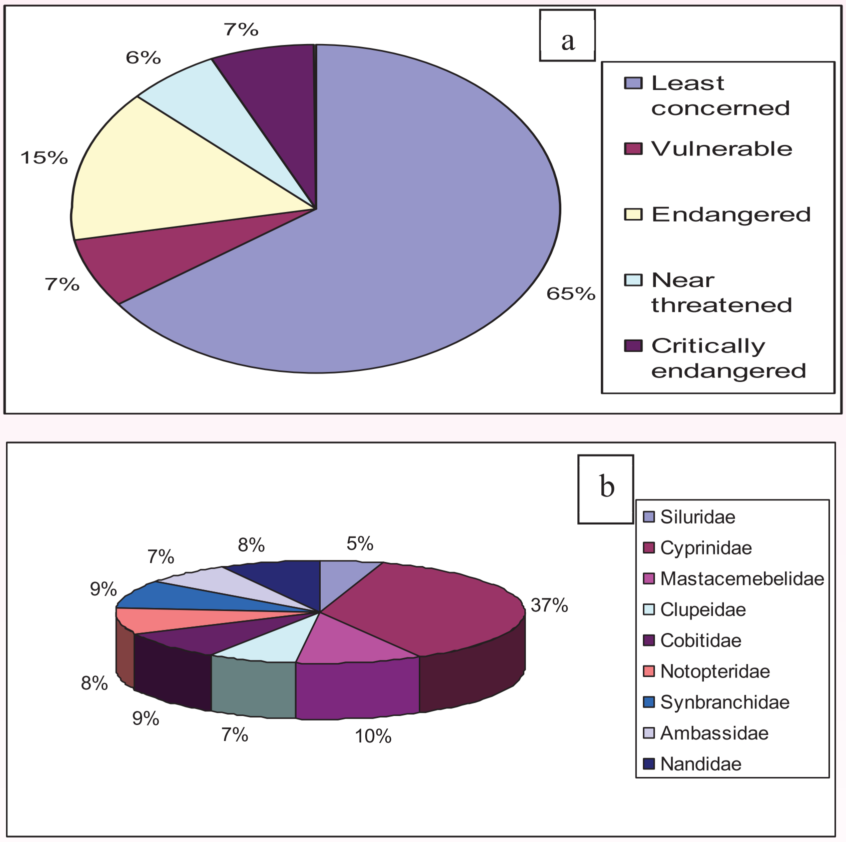


Fig 13. Percentages of four biodiversity indices **(a)** and eleven families **(b)** fish species under eleven families obtained from Khatura *Baor*, Jashore.

According to the abundance of fish species, they were categorized into 4 groups like, highly endangered (8.70%), common (60.87%), locally extinct (15.22%) and rare (15.22%) similar to (Halim et al., 2017). A total of 14 non-resident and resident fish species were identified in Pirla beel, of which 30 were common, 9 were rare, and 5 were critically endangered (Siddique, 2001). A list of 106 fish species from the districts of Mymensingh and Tangail, belonging to 68 genera, has been recorded (Doha, 1973). In the Chalan *beel*, 45 fish species were threatened, including 25 endangered, 14 vulnerable, and 6 critically endangered (Ahsan, 2008). A total of 106 fish species from Chalan *beel*, belonging to 10 orders, 31 families, and 71 genera, including critically endangered (6), endangered (20), vulnerable (10) and threatened (18) were identified (Sayeed, 2010).

According to the *Baor* fishers, Small indigenous fish species (SIFS), and Indian major carps (IMCs) found abundant in the *Baor* areas throughout the period.

Biodiversity index

The values of the Shanon-Weaver index, Evenness index and Richness index were estimated. However, the highest Shannon-Weaver index value (2.266) was observed in Khatura *Baor* and the lowest value (2.244) was observed in Bukvora *Baor*. The highest value of Evenness index (0.984) was observed from Khatura *Baor*, while the lowest rate value was (0. 975) reported from Bukvora *Baor*. In addition, the highest value of Richness index (1.064) was observed from Khatura *Baor*, while the lowest rate value was (1.018) reported from Bukvora *Baor*.

According to Jewel et al., (2018), the mean Simpson dominance index, the Shannon-Wiener diversity index, Pielou's evenness index and Margalef's richness index in the LW and AR habitats were counted as 0.91 and 0.94, 2.77 and 3.12, 0.67 and 0.66, and 4.83 and 5.87, respectively in two different aquatic habitats in Bangladesh: Lakhandaha Wetland and Atari River.

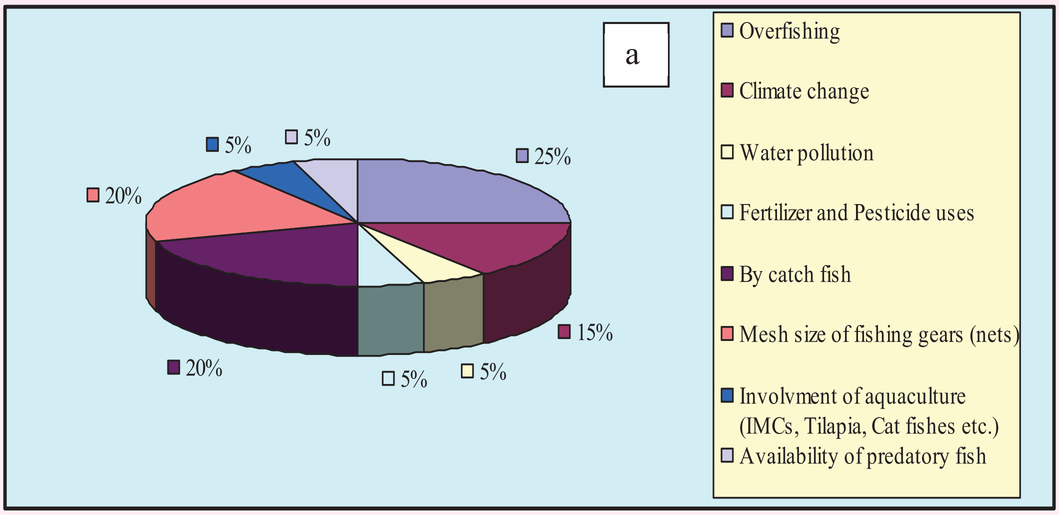
11.2.6. Causes of SIFS fish reduction

It was reported by respondent fishers and government and NGO personnel that availability of fish in the Bukvora and Khatura *Baor* has been decling due to various man-made and natural causes (Fig. 14). Principal causes for the declining fish diversity were as follows:

- The presence of a large number of predatory fish in Baors is responsible for a decrease in biodiversity and fish production in the research region due to reduction of prey species.
- The addition of cultural fish species is another significant factor in the reduction of fish diversity in the research region as a result of competition for food and habitat.
- Floods reduce fish populations because the offspring are isolated by the retreating waters following the flood.
- During the breeding season, fishers catch brood fish and fish fry without discrimination, diminishing biodiversity.
- Use of distructive fishing gears *i.e.* fine seine net (*ber jal*) and currunt *jal* are responsible for destroying SIS fishes.
- Killing fish by poison is done in winter and early monsoon season, which destroys all organisms in the water bodies.
- Pesticides and other chemicals used in agriculture are dangerous not just to fish but also to aquatic species. Pesticides and chemicals enter the river through canals and kill a large number of fish, including eggs.

- Water quality degradation caused by jute decomposition has had a negative impact on fish populations.

- Roads, dams, and other infrastructure construction disrupts fish spawning grounds, limiting fish productivity



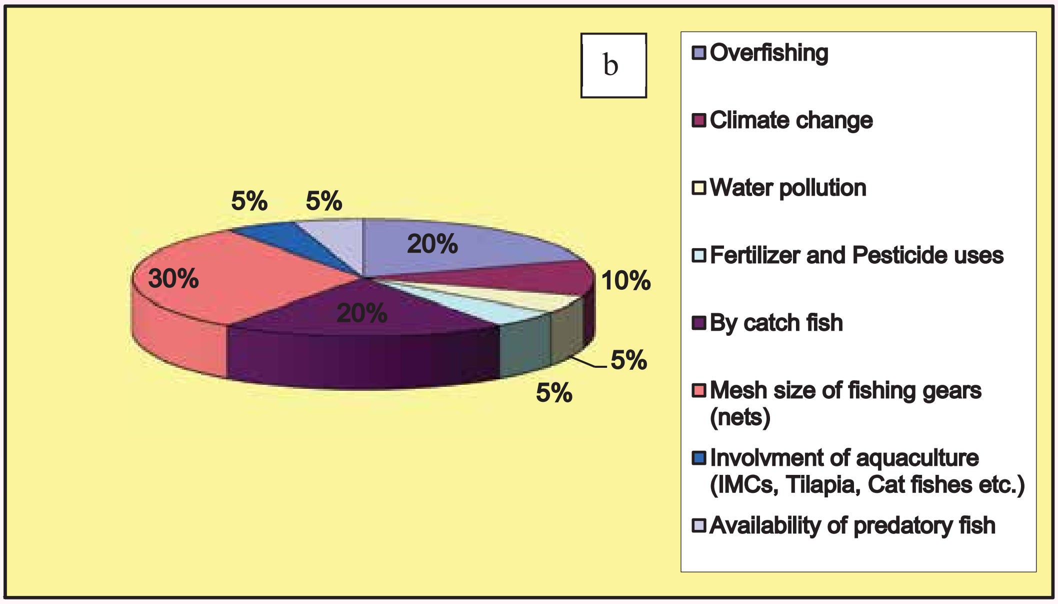


Fig 14. Causes of *Baor* SIFS reduction **(a)** Bukvora *Baor* **(b)** Khatura *Baor*

Therefore, proper management measures should be taken to protect SIFS wild stock in the *Baor*s. It must, however, be noted that a reduction of fishing pressure can be effective if it is preceded by community education. It is an urgent need to set up an effective fisheries management plan to protect and conserve this species including other species that have commercial values. From an investigation along with 400 fishermen, it is clear that over fishing, climate change, habitat degradation, using of illegal fishing gear, small mesh size of fishing gears, destroy of fry and fingerlings are the principal causes for declining of SIFS in the *Baor*s. To save the fish habitat and fishes in the *Baor*s, government and non-government organization should come forward. Rahman et al. (2012) state that the main factors contributing to the decline in fish biodiversity are overfishing, environmental degradation, pesticides and aquatic pollution, disease transmission, unrestricted introduction of exotic fish, destruction of breeding grounds, excessive water abstraction, siltation, various ecological changes in the fish's natural habits, and improper management leading to the withdrawal of water from the Baors, which is almost similar with our study

11.2.7. Problems of *Baor* fishermen

During study period, we found following problems of *Baor* fishermen through field survey where 400 respondents randomly selected from two *Baor*s. The major contributor were low market price of fish (14%), lack of fishing gear and crafts (12%), marketing problem (11%), lack of other income sources (11%) and large family size (9%), respectively (Fig. 15).

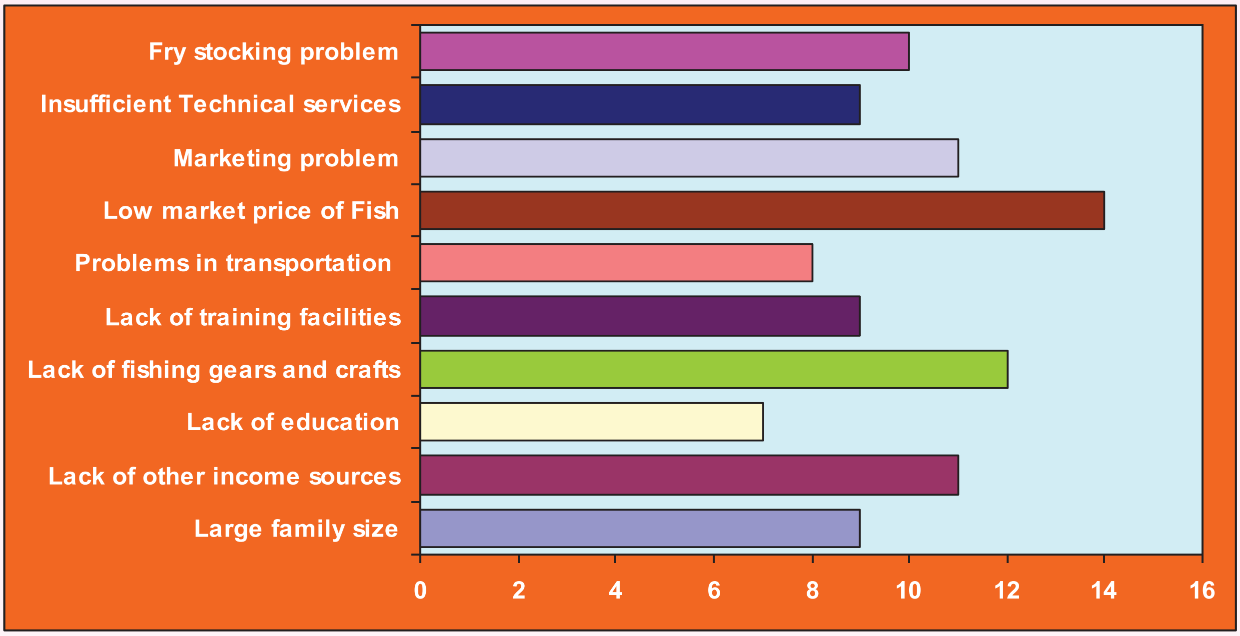


Fig 15. Problems of *Baor* fishers from the two selected *Baor*s, Jashore region, south-western Bangladesh

11.2.8. Livelihood and socio-economic study

Socio- demographic information

A total 400 respondents were interviewed during project period. The age and gender of the participants are among the social-demographic data obtained through the questionnaire, oral history, and telephonic interviews. Around 75% of the participants were men and 25% were women. Respondents who were completely reliant on fishing in *Baor* were selected for interview. We have also collected data on impact of Covid-19 on livelihoods of *Baor* Fishers community.

Fishing practice

The majority of the *Baors* (85%) are administered using a community-based fisheries management (CBFM) approach, with individual fish harvesting SIFS and group fish harvesting (IMCs and cat fishes).

Educational background

In Bukvora *Baor*, 45 % fishermen are completed primary education; 35% fishermen can just signature and 20% are completed their secondary education. In Khatura 45% fishermen are completed primary education; 35% fishermen can just signature and 20% are completed their secondary education (Fig. 16). Individual preferences, behavioral patterns, performance, skill, and capability are all influenced by educational qualification. The respondent's literacy levels were extremely low. The majority were illiterate, with only a few fishermen and intermediaries having completed primary school. Some could only write their name and sign their name. Their children attended school until the primary level and then dropped out to work.

According to Mondal et al., (2018), primary education attainment in two villages in Chittagong was 65 % and 69 %, respectively, while secondary education attainment was 45 % and 47 %. In his study in Jashore town, Mia (1996) discovered that the majority of fish retailers had a secondary level of education. Dasgupta (2004), on the other hand, reported that the majority of fish traders in Fulpur upazila had only a primary level of education. According to Rahman et al., (2017), 33 % of contact farmers had a secondary level of education (S.S.C.) and only 7 % had a master's degree.

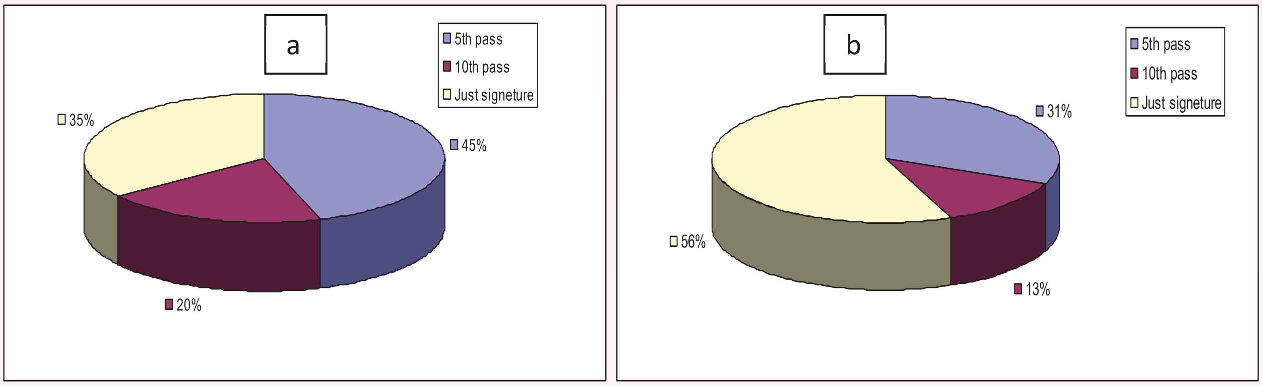


Fig 16. Educational background of fisher's community of (a) Bukvora *Baor* (b) Khatura *Baor*, Jashore

Family size

The figure shown above that 60% of the family of the respondents were nuclear and others 40% of the respondent are with Joint family in Bukvora *Baor*. The figure also shown above that 70% of the family of the respondents were nuclear and others 30% of the respondent are with Joint family in Khatura *Baor* (Fig. 17). The number of people in the same family, whether working or not, is defined as family size. Family size and composition are related to occupation and income and are likely to have a significant impact on fishing practice. The family consists of a husband, wife, son, daughter, sister, and parents. Adhikary et al., (2018) discovered that approximately 77%of fish farmer families were joined and 23% of fish farmer families were nuclear. The study area was dominated by joint families, which corresponds well with the findings of Ali et al. (2009) in Mymensingh district; Asif et al., (2015); Asif and Habib (2017); Hossain et al., (2015); Sharif et al., (2015); and Vaumik et al., (2017). Furthermore, it was discovered that small families comprised 24%, medium families comprised 54%, and large families comprised 18%. Farid et al., (2013) discovered that 58% of fishermen lived in joint families, which is consistent with the current study.

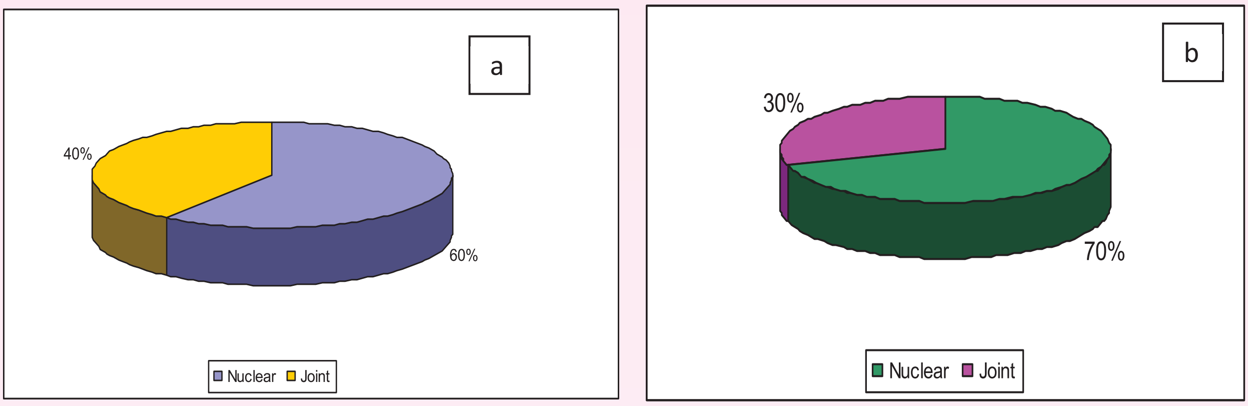


Fig 17. Family size of fisher's community of **(a)** Bukvora *Baor* **(b)** Khatura *Baor*, Jashore

Religion

In Bukvora *Baor*, 87% fishermen were Hindu religion and 13% fishermen were Muslim but in case of Khatura *Baor*, 56% fishermen were Muslim and 44% fishermen were Hindu religion (Fig. 18). Mondal et al., (2018) identified two villages in Chittagong as having 65% Hindu communities and 35% Muslim According to the report, Muslim fish sellers predominated (68.33%). According to Khatun et al., (2013), 82 % of fish farmers were Muslims and 18% were Hindus in Charbata, Noakhali district. According to Sharif et al., (2015), all fish farmers were Muslims, which is relevant to my study. Similar findings were made by Asif et al., (2015), Hossain et al., (2015), Islam et al., (2014), and Islam et al., (2015).

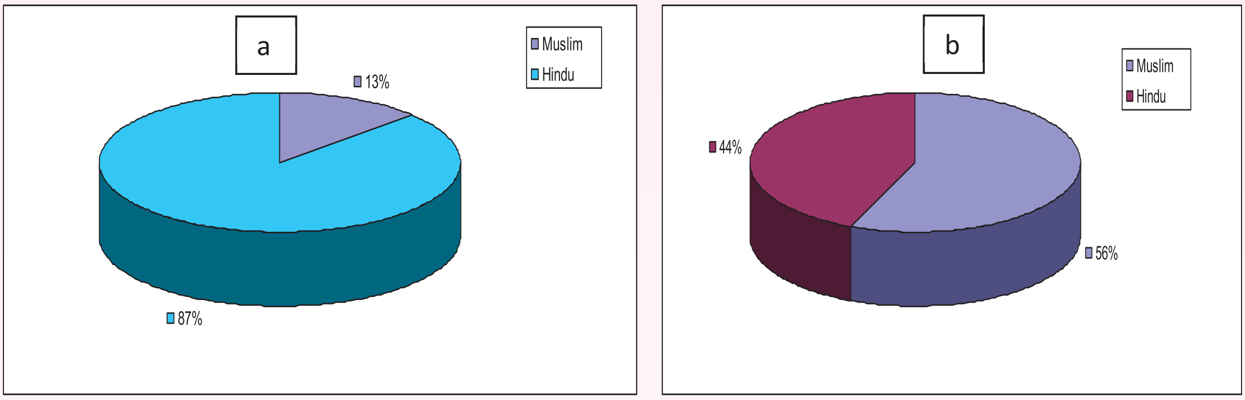


Fig 18. Religion of fisher's community of **(a)** Bukvora *Baor* **(b)** Khatura *Baor*, Jashore

Housing condition

One type of indicator of economic status is housing condition. Attempts were made to learn the status of the fishermen. In Bukvora *Baor*, 75% housing condition of fishermen were Bamboo/Tin; 20% were semi concrete and 5% were concrete but on the other hand, In Khatura *Baor*, 79% housing condition of fishers were semi concrete; 13 % were Bamboo/Tin and 8% were concrete (Fig. 19). Approximately 69% of the fish farmer's households were tinshed, 23% were kacha and just 8% were half-buildings (Adhikary et al., 2018). According to Rahman (2003), 70% of people were kacha, 21% were semi-paka, and only 9% were paka in the Gazipur district. Asif and Habib (2017) reported that 88% of households had concrete homes in Jhikargachha upazila, Jessore, which contrasts with the findings of the study. Sharif et al. (2015) discovered that 54% of farmer's utilized semi-paka, 19% of fish farmers lived in paka houses, and the remaining 27% of farmers lived in earthen houses in Chaugachha, Jessore.

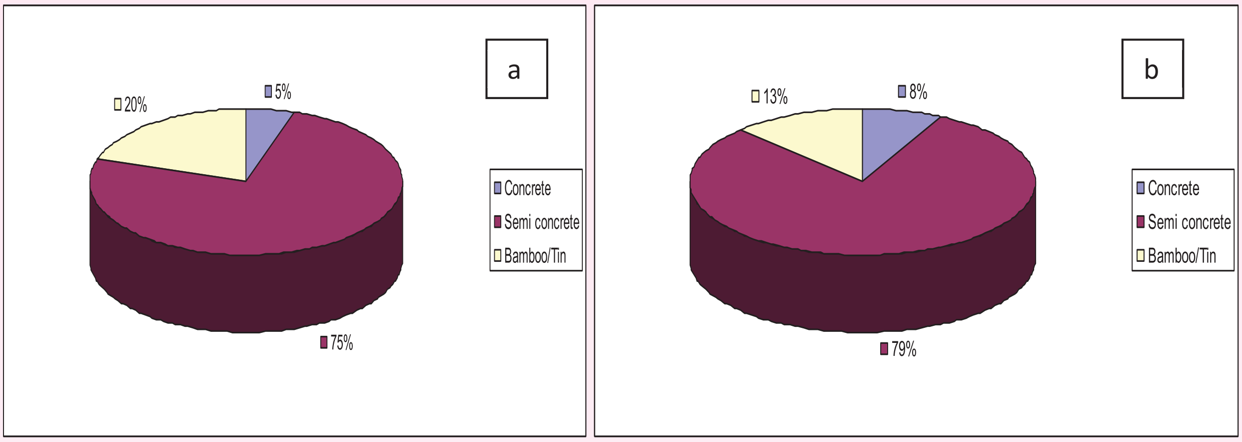


Fig 19. Housing condition of fisher's community of **(a)** Bukvora *Baor* **(b)** Khatura *Baor*, Jashore

Drinking water facilities

The fishermen's drinking water facilities were found to be satisfactory from two selected *Baor*. In case of Bukvora *Baor*, 85% fishermen drinks water from their own tube well; 10% from govt. tube well and 5% from neighbors tube well. In Khatura *Baor*, 81% fishermen drinks water from their own tube well; 10% from govt. tube well and 9% from neighbour's tube well (Fig. 20). A hundred percent of the fishermen studied used tube-well water for drinking purposes, with 64 percent having their own tube-well and 36 percent using a neighbor's tube-well (Adhikary et al., 2018; Mondal et al., 2018).

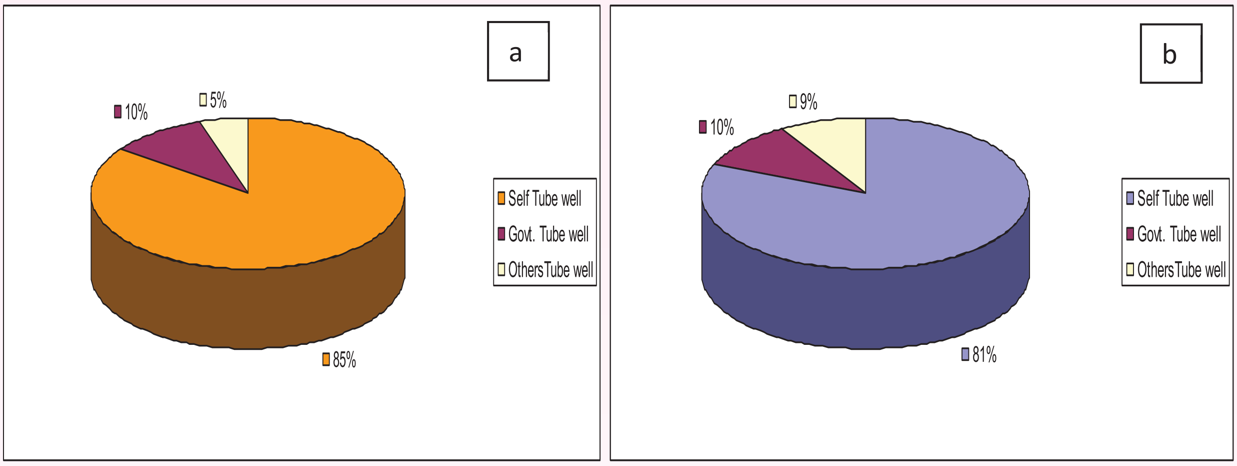


Fig 20. Drinking water facilities of fisher's community of **(a)** Bukvora *Baor* **(b)** Khatura *Baor*, Jashore

Sanitary condition

The fishermen's sanitary conditions were found to be satisfactory. Toilets of various types are used, including kacha toilets and semi kacha which are made of bamboo fencing with leaf and inadequate drainage disposal, sanitary latrines, open fields, and open holes. In case of Bukvora *Baor*, 53% fishermen use kacha toilet; 44% fishermen use paka toilet and 3% uses semi paka toilet. In Khatura *Baor* 53% fishermen use kacha toilet; 44% fishermen use paka toilet and 3% uses semi paka toilet (Fig. 21). Ali et al., (2009) discovered that 62.5% of farmers had semi-paka toilets, 25% had kacha (made of bamboo with leaf shelter and inadequate drainage disposal), and 12.5% had paka toilets. Similar findings were found by Asif et al., (2015), Asif and Habib (2017), Hossain et al., (2015), and Islam et al., (2014).

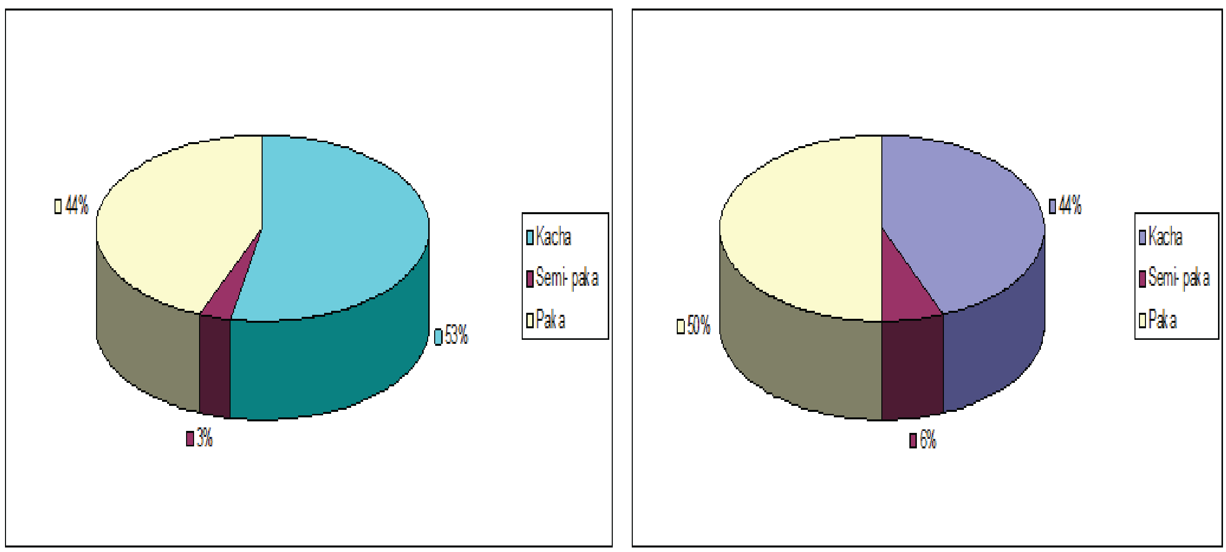


Fig 21. Sanitary condition of fisher's community of **(a)** Bukvora *Baor* **(b)** Khatura *Baor*, Jashore

Health facilities

In Bukvora *Baor*, 66% fishermen take treatment from village doctor; 11% from Upazila Health Complex and 23% from private clinic. But, in Khatura, 50% fishermen take treatment from village doctor; 31% from UHC and 19% from private clinic (Fig. 22).

Fourteen percent sought medical attention from the UHC, while only six percent sought medical attention from an MBBS doctor (Adhikary et al., 2018). In Rajshahi district, Ali et al. (2008) discovered that 46 percent of farmers received health care from village doctors, 18 percent from UHC, 14 percent from district hospitals, and 20 percent from MBBS doctors. Similar findings have been reported by Asif et al. (2015), Asif and Habib (2017), Hossain et al. (2015), Sharif et al. (2015), Vaumik et al. (2017), and Islam et al. (2014).

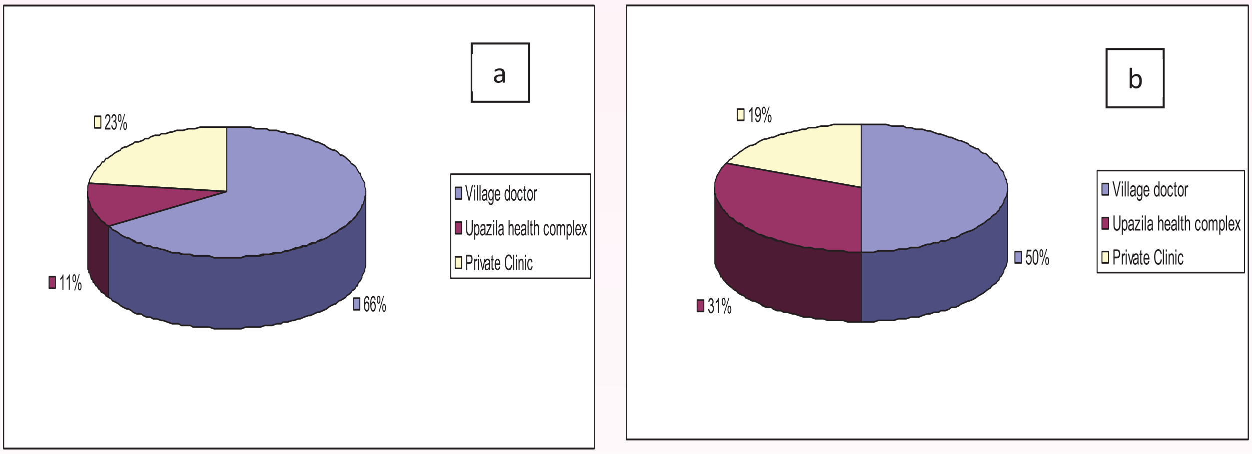


Fig 22. Health facilities of fisher's community of **(a)** Bukvora *Baor* **(b)** Khatura *Baor*, Jashore

11.2.9. Effects of of Covid-19 pandamic on *Baor* fisher's community

11.2.9.1. Negative effects of Covid-19 pandamicon *Baor* fisher's community

Different negative consequences of Covid-19 pandamic on *Baor* fisher's community are demonstrated in Fig 23.

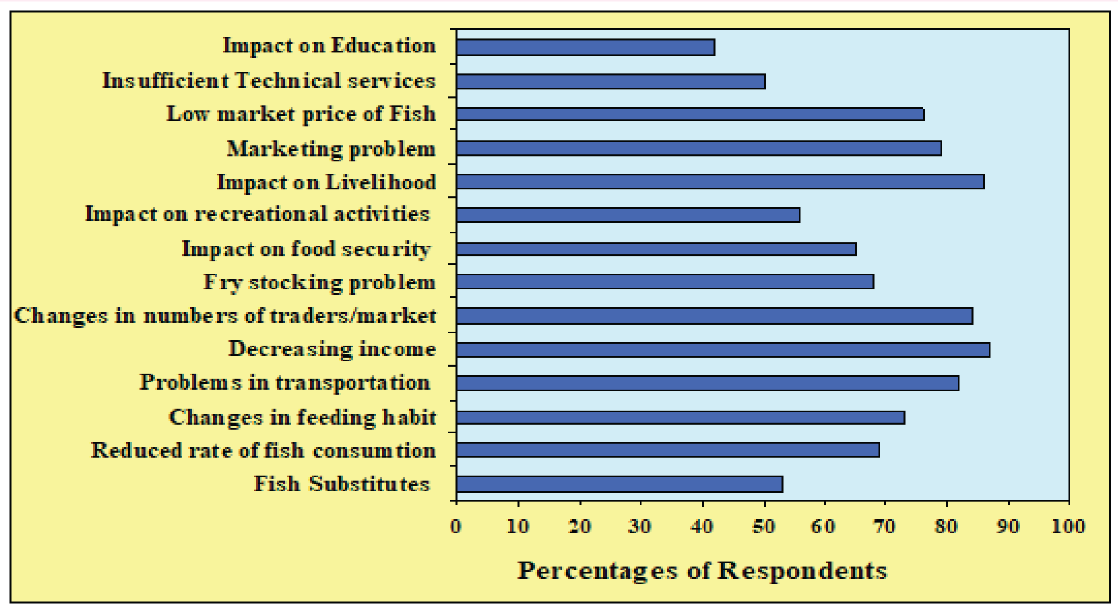


Fig 23. Major negative impacts of *Baor* fisher's communities during Covid-19 pandamic

Impacts on livelihood

The Novel Corona Virus (Covid-19) had quite a substantial detrimental impact on Bangladesh's disadvantaged community. This global health crisis affected livelihood and food security for the *Baor* fisher's community also. Members of this community who are mainly depends on fishing (90%), they can't harvest fish from *Baors*. Sometimes they harvested fish but they could not sell all of those fish with appropriate price due to Covid-19 pandemic (60%). From the middle of March 2020, the government of Bangladesh implemented statewide general holidays and lockdown, which had a significant influence on the general people livelihood, particularly for lower-income people who live on the *Baor* fisher's community. A total of 28% respondents were working in the informal sector have lost their employment and income as a result of the on-going epidemic crises. They could not fulfil their basic needs due to financial problem. A sum of 34% respondents was affected with Covid-19. As their income was very low during this period, so they reduced the sacrifice of animal lives during this pandemic situation in their religious festival. They also minimized their use of recreational item cost (Mobile, Television) for entertainment. The effects of Covid-19 were projected to have a considerable impact on world fisheries, with projections of possibly negative consequences for small scale fisheries livelihood and income on underdeveloped nations (Bennett et al., 2020; FAO, 2020). Most of the least developed and lower middle income countries (third world countries) including Bangladesh, profoundly depends on informal employment sectors (Hasan & Tamanna, 2015). In addition, Kar & Marjit (2009) stated that higher than 51% of urban jobs in third world countries are in the informal sector. It also demonstrates that the pandemic had an impact on the incomes of the majority of families in *Baor* communities. Therefore, they had to struggle for basic requirements of their livelihoods.

Impacts on marketing

The primary problem fisher's encounter was fish marketing (86%). Because of the lockdown, transportation was severely limited, and fishers were unable to market their harvested fish, despite the fact that the fish were appropriate for harvest in March. The cost of transportation increased from 40% to 80% during the panamic period, whereas the cost of fish reduced 15% to 30% from normal levels. Fishers (40%) typically picked limited quantity of fish, with the remainder being preserved in the *Baor*s, which have been known to harbour diseases in some situations. Restrictions on movements, less demand of fish were responsible for aggravating the situation of fish marketing during the study period. Disruptions were induced by Covid-19 in transportation, marketing, labor, combined with unstable supply and demand trends, and affected perishable food and food stuffs like fish, meat and aquatic food supply chains (CGIAR, 2020). As a result of the transportation crisis, disadvantaged group experienced higher raw material prices and the middleman's interference further exacerbated the situation (Mohammed et al., 2016). Fishing has been decreased by up to 80% in many regions due to the combination of decreased demand, cheaper prices, and lockdowns (Korten, 2020). Furthermore, lower market demand for fish and fisheries products resulted in lower prices for fish and fisheries products; as a result, numerous fishers curtailed their commercial fishing, and some of them stopped completely, as their work became economically unviable (FAO, 2021).

Impacts on fry stocking

Two types of fish culture including exotic carp culture (78%) and indigenous species capture (22%) were found during this study. Fish harvest was postponed in some *Baors* (75%) due to transportation issues, the marketing system, and low fish prices, as well as the inability to stock new fish fry for the remaining fishes. Hatchery owners also did not produce fish fry because of the decreasing the seed demands. The demands of fry or fingerlings were dropped by about 20%, resulting in significant financial losses for hatchery/nursery owners. The introduction of aquaculture practices has contributed significantly to increase total fish production and people's incomes as the wetland was previously only used for capture fisheries (Islam et al., 2018). The best time for fish fry release was between April and June (Rashid, 2020). As, the peak season of fish fry releasing into Baor was fallen due to pandemic situation, they were unable to release fish fry for the following culture season. Even, Boar beneficiaries had to retain the marketable sizes of fish in Baors during those time periods. Furthermore, fish fry stocking was hindered due to inadequacy of transportation facilities during the period of lockdown.

Impacts on feeding habits

Bangladesh's Covid-19 pandemic has prompted modifications in traditional food purchasing patterns and eating behavior. Due to a lack of income (87%), people have become more reliant on cheaper foods (e.g., more rice with less meat, eggs, vegetables, and fruit) and people are spending more time indoors and limiting their physical activity. On the other hand, they have resulted in some positive behaviours such as an increase in cooking (30%), household consumption (25%), increase social interaction (36%) etc. People in *Baor* villages are coping with new techniques as a result of the pandemic. Fishermen's protein requirements were mostly met by consumption of lentils, eggs, and low-cost fish. Due to limited access to market and a severe income crisis, the majority of *Baor* beneficiaries had to adjust their feeding habits. The *Baor* fishery provides a vital source of income and micronutrients, such as vitamins, iron, calcium, and minerals, to the neighboring inhabitants (Kohinoor et al., 2001). The globe is already dealing with food and nutrition security issues, with the least developed, developing, and lower middle countries being particularly vulnerable (FAO, 2020). This incorporates not only fishers, but also transportation owners and workers, feed distributors, hatchery proprietors and employees, all of whom rely on the *Baor* fisheries for their living. Simultaneously, the Covid-19 pandemic is causing a significant decline in these individuals' earnings (Zurayk, 2020).

Impacts on income

To deal with the loss of income, many urban households lowered their food consumption; a similar number of people sought assistance from friends. Many people in the *Baor* fishing villages have lost their jobs, their working hours have been cut, and their profession has changed. In the rural homes of the fishery community, 38% reduced their food consumption, 10% received support from friends, and 10% received reliefs from the government. 8% had to use their savings, 20% looked for additional work, and 15% took micro-credit loan from different microcredit financing organizations. The secondary source of income of *Baor* fisher's community was from labour of netting in other aquaculture farms, but they were not hired to fishing from other water bodies such as fish farming ponds, reservoirs and ghers during the Covid-19 pandemic situation. As a result, their secondary income was significantly reduced during those times. Fishermen of *Boar* beneficiary community who rely primarily on fishing are unable to harvest fish from *Baors*. Fishing area limitations arising from the implementation of spatial and temporal lockdowns across the country were a major issue for fishers (Jomitol et al., 2020). As, the complete halts of fisheries and stay-at-home orders prohibiting travel to and within fishing areas during the imposition of harsh policies of lockdown was also a major impaired issue to exert impacts on daily works (Okyere et al., 2020). They occasionally caught fish, but due to the Covid-19 pandemic, they were unable to sell all of them at a reasonable price. *Baor* fishermen's livelihoods were affected by unsold fish and the additional expenditures of supplying extra feed for the remaining fish (Nazrul, 2020).

Impacts on fish consumption

In Bangladesh, fish is a significant and vital animal source of food, and it plays an important part in providing food security. The nutritious benefit of fish consumption, increased profits from fish sales, and improved economic stability of women through aquaculture participation are indicators of fish's support to family food security in poor nations. In the current study, the frequency of fish eating by *Baor* fishermen in Jashore areas throughout a seven-day period was found to be associated with average incomes before and during the pandemic. The frequency of fish consumption was significantly decreased by 37.5%. More relatively wealthy families consumed fish at a higher frequency than economically disadvantaged families. However, after the execution of Covid-19, the overall consumption of fish decreased significantly. The locdown hampered fish worker transit and availability, causing agricultural commodities supply chains around the world, especially in Bangladesh, to be interrupted. The fishing sector in Bangladesh, like all agricultural supply chains, has been severely disrupted by bottlenecks in transportation, commerce, and labour. Reduced household incomes and the loss of a housemaid as a result of the Covid-19 lockdowns may have influenced demand for fish. Large families ate less fish, and tiny families couldn't eat fish all seven days of the week, because it was quite difficult to eat fish twice a day for *Baor* fisher's family, so they had to settle with low-cost fish like Silver, tilapia and Pangas. Janssen et al. (2021) reported that in the pandemic situation 15-42% respondents lowered their frequency of daily consumption unlike as before. According to Huang et al. (2021), lower income people are likely to decrease their expenditure on grocery during the pandemic situation. It is, however, critical for dismantling the traditional syndicate-based market and developing an independent fish-marketing system. As a result, Retail consumers had to pay extra charge for groceries and necessary things due to the disturbance of manufacturing and supply channel (Richards et al., 2020, Kim et al., 2020).

Changes in numbers of traders/market

The government has made adjustments to market place locations in order to comply with social distancing regulations, such as relocating to non-market public spaces (such as a school playground, field, or open space), which has resulted in fewer customers visiting them. Traders that do not have an established shop in the market area may have been impacted by these regulations. As a result of the open environment and exposure to direct sunshine, fresh fish became dirty and dried quickly. Vendors gave varying assessments of whether and how the market composition had altered in recent weeks. Because of changes in vocations, the respondent believed the number of sellers had increased.

Impacts on food security

Since March 2020, the entirety of the world's population has been confined as a result of the continuing pandemic disaster, which has impacted global food security. The prevalent lockdown has exacerbated the whole food supply chain from harvest to consumption, such as food manufacturing, supply and discharge, and consumption, in which people work in different supply chain segments such as fisheries input suppliers, fishers, food manufacturers, wholesalers and vendors, shipping, and various organizations. Furthermore, food supply had been disrupted on a massive scale, and people will go hungry twice as fast if local governments and associated institutions do not take corrective action. The government's efforts to stop the virus from spreading resulted in a transportation halt, making it difficult for farmers to obtain production inputs, keeping products from reaching markets, and preventing customers from making routine purchases. As a result of the limited supply, prices increased and demand decreased. The problem of fish value chain due to Covid-19 interrupted food security and resulted in massive losses.

Significant threats to immediate food security, health and nutrition were appeared among the many poor and vulnerable people (IFPRI, 2021). Das et al. (2022) reported that the impacts of Covid-19 pandemic on food security have been manifested by declining income.

Impacts on recreational activities and economic losses

The *Baor*s are an important recreational area for the residents of the Jashore districts. About 50% members of the *Baor* communities earn extra money from boating for recreational purposes throughout the year, but they are unable to earn money due to movement restrictions. During the winter season, the wider populace visits *Baor*s in search of migrant birds, but during the Covid-19 pandemic, they are unable to do so. As a result, the *Baor* fishing community suffer significant economic losses.

Fish substitutes

In Jashore districts, about 90% of fisher’s households studied used available alternative food items in varying proportions. As a substitute to fresh fish, five types of foods were consumed: poultry, eggs, domestic hens and ducks, lentils, and vegetables. Eggs were the most commonly used substitute for fish among the five types. During the pandemic, 50% of survey participants said they ate eggs instead of fish, and 15%, 22.5%, 7.5%, and 5% ate poultry, domestic hens and ducks, lentils, and vegetables, respectively. As an alternative to fish, households became reliant on other foods such as eggs, lentils, and chicken. Five types of foods were consumed by Baor fisher's community in place of fresh fish: poultry, eggs, domestic hens and ducks, lentils, and vegetables in our study. According to Akhtar et al. (2018), the consumption of eggs increased the most, followed by chicken and fish. Moreover, Belton and Toufiue (2014) discovered that over a period of 14-days, consumers in Bangladesh consumed the most fish, followed by vegetables, fruits, eggs, milk, and meat. During corona pandemic lower class consumers expended their income on low cost staple foods like rice flour as a substitute of high cost food items such as meats, eggs, milk and other aquatic foods (Headey & Ruel, 2020). According to the Global Alliance for Improved Nutrition (Pe'rez-Escamilla et al. 2020), lower-income households struggled with more capital difficulties so that they can reduced spending to purchase fundamental goods and needs for covering inflated food prices. Pe'rez-Escamilla et al. (2020), speculate that this may require them to make concessions in terms of food quality or quantity, or to substitute canned goods for fresh vegetables. Specifically, the U.S. Bureau of Labor Statistics found that, while the price of vegetables and fruits increased in August in 2020, the purchasing cost was relatively lower in January of the same year (US BLS, 2020).

Extra cost for health measures

Baor fishers' community has to spend additional currency for protecting themselves from the infection by Covid-19. Majority of the respondents compelled to pay out money for purchasing health protective mask, disinfectants (hand sanitizers), soaps, oral medicine (paracetamol, anti-allergic drugs, anti-asthmatic drugs, zinc tablet etc) for defending for both pandemic phobia and infection.

Insufficient technical services

Complete and temporally spatial lockdown across the country imposed by the government of Bangladesh disrupted the technical services required for sound management of *Baor* fisheries. Measures for protecting fish disease outbreaks, harvesting of target species, impaired to hold meeting among the *Baor* beneficiaries with authorities of Department of Fisheries to make a decision on time of harvesting, marketing, releasing of threatened fish species caught inside the net for conservation purposes along with community health center services were not available during the pandemic situation due to movement restriction and unavailability of public transport facilitates.

11.2.9.2. Positive effects of Covid-19 on *Baor* fisheries

Although, the majority of the effects are negative indicated with red line, there are some positive aspects indicated with green line generated and innovated to normalize our daily lives (Fig. 24) aftermath the long-term prevalence of Covid-19 pandemic situation. To cope with the on-going challenging situation, the member of *Baor* fisher's community have adapted and adopted to new technology for their occupations, increase homestead income generation through developing innovative business idea, and increase social interaction among their neighbors as well as their friends and relatives through the usage of social media (apps) and ways of physical communications. As *Baor* fisher's communities have the potential natural resources and capacity to be locally independent in terms of food productions and food security, they introduced a voluntary work of food sharing with the neighbors who were susceptible to starvation.

In addition, household fish consumptions for subsistence fishers were increased by *Baor* fishers due to sudden losing their employment from their work place. During this period, they spent their leisure period by fishing self-recruiting species using traditional fishing gears. As, there was a long term strong restriction on fish market accessibility to the mass people, they had to intake the remaining fish (unsold) even if after meeting their daily household consumption. Moreover, fish productions of *Baor*s were increased due to restoring favourable conditions of environmental factors and reduction of anthropogenic interferences. Besides, fish harvesting was disrupted during this time, brood fish under self-sustaining fish species (SRS) have more opportunities to spawn freely and thus by recruitment occurs to new year class. People were prevented from leaving their homes due to extensive media coverage, restrictions imposed by the government, and physical trips to the grocery store were reduced. Instead, many people have begun to rely on online marketing platforms or e-commerce sites for their daily needs (Shawki, 2020).

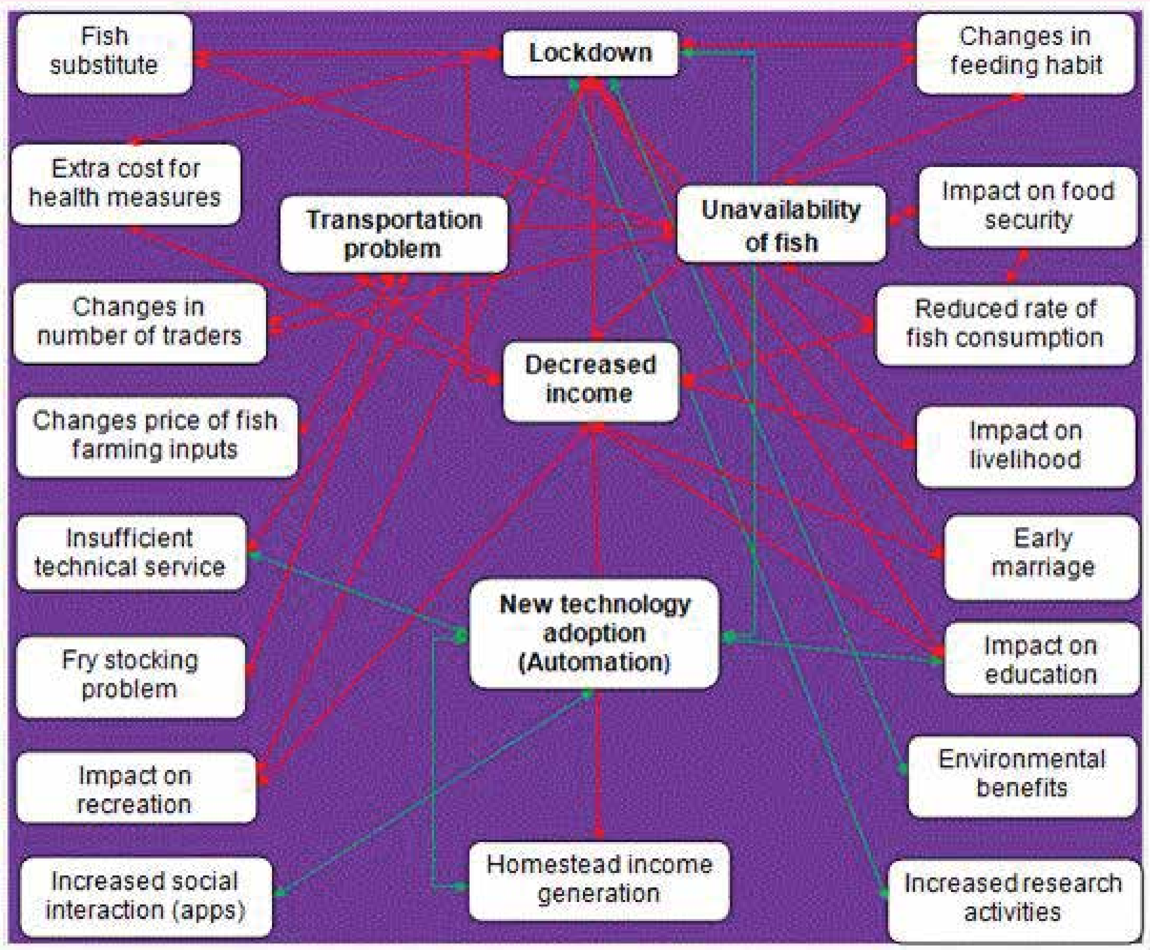


Fig 24. Major positive (green line) and negative effects (red line) of *Baor* fisher's communities during Covid-19 situation.

11.2. 10 Impact of marketing

During Covid-19 pandemic, the primary problem encountered by fisher's was fish marketing (86%). Because of the lockdown, transportation was very limited, and fishers were unable to market their harvested fish, despite the fact that the mast fish got appropriate marketable size during the on-set of rainy -summer months. The cost of transportation climbed from 40% to 80% during the same time period, whereas the cost of fish reduced 15% to 30% from typical levels. Fishers (40%) typically picked limited quantity of fish, with the remainder being preserved in the *Baor*s, which have been known to harbour diseases in some situations. The entire food supply chain from harvest to consumption, such as food manufacturing, supply and discharge, and consumption, in which people work in different supply chain segments such as fisheries input suppliers, fishers, food manufacturers, wholesalers and vendors, shipping, and various organizations had been disrupted on a massive scale during lockdown period. The lockdown in Bangladesh has interrupted the food supply chain, increasing the risk of food shortages (Alam & Khatun, 2021). Fish products are being forced to sell at a low price due to buyer shortages and the lack of supply channels, and it will take years to recover from this trauma (Zabir et al., 2021). In addition to structural defects, environmental extremes (such as drought, flood, pandemic, or disease) have a significant impact on the food supply chain, resulting in food insecurity (Devereux et al., 2020). OECD (2021) reported that the providing food security and nutrition to a growing global population, ensuring the livelihoods of the people working across the food chain from farm to consumer, and ensuring the industry's environmental protection are all critical goals.

Table 24. Fish prices during market survey in Jashore Sadar upazila, Jashore.

Species	Average price
Amblypharyngodon mola	250
Anabas testudineus	500
Chanda nama	200
Channa punctatus	400
Channa striatus	400
Glossogobius giuris	250
Gudusia chapra	250
Heteropneustes fossilis	600
Lepidocephalichthys guntea	450
Macrognathus pancalus	500
Mystus tengara	550
Ompok pabda	450
Pethia ticto	250
Puntius sophore	220
Cirrhinus cirrhosus	200
Cirrhinus reba	170
Labeo bata	180
Labeo calbasu	200
Labeo rohita	250
Aristichthys nobilis	250
Hypophthalmichthys molitrix	200
Gibelion catla	250

Changes in fish and fish farming inputs price

The sharp drop in consumer demand for fish has resulted in lower prices, prompting some farmers to postpone harvesting their product. Due to a lack of liquidity, some farmers have been compelled to sell at considerably lower prices, resulting in significant losses. As a result of Covid-19, the mid-stream of supply chains has been dramatically reorganized. Prior to Covid-19, the chain was dominated by a limited number of large traders who bought fish directly from *Baor* farmers and sold it to major marketplaces in the big cities. However, a new form of trading pattern emerged as a result of the Covid-19 local overstock of fish and the absence of major established traders from the market. Prior to the Covid-19 epidemic, established dealers provided farmers competitive pricing to generate high turnover, but local oversupply during the pandemic created a buyers' market, causing farmers to sell fish at far lower prices than before the pandemic. Prices of fish farming inputs- fish seeds, fish feeds, fertilizers etc were going up to the apex because of inadequate artificial seed productions from hatchery, increasing transportation costs along with activities of the unscrupulous and dishonest traders associated with fish farming inputs. During the same period, fish feed production fell by 75% (Kibria et al., 2020). Furthermore, the majority of the ingredients in the fish food, particularly proteins, were previously imported from other nations, a position made more difficult by the COVID-19 pandemic-related international embargo (FAO, 2020)

11.2.11. Study of stock structure analysis

The population structure of small indigenous fish species were studied using conventional (based on body morphometrics and meristic) and image-based analysis (truss network system) methods. The study was carried out with different stocks from Bangladeshi waters. However, the phenotypic flexibility of fish is very high and they adjust rapidly by altering their body maintenance and conduct to natural vicissitudes due to the fluctuations of their habitats as well as their environments. Stock structure analysis of different fish species are described below.

Stock structure analysis of *Hyporhamphus limbatus*

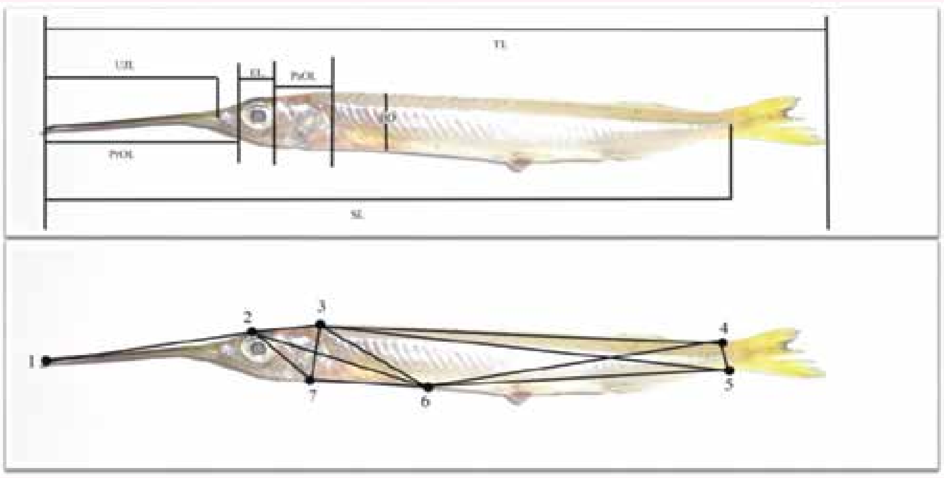


Fig 25. Position of different anatomical landmarks of *Hyporhamphus limbatus* for creating truss networks on fish body illustrated as a close circle (black).

Inside the figures of *Hyporhamphus limbatus*, conventional morphometric characters were drawn (upper image) and truss based morphometric characters were drawn by using landmark seven landmark points “lower image” (Fig 25).

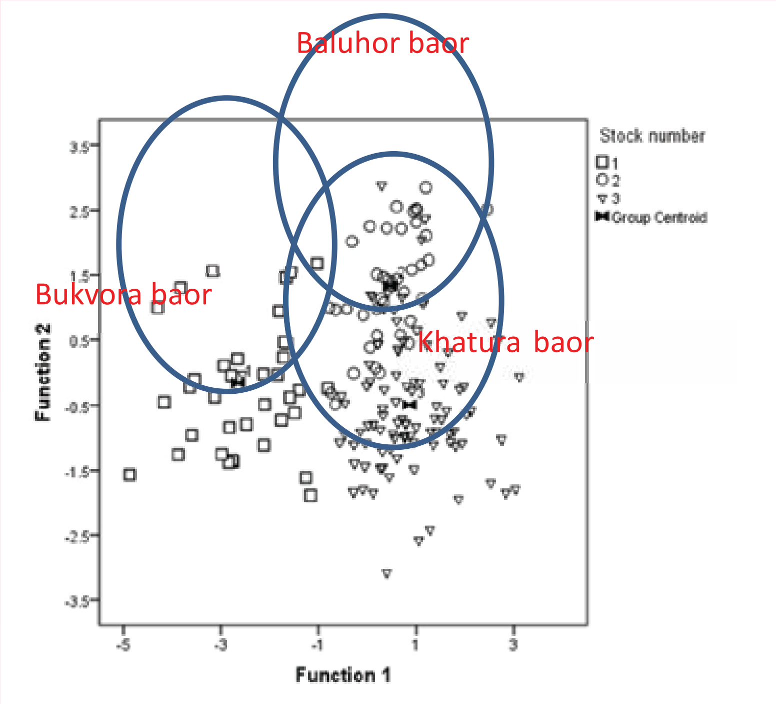


Fig 26. Principal component analysis (PCA) of morphometric data and ratios of *Hyporhamphus limbatus* obtained from different stocks of Bangladesh

In the bi-plot analysis of the canonical discriminant function analysis from three populations revealed that they are highly intermingled to each other. From the orientation of the bi-plot result, it can be concluded that the three populations are merged based on their respective phenotypical characters (Fig. 26).

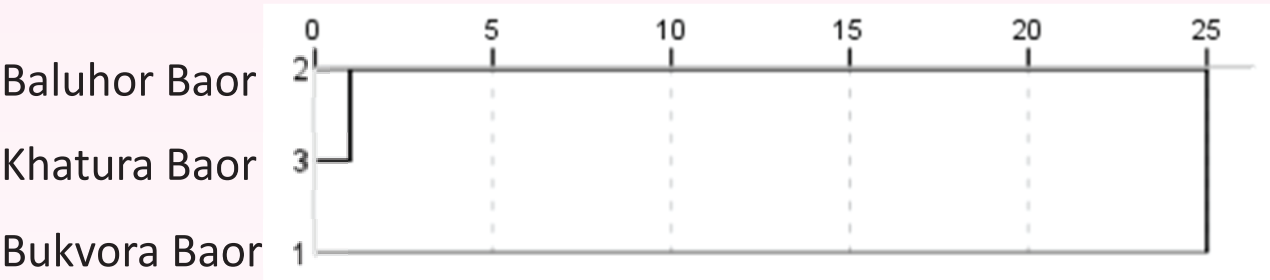


Fig 27. Dendrogram from truss measurements derived from UPGMA cluster analysis based on the Euclidean distance between the stock centroids

A dendrogram was drawn on the basis of morphometric and truss distance data for the stock Bukvora *Baor* and Khatura *Baor* and Baluhar *Baor*. The samples of Bukvora *Baor* formed the first group. And the second group formed by Baluhar *Baor* and Khatura *Baor* combindly, where Khatura *Baor* also formed a sub-cluster with Baluhor *Baor* (Fig. 27).

These findings are completely similar to those findings documented by Mahfuj *et al*. (2019a) in *Xenotodon cancila* from four natural stocks of South-Western Bangladesh.

Stock structure analysis of *Ompok bimaculatus*

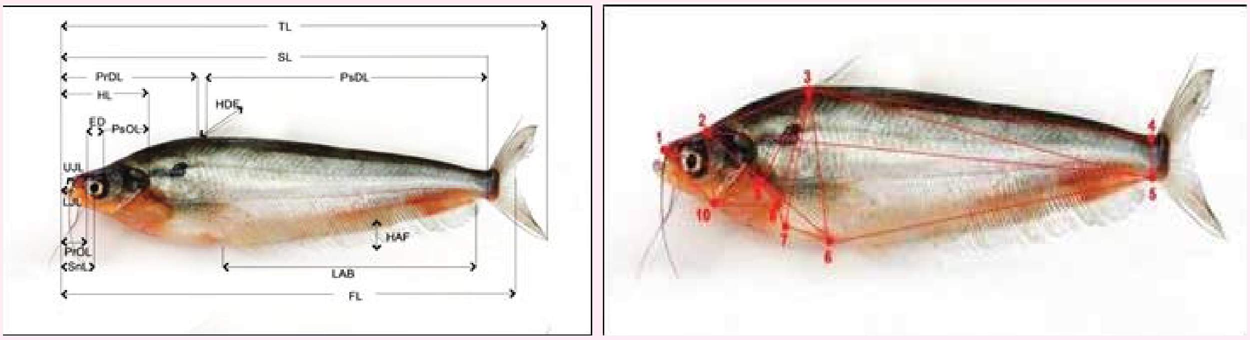


Fig 28. Position of different anatomical landmarks of *Ompok bimaculatus* for creating truss networks on fish body illustrated as a close circle (red).

Inside the figures of *Ompok bimaculatus*, conventional morphometric characters were drawn (upper image) and truss based morphometric characters were drawn by using landmark seven landmark points "lower image" (Fig. 28).

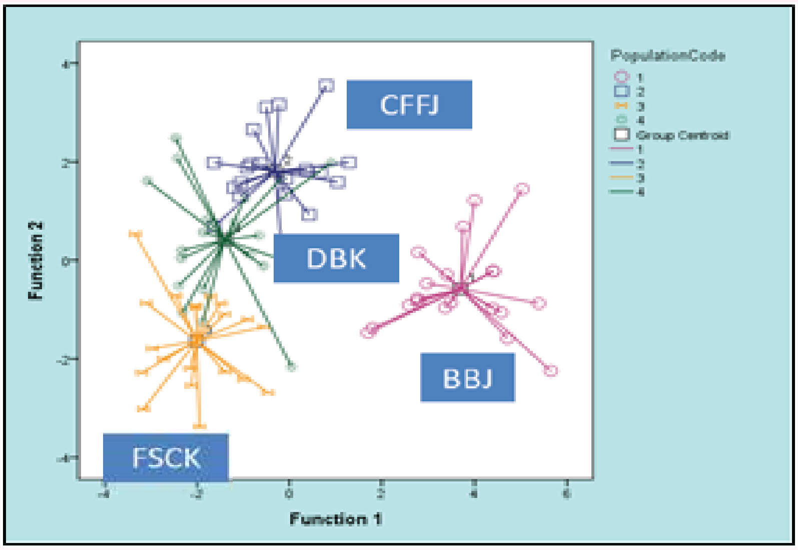


Fig 29. Principal component analysis (PCA) of morphometric data and ratios of *Ompok bimaculatus* obtained from different stocks of Bangladesh

In the bi-plot analysis of the canonical discriminant function analysis from four populations namely, Bukvora *Baor*, Jashore and Fish Seed Complex, Khulna, Dakatia Beel, Khulna and Chanchra Fish Farm, Jashore, revealed that they are highly intermingled to each other. From the orientation of the bi-plot result, it can be concluded that the three populations' viz., Jashore and Fish Seed Complex, Khulna, Dakatia *Beel*, Khulna and Chanchra Fish Farm, Jashore are merged based on their respective phenotypical characters whereas, Bukvora *Baor*, Jashore formed a single isolated stock based on the canonical bi-plot analysis (Fig. 29).

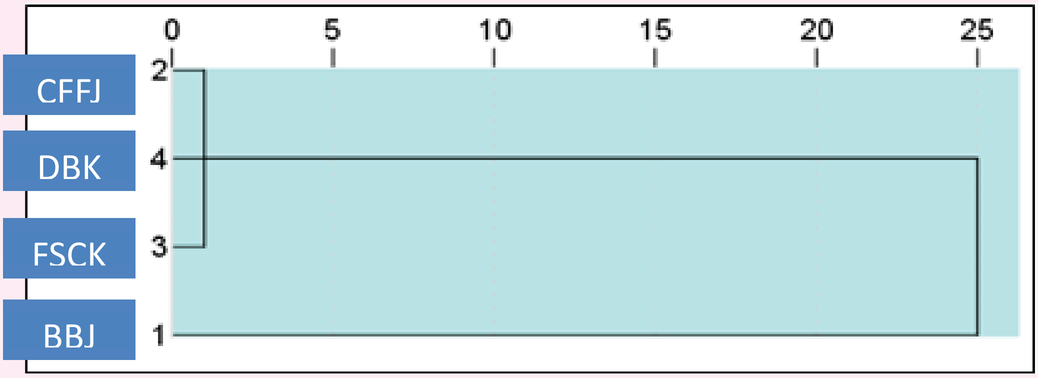


Fig 30. Dendrogram from truss measurements derived from UPGMA cluster analysis based on the Euclidean distance between the stock centroids

An UPGMA dendrogram was drawn on the basis of morphometric and truss distances data for the stock Bukvora *Baor*, Jashore and Fish seed complex, Khulna, Dakatia *Beel*, Khulna and Chanchra fish farm, Jashore. The samples of Bukvora *Baor* formed the first group. And the second group formed by Jashore and Fish seed complex, Khulna, Dakatia *Beel*, Khulna and Chanchra fish farm, Jashore, where Chanchra fish farm, Jashore and Fish seed c omplex, Khulna also formed a sub-cluster with Dakatia *Beel*, Khulna (Fig. 30).
These findings are completely similar to those findings documented by Rahman, (2005) in *O. bimaculatus*, Chaklader *et al.* (2016) in *Ompok pabda*, Ng and Tan (2004) in *O. platyrhynchus* and Mahfuj *et al*. (2019b) in *O. pabo.*

Stock structure analysis of *Cirrhinus reba*

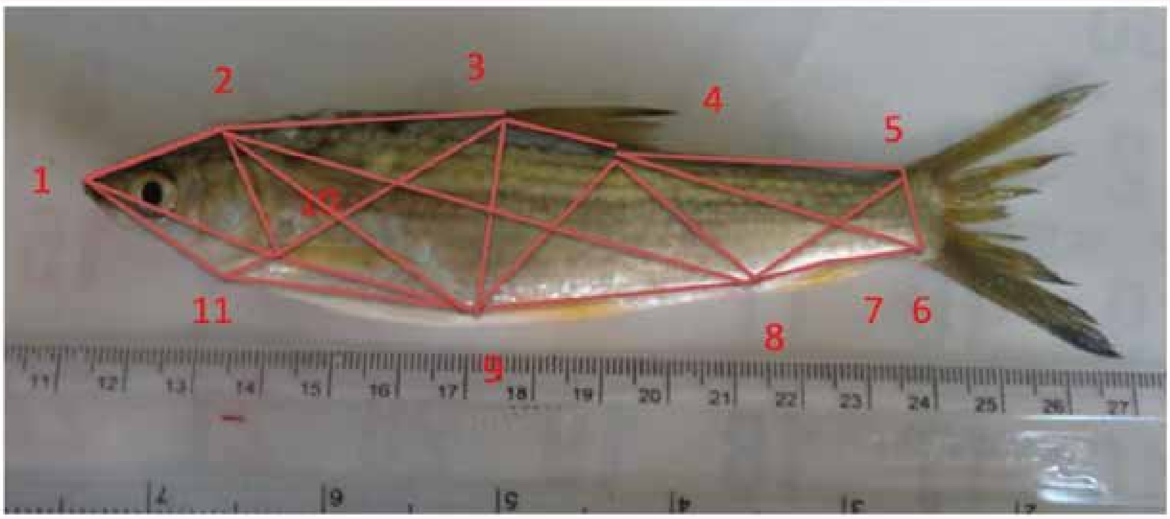


Fig 31. Position of different anatomical landmarks of *Cirrhinus reba* for creating truss networks on fish body illustrated as a close circle (red).

Truss-based morphometric characters of *Cirrhinus reba* were drawn by using eleven landmark points (Fig. 31).

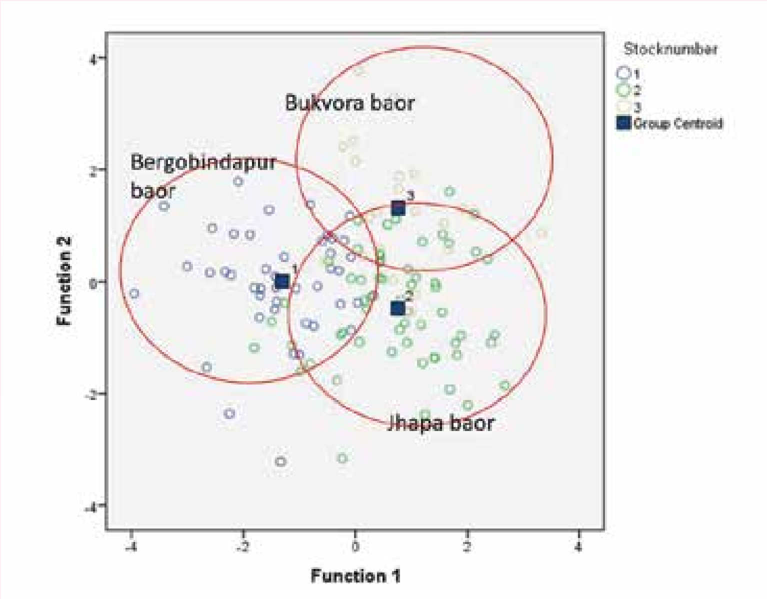


Fig 32. Principal component analysis (PCA) of morphometric data and ratios of *Cirrhinus reba* obtained from different stocks of Bangladesh

In the bi-plot analysis of the canonical discriminant function analysis from three populations namely, Bukvora *Baor*, Jashore and Bergobindapur *Baor* and Jhapa *Baor*, Jashore, revealed that they are moderately intermingled to each other. From the orientation of the bi-plot result, it can be concluded that the three populations' viz., Bukvora, Bergobindapur and Jhapa *Baor* are merged based on their respective phenotypical characters (Fig. 32).

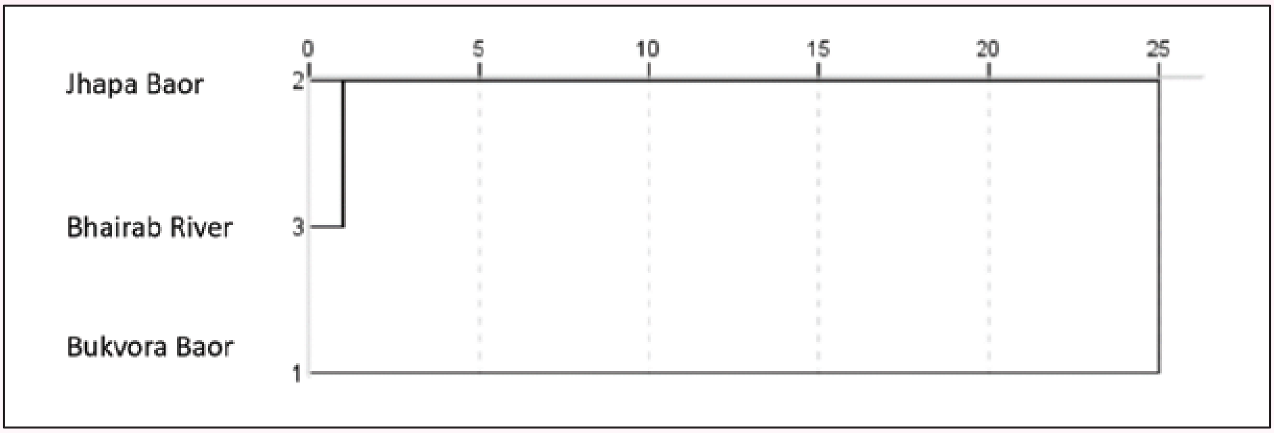


Fig 33. Dendrogram from truss measurements derived from UPGMA cluster analysis based on the Euclidean distance between the stock centroids

An UPGMA dendrogram was drawn on the basis of morphometric and truss distances data for the stock Bukvora *Baor*, Jashore and Bhairab river, Jashore and Jhapa *Baor*, Jashore. The samples of Bukvora *Baor* formed the first group. And the second group formed by Bhairab River and Jhapa *Baor*, Jashore (Fig. 33).

The finding of Rahman (2005) has also taken into account the variation in morphometric counts of *C. reba.* The aforementioned expert might have examined stocks that were subject to comparable ecological conditions or had a common ancestor and, as a result, did not experience separation while being geologically apart. A truss network architecture has been used by numerous researchers and has substantial rules to identify species, subspecies, races, and strains without regard to morphometric characteristics (Siddik et al., 2016; Mahfuj et al., 2017;Azadetal.,2020;Mahfujetal.,2019a).

Stock structure analysis of *Lepidocephalichthys annandalei*

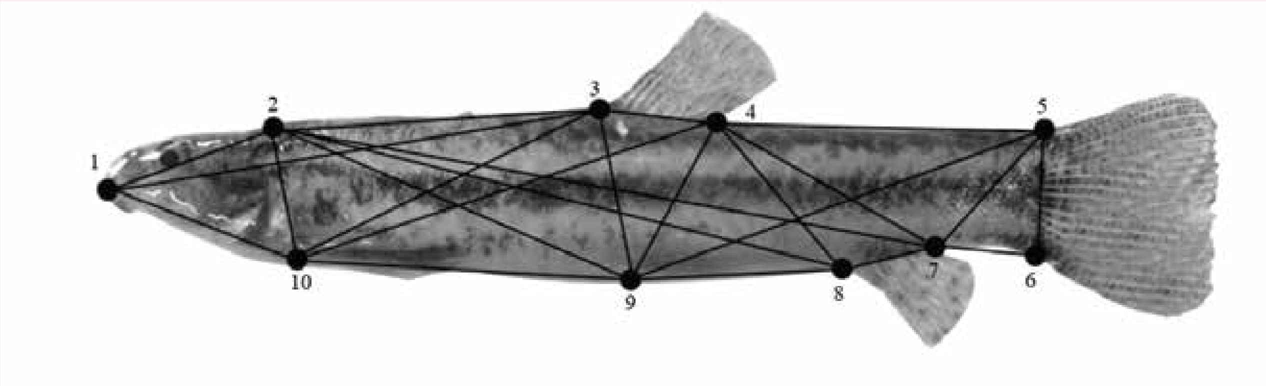


Fig 34. Position of different anatomical landmarks of *Lepidocephalichthys annadalei* for creating truss networks on fish body illustrated as a close circle (black).

Truss-based morphometric characters of *Lepidocephalichthys annadalei* were drawn by using ten landmark points (Fig. 34).

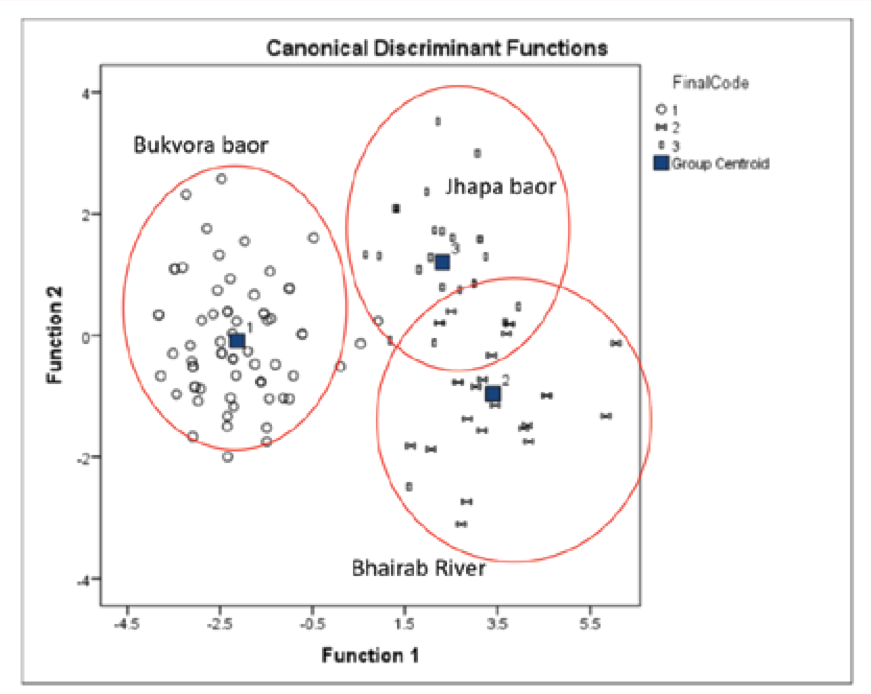


Fig 35. Principal component analysis (PCA) of morphometric data and ratios of *Lepidocephalichthys annadalei* obtained from different stocks of Bangladesh

In the bi-plot analysis of the canonical discriminant function analysis from three populations namely, Bukvora *Baor*, Jashore and Jhapa *Baor* and Bhairab River, Jashore, revealed that they are completely isolated to each other. From the orientation of the bi-plot result, it can be concluded that the three populations' viz., Bukvora *Baor*, Jashore and Jhapa *Baor* and Bhairab River, Jashore are isolated based on their respective phenotypical characters (Fig 35).

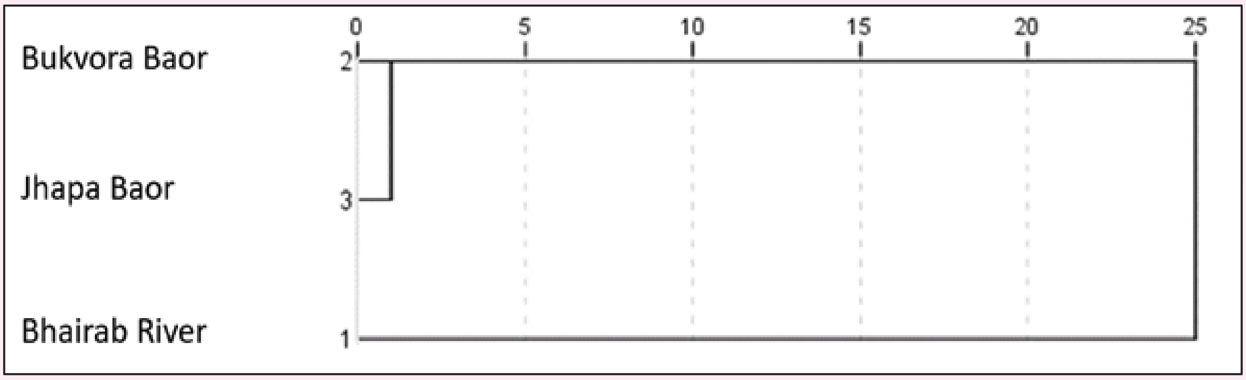


Fig 36. Dendrogram from truss measurements derived from UPGMA cluster analysis based on the Euclidean distance between the stock centroids

An UPGMA Dendrogram was drawn on the basis of morphometric and truss distances data for the stock of Bukvora *Baor*, Jashore and Jhapa *Baor* and Bhairab River, Jashore. The samples of Bhairab River formed the first group. And the second group formed by Jhapa *Baor* and Bukvora *Baor*, Jashore (Fig 36). Similar findings were made for the *Liza abu* (Turan et al., 2004) stocks from three rivers in Turkey and the *Labeo bata* (Mahfuz et al., 2017) populations from six natural sources in Bangladesh when the spatial separation was considered as a constraining variable to movement among stocks.

Stock structure analysis of *Glossogobius giuris*

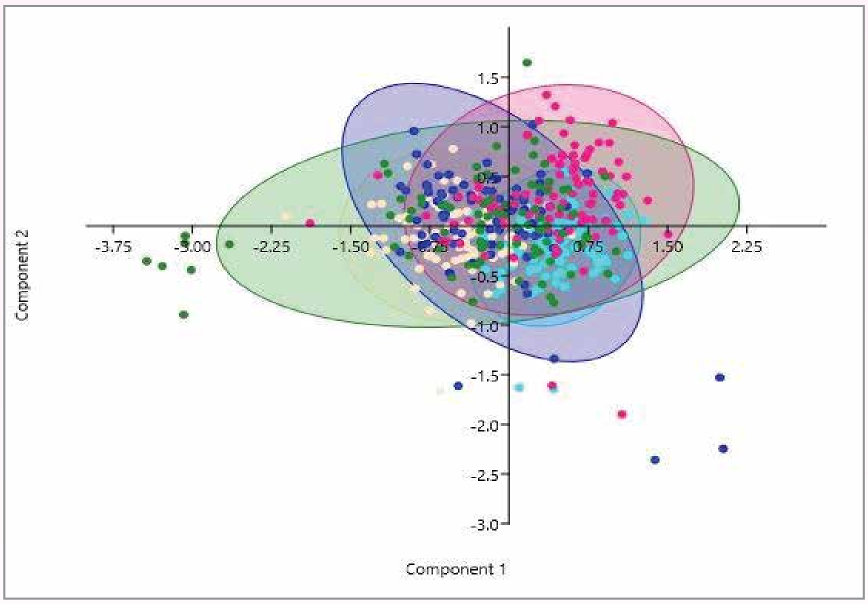


Fig 37. Principal component analysis (PCA) of morphometric data and ratios of *Glossogobius giuris* stocks obtained from five *Baor*s of Bangladesh

In the bi-plot analysis of the canonical discriminant function analysis from four populations namely, Baluhar *Baor*, Bukvora *Baor*, Jhapa *Baor*, Khatura *Baor* and Bergobindopur *Baor*, Jashore, revealed that they are completely isolated to each other. From the orientation of the bi-plot result, it can be concluded that the four populations' viz., Baluhar *Baor*, Bukvora *Baor*, Jhapa *Baor*, Khatura *Baor* and Bergobindopur *Baor*, Jashore are isolated based on their respective phenotypical characters (Fig 37).

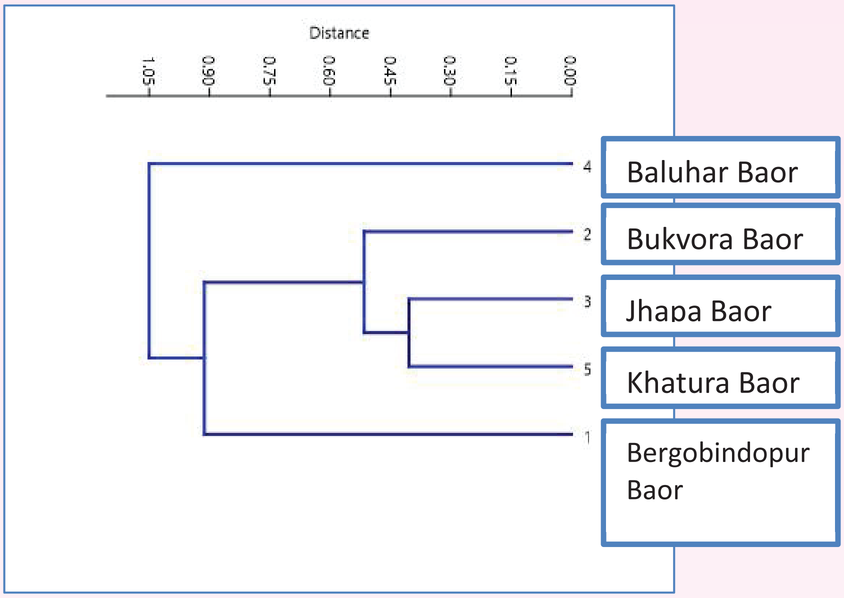


Fig 38. Dendrogram from truss measurements derived from UPGMA cluster analysis based on the Euclidean distance between the stock centroids

An UPGMA Dendrogram was drawn on the basis of morphometric and truss distances data for the stock of Baluhar *Baor*, Bukvora *Baor*, Jhapa *Baor*, Khatura *Baor* and Bergobindopur *Baor*, Jashore. The samples of Baluhar *Baor* formed the first group and the second group formed by Bukvora *Baor* Jhapa *Baor*, and Khatura *Baor*, Jashore (Fig. 38). When the spatial separation was taken into account as a limiting variable to movement among stocks, similar results were obtained for the Glossogobius giuris in three stocks in Bangladesh (Mollah et al., 2013).

Stock structure analysis of *Channa punctata*

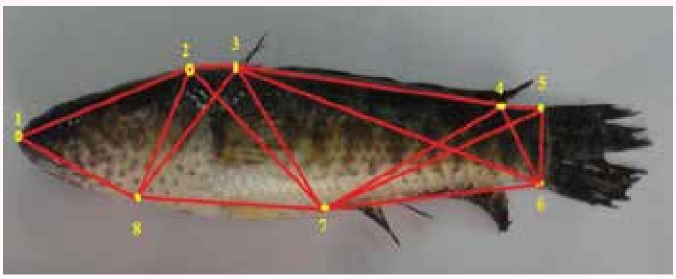


Fig 39. Position of different anatomical landmarks of *Channa punctata* for creating truss networks on fish body illustrated as a close circle (red).

Truss-based morphometric characters of *Channa punctata* were drawn by using ten landmark points (Fig 39).

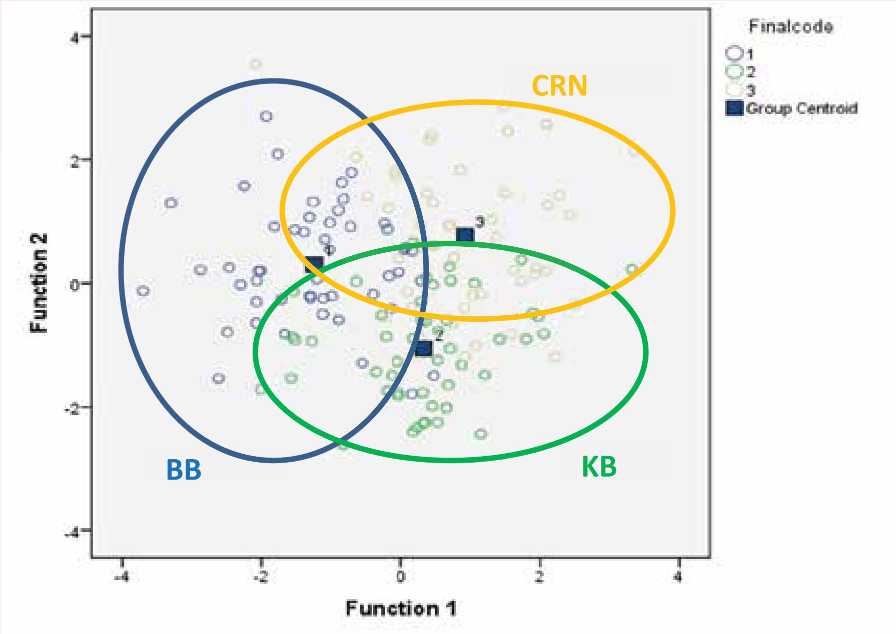


Fig 40. Principal component analysis (PCA) of morphometric data and ratios of *Channa punctata* obtained from different stocks of Bangladesh

In the bi-plot analysis of the canonical discriminant function analysis from three populations namely, Bukvora *Baor*, Khatura *Baor*, Jashore and Citra River, Narail, revealed that they are completely isolated to each other. From the orientation of the bi-plot result, it can be concluded that the three populations' viz., Bukvora *Baor*, Khatura *Baor*, Jashore and Citra River, Narail are isolated based on their respective phenotypical characters (Fig 40).

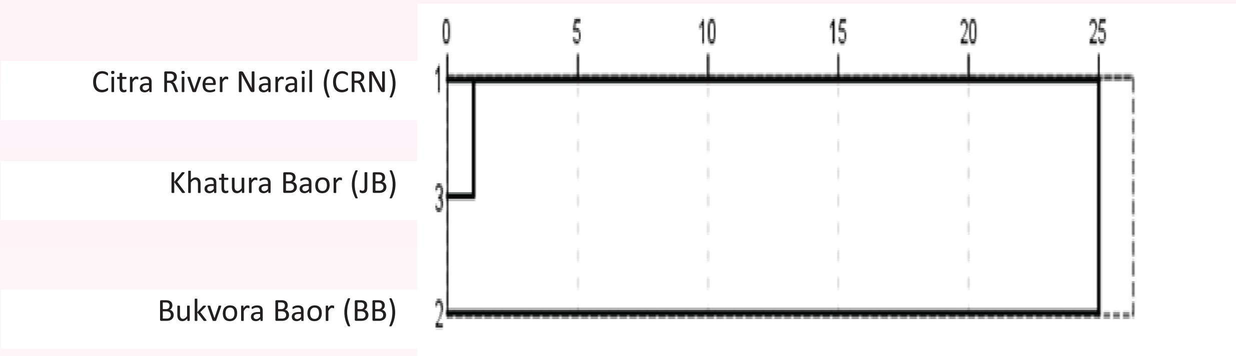


Fig 41. Dendrogram from truss measurements derived from UPGMA cluster analysis based on the Euclidean distance between the stock centroids

An UPGMA Dendrogram was drawn on the basis of morphometric and truss distances data for the stock of Bukvora *Baor*, Khatura *Baor*, Jashore and Citra River, Narail. The samples of Citra River formed the first group. and the second group was formed by Khatura *Baor* and Bukvora *Baor*, Jashore (Fig 41).

These explanations also matched with the previous research accomplished by Khan et al., (2013) in *Channa punctatus* populations from three Indian rivers.

Stock structure analysis of *Lepidocephalichthys guntea*

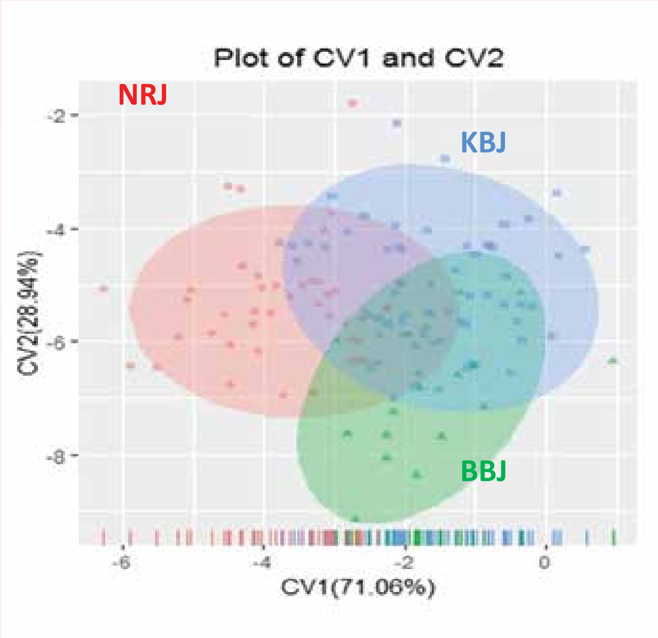


Fig 42. Canonical Variate Analysis (CVA) of morphometric data and ratios of *Lepidocephalichthys guntea* obtained from different stocks of Bangladesh

In the bi-plot analysis of the canonical discriminant function analysis from three populations namely, Bukvora *Baor*, Khatura *Baor*, Jashore and Nabaganga River, Jashore revealed that they are completely isolated to each other. From the orientation of the bi-plot result, it can be concluded that the three populations' viz., Bukvora *Baor*, Khatura *Baor*, Jashore and Nabaganga River, Jashore are isolated based on their respective phenotypical characters (Fig 42).

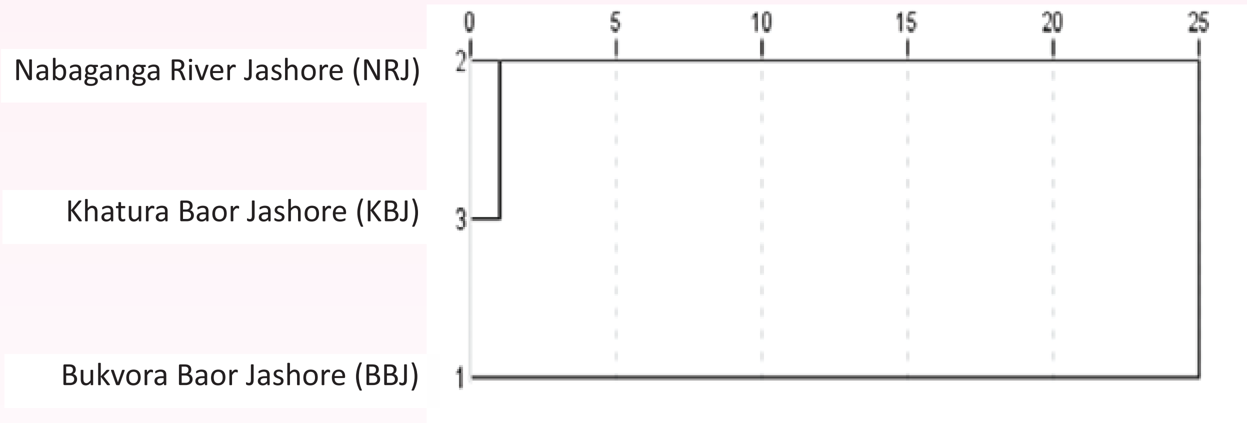


Fig 43. Dendrogram from truss measurements derived from UPGMA cluster analysis based on the Euclidean distance between the stock centroids

An UPGMA Dendrogram was drawn on the basis of morphometric and truss distances data for the stock of Bukvora *Baor*, Khatura *Baor*, Jashore and Nabaganga River, Jashore. The

samples of Nabaganga River, Jashore formed the first group. And the second group formed by Khatura *Baor* and Bukvora *Baor*, Jashore (Fig 43).
The geographic detachment is a constraining variable to movement among stocks and also found similar results for *Liza abu* (Turan et al., 2004) stocks from three rivers of Turkey and for *Lepidocephalichthys guntea* (Mahfuz et al., 2019d) populations from Bangladesh.

Stock structure analysis of *Macrognathus pancalus*

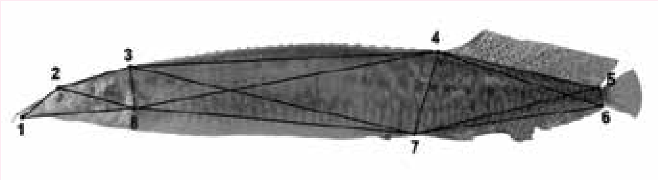


Fig 44. Position of different anatomical landmarks of *Macrognathus pancalus* for creating truss networks on fish body illustrated as a close circle (black).

Truss-based morphometric characters of *Macrognathus pancalus* were drawn by using ten landmark points (Fig. 44).

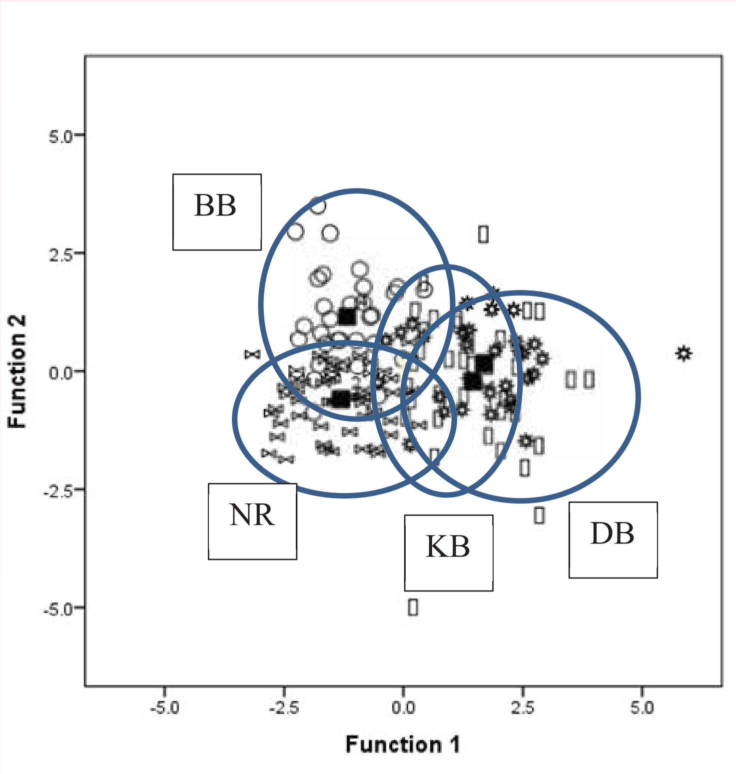


Fig 45. Principal component analysis (PCA) of morphometric data and ratios of *Macrognathus pancalus* obtained from different stocks of Bangladesh

In the bi-plot analysis of the canonical discriminant function analysis from four populations namely, Bukvora *Baor*, Khatura *Baor*, Nabaganga River, Jhenaidah and Dhakuria Beel, Jashore, revealed that they are completely isolated to each other. From the orientation of the bi-plot result, it can be concluded that the four populations' viz., Bukvora *Baor*, Khatura *Baor*, Nabaganga river , Jhenaidah and Dhakuria Beel, Jashore are isolated based on their respective phenotypical characters (Fig 45).

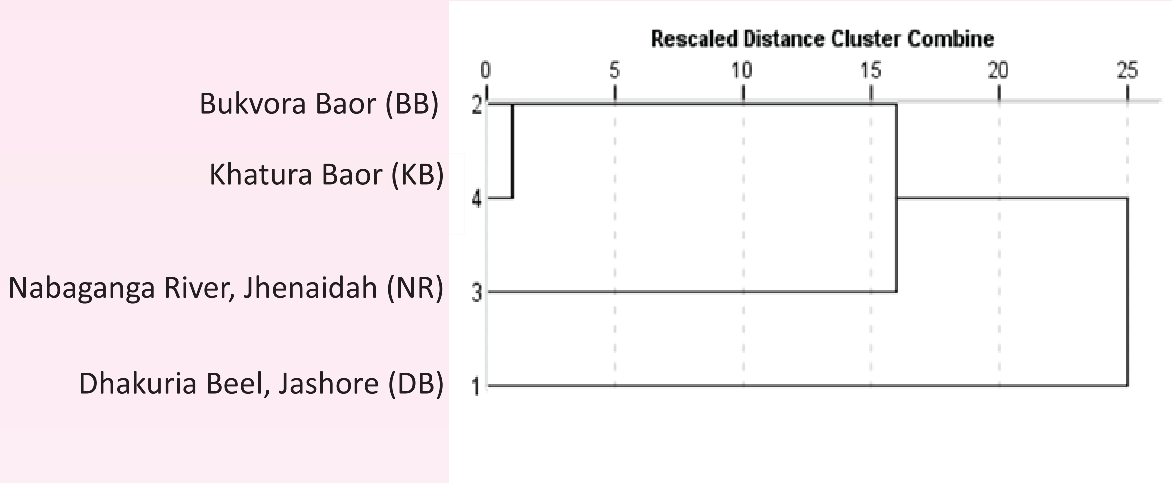


Fig 46. Dendrogram from truss measurements derived from UPGMA cluster analysis based on the Euclidean distance between the stock centroids

An UPGMA Dendrogram was drawn on the basis of morphometric and truss distances data for the stock of Bukvora *Baor*, Khatura *Baor*, Nabaganga river, Jhenaidah and Dhakuria Beel, Jashore. The samples of Bukvora *Baor* formed the first group and the second group formed by Khatura *Baor*, Nabaganga River, Jhenaidah and Dhakuria Beel, Jashore (Fig 46). All populatons were undoubtedly intermingled from each stock in the discriminant space.For morphological and truss measurements first, second and third (DF) accounted 78%, 16.9% and 5.1% of among group variability, respectively. These univariate statistics differences completely matched with the previous experiment conducted following same procedure by Mahfuj et al. (2019c) for *Macrognathus pancalus* from four natural sources of Bangladesh.

11.2.12. Study of reproductive biology

Size at first sexual maturity (L_m)

The calculated size at first sexual maturity of *Amblypharyngodon mola*, *Anabas testudineus*, *Chanda nama, Channa orientalis, Channa punctatus, Channa striata, Heteropneustes fossilis, Lepidocephalichthys guntea, Macrognathus pancalus, Mystus tengara, Puntius sophore, Trichogaster fasciata, Glossogobius giuris,* and *Xenentodon cancila* were 4.57, 7.74, 3.87, 10.27, 12.87, 17.46, 9.80, 6.41, 8.97, 7.80, 4.72, 2.94, 9.63, and 8.67 cm respectively. Hasan et al. (2021) reported size at first sexual maturity of *A. mola*, *A. testudineus*, *C. nama, C. orientalis, C. punctatus, C. striata, H. fossilis, L. guntea, M. pancalus, M. tengara, P. sophore, T. fasciata, G. giuris,* and *X. cancila* were 4.99, 9.85, 4.64, 11.27, 11.49, 25.33, 14.02, 6.44, 9.47, 7.74, 6.83, 5.86, 8.91 and 13.96 cm, respectively from the Gajner Beel, Bangladesh. Makmur et al., (2003) recorded L_m of *Channa striata* 15.40 and 18.00 cm in the Musi River, south Sumatera, and 25.00 cm was found in Indonesia (Herre, 1924). For *P. sophore*, Halls et al. (1999), Halls (2005), and Hossain et al. (2012) reported that L_m was 6.10, 4.50, and 5.00 for the *P. sophore* in the Talimnagar sluicegate, Lohajang River, and Padma River, respectively. The L_m of fish specimens might differ due to several factors like feeding rate, sex and gonadal development, behavior, season, the flow of water, populations density, water temperature, and food (Hossain et al., 2006, 2012; Hasan et al., 2021).

Table 25. Calculated size at first sexual maturity of some fishes from the selected two *Baor*s based on maximum length.

SL No.	Species name	L_{max} (cm)	L_m (cm)	95% CL of L_m
1	*Amblypharyngodon mola*	7.5	4.57	3.42-6.12
2	*Anabas testudineus*	13.25	7.74	5.62-10.64
3	*Chanda nama*	6.25	3.87	2.92-5.12
4	*Channa orientalis*	18	10.27	7.35-14.35
5	*Channa punctatus*	23	12.87	9.10-18.21
6	*Channa striata*	32	17.46	12.14-25.12
7	*Heteropneustes fossilis*	16.30	9.80	7.80-12.32
8	*Lepidocephalichthys guntea*	10.25	6.41	5.20-7.94
9	*Macrognathus pancalus*	14.8	8.97	7.17-11.24
10	*Mystus tengara*	12.7	7.80	6.27-9.73
11	*Puntius sophore*	7.75	4.72	3.52-6.31
12	*Trichogaster fasciata*	4.64	2.94	2.25-3.83
13	*Xenentodon cancila*	16.08	9.63	6.92-13.41
14	*Glossogobius giuris*	15	8.67	6.27-12.01

Spawning season of *Gudusia chapra*

The monthly changes of GSI for *Gudusia chapra* are shown in Fig. 47. The GSI values were low in the month of January to February and October to December 2021. However, the higher GSI were found during the month of March to May and September, which indicated the spawning season for *Gudusia chapra* in the Bukvora *Baor*. In addition, peak value of GSI was found in the month of April, which was the peak spawning season for this species. According to Kumari et al. (2021), the spawning season of *Gudusia chapra* was February to October in large reservoir, India and peak season was in the month of April which is similar with our findings.

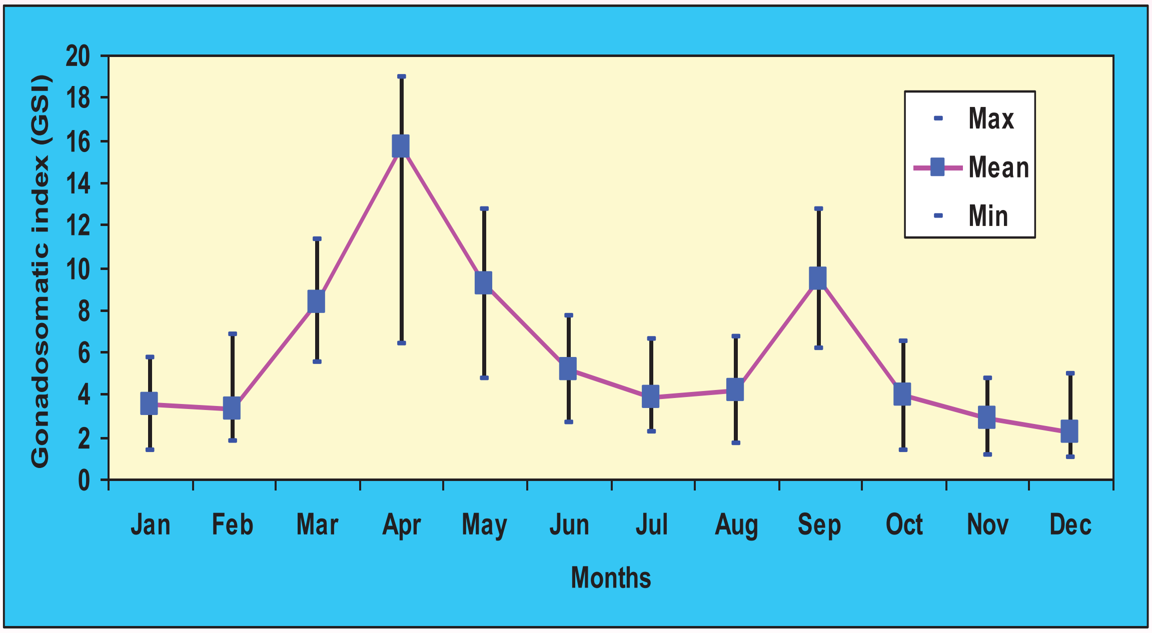


Fig 47. Monthly variation of GSI of *Gudusia chapra* from the two selected *Baor*s, Jashore region, south-western Bangladesh

The monthly changes of GSI for *Glossogobius giuris* are shown in Fig. 48. The GSI values were low in the month of January to February and September to December 2021. However, the higher GSI were found during the month of May to August, which indicated the spawning season for *Glossogobius giuris* in the Bukvora *Baor*. In addition, peak value of GSI was found in the month of June–July, which was the peak spawning season for this species. According to Qambrani et al. (2015), the spawning season of *Glossogobius giuris* was March to September in Manchar Lake Sindh, Pakistan and peak season was in the month of March.

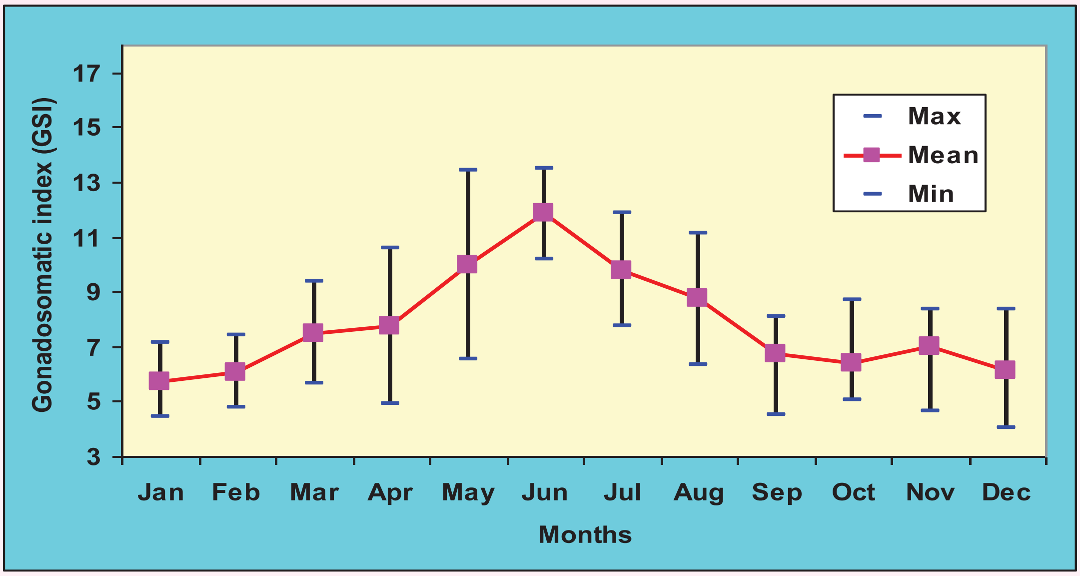


Fig 48. Monthly variation of GSI of *Glossogobius giuris* from the two selected *Baor*s, Jashore region, south-western Bangladesh

The monthly changes of GSI for *M. pancalus* are shown in Fig 49. The GSI values were low in the month of January to February and September to December 2021. However, the higher GSI (>0.80%) were found during the month of April to July, which indicated the spawning season for *M. pancalus* in the Bukvora *Baor*. In addition, peak value of GSI was found in the month of May-July, which was the peak spawning season for this species. Borah and Biswas (2018) reported the spawning season from March–September for *M. pancalus* at India and highest value of GSI was found in the month of August that indicating the peak spawning season. However, Pathok et al. (2012) observed that the monthly fluctuations in gonadosomatic index were recorded with maximum value (one pick) during August for *M. pancalus* collected from ponds while two peaks were recorded during March and July from the river population. In addition, Suresh *et al*. (2006) reported that the *M. pancalus* had a long spawning period, which extends from March to September which is quite similar with this study. On the other hand, Zahid *et al*. (2013) also reported that the *M. pancalus* breeds during February to September with peak spawning during February and March and July and August that was indicating two main breeding periods.

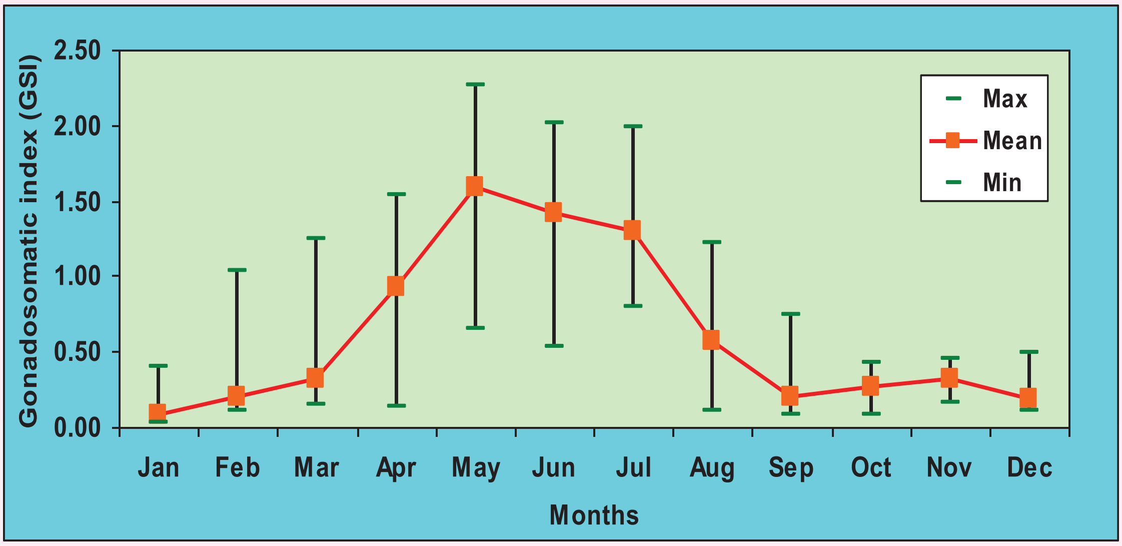


Fig 49. Monthly variation of GSI of *Macrognathus pancalus* from the two selected *Baor*s, Jashore region, south-western Bangladesh

The monthly changes of GSI for *Heteropneustes fossilis* are shown in Fig 50. The GSI values were low in the month of January to February and October to December 2021. However, the higher GSI were found during the month of April to July, which indicated the spawning season for *Heteropneustes fossilis* in the Bukvora *Baor*. In addition, peak value of GSI was found in the month of May-June, which was the peak spawning season for this species. Thakur and Nasar (1977) have documented the reproductive season in June–July for *H. fossilis* in Darbhanga, Bihar, India, whereas Nayyar and Sundararaj (1970) reported July–August for the species at the River Yamuna, Delhi, India. However, these diferences may be accredited to environmental parameters, specially the rainfall and water temperature, population size, and food accessibility.

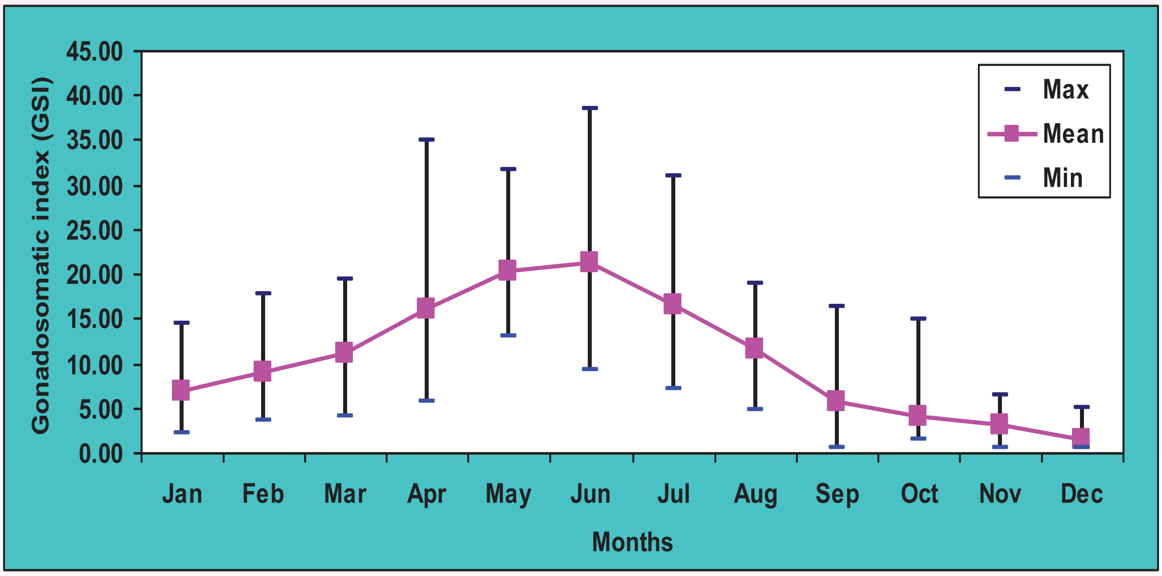


Fig 50. Monthly variation of GSI of *Heteropneustes fossilis* from the two selected *Baor*s, Jashore region, south-western Bangladesh

The monthly changes of GSI for *Lepidocephalichthys guntea* are shown in Fig 51. The GSI values were low in the month of January to February and October to December 2021. However, the higher GSI were found during the month of May to August, which indicated the spawning season for *Lepidocephalichthys guntea* in the Bukvora *Baor*. In addition, peak value of GSI was found in the month of June–July, which was the peak spawning season for this species. According to Sayeed et al. (2009), the spawning season of *Lepidocephalichthys guntea* was June-July in Manchar Lake Sindh, Pakistan and peak season was in the month of June which is in accordance with our results.

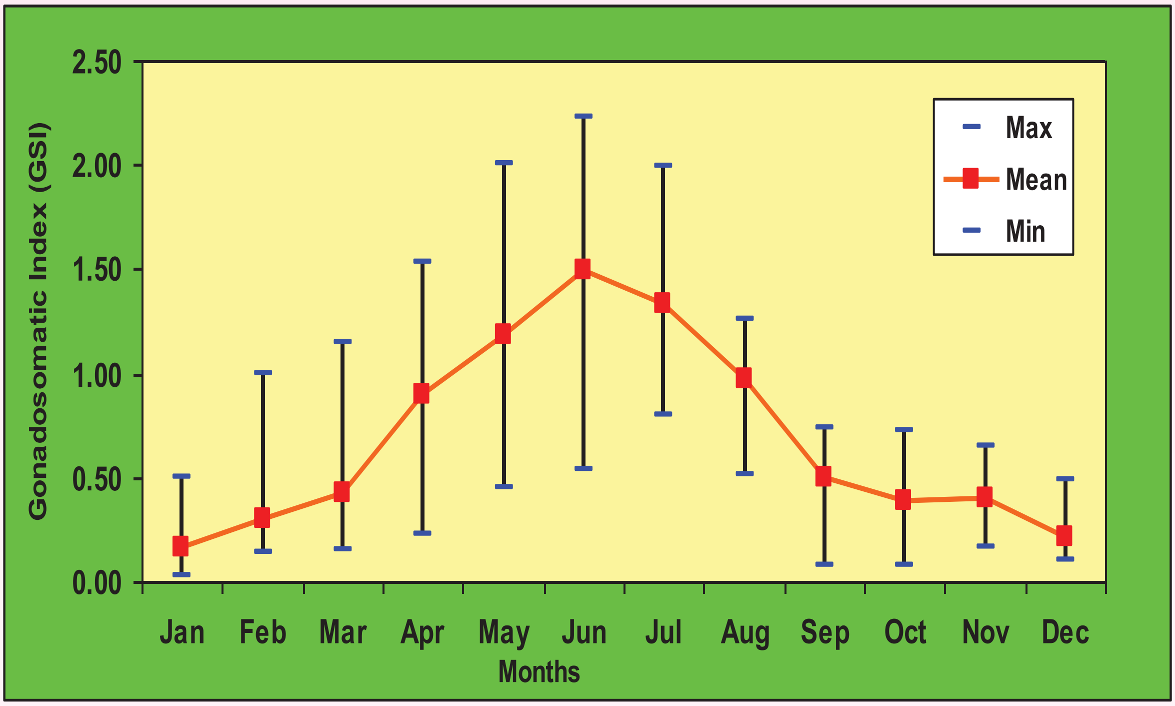


Fig 51. Monthly variation of GSI of *Lepidocephalichthys guntea* from the two selected *Baor*s, Jashore region, south-western Bangladesh

The monthly changes of GSI for *A. testudineus* are shown in Fig 52. The GSI values were low in the month of January to February and November to December 2021. However, the higher GSI were found during the month of May to August, which indicated the spawning season for *A. testudineus* in the Bukvora *Baor*. In addition, peak value of GSI was found in the month of June–July, which was the peak spawning season for this species. In agreement with our findings, the spawning season of *A. testudineus* has been documented from June to July in the Padma river of Rajshahi (Islam and Hossain 1983), April to July in several water bodies of Bangladesh (Rahman 2005), and July to October in the Sylhet region of Bangladesh (Uddin et al. 2017). The documented variations in the spawning season are probably linked to environmental parameters, mostly water temperature and precipitation, population density, and food availability (Mitu 2017; Khatun et al. 2019).

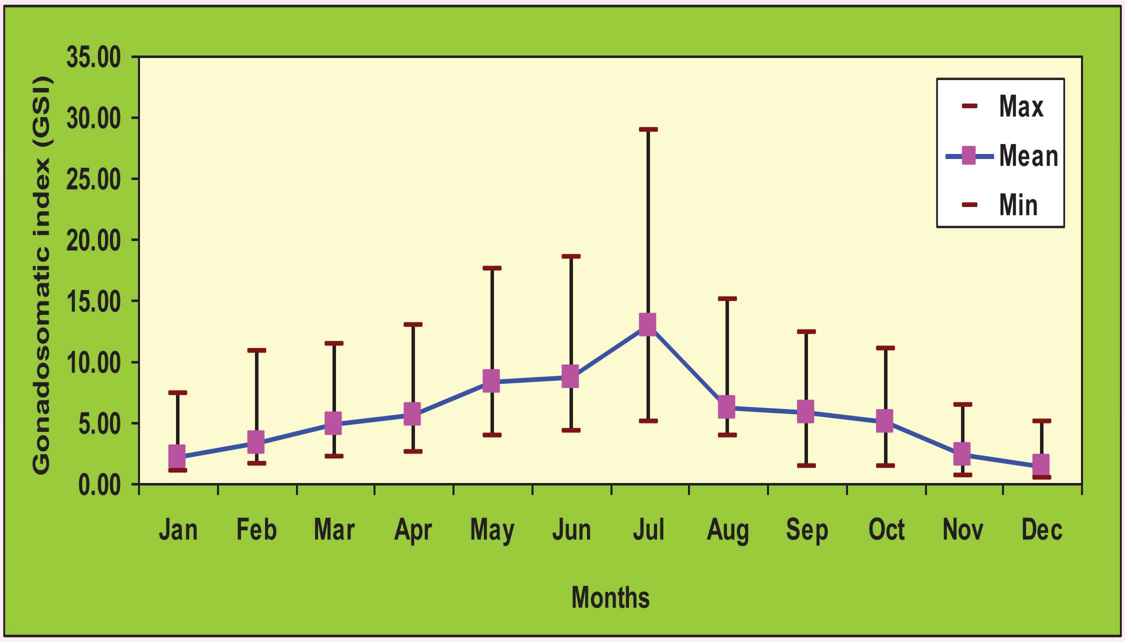


Fig 52. Monthly variation of GSI of *Anabas testudineus* from the two selected *Baor*s, Jashore region, south-western Bangladesh

11.2.13. Study of food and feeding habit

Feeding habit of *Pethia ticto*

Indexes of 157 gut of *P. ticto* are given in Fig 53. The observations of their gut gave four guts were categorized indexes such as full empty, ½ full, 1/3 full. During the study period, Gut of the male and female of were dissected and the observation that most of the guts 39.52% were empty and several of them were full 16.54%, ½ full 22.96% and 1/3 full 20.98%.

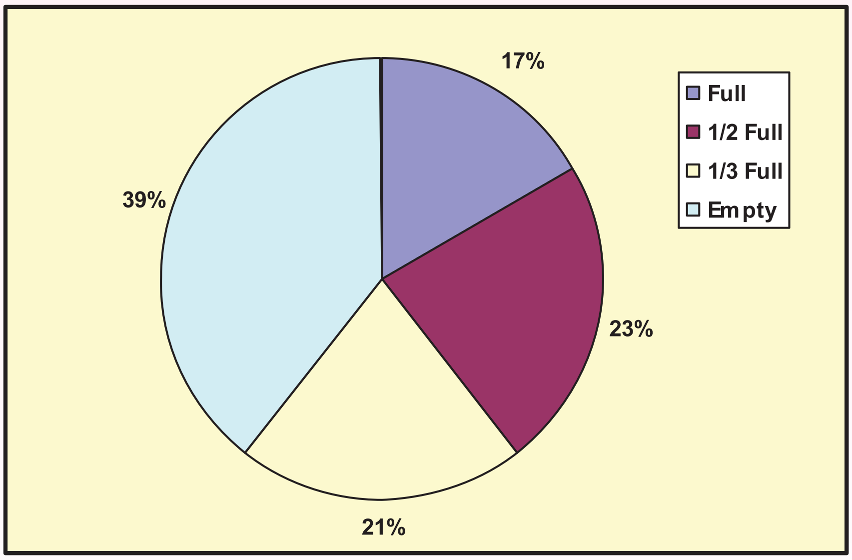


Fig 53. Indexes of the gut content and their percentage for combine sex of *P. ticto* collection from Bukvora *Baor*, Jashore.

During the study, an index of total 62 no's guts of male and 95 no's guts of female individual are presented in Fig 54.

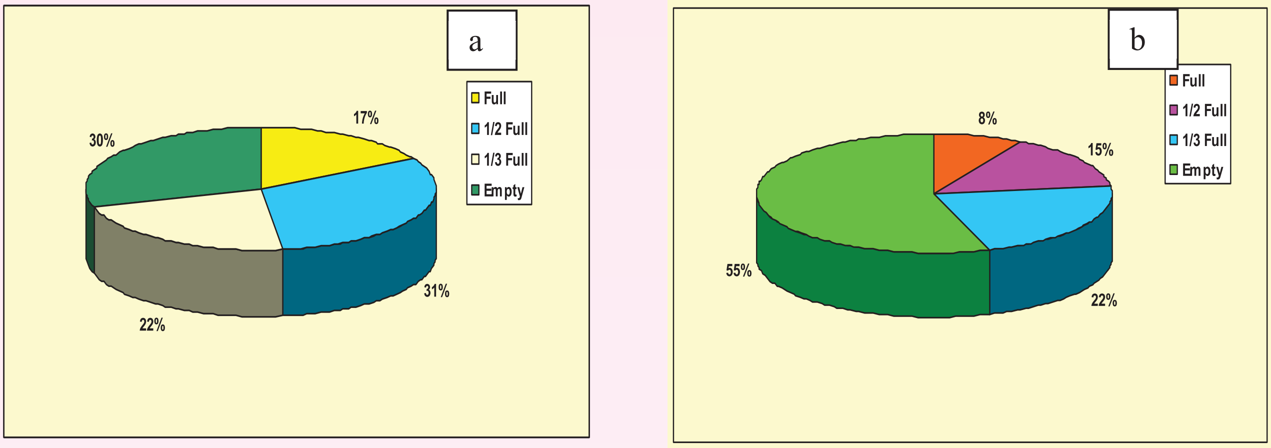


Fig 54. Indexes of the gut content and their percentage for male (a) and female (b) of *P. ticto* collection from Bukvora *Baor*, Jashore.

Monthly gut index of individuals are presented in (Table 26). The observation of their guts gave four stomach indexes. Out of 157 guts collected over a period of 6 month (July to December 2021). It had been recorded that maximum percentage (25%) of full guts were found in the month November. Beside the 1/3 full gut was highest observed in October. December (40%) and ½ full gut 42% December. The highest percentage of empty guts was (63.50%).

Table 26. Monthly gut index of the *Pethia ticto* (Hamilton, 1822) in the Bukvora *Baor*, Jashore, Bangladesh

Month	No. of Observation	Full	½ full	1/3 full	Empty
July	50	17.00	11.25	22.00	49.75
August	30	21.00	22.00	13.00	44.00
September	20	24.00	26.00	18.00	32.00
October	25	7.25	11.50	17.75	63.50
November	22	25.00	25.00	15.12	34.88
December	10	5.00	42.00	40.00	13.00
Average	157	16.54	22.96	20.98	39.50

The main food items that of observed in the guts of *P. ticto* crustaceans (15%), aquatic insects (33%), aquatic vegetation (12%), digested matter (11%), mollusks (4%), sand and mud (5%), annelids (3%) and scale of fish (6%) were also found. Unidentified foods for all individuals were (11%) (Fig 55).

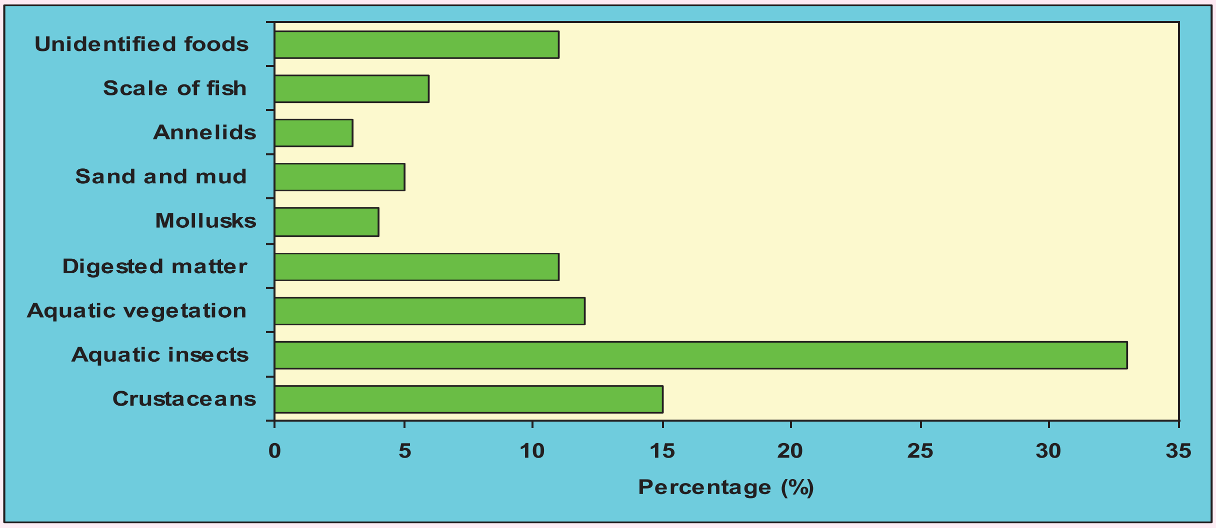
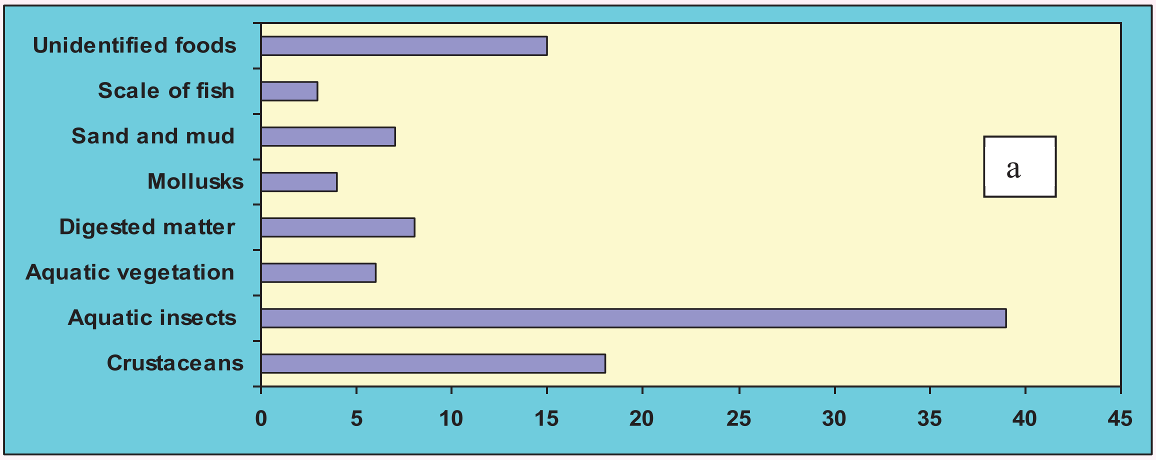


Fig 55. Food items of individuals for combined sex of *P. ticto* collected from Bukvora *Baor*, Jashore.

The food items that found in the gut of female aquatic insects 23% and digested matter 16% and the most food items that were observed in the gut of male were insect 39% and crustaceans. Crustaceans, scale of fish, digested matter, aquatic vegetation, sand and mud, and mollusks etc. were also found in both female and male. On the other hand, male did not found annelids food items in their feeding (Fig 56)



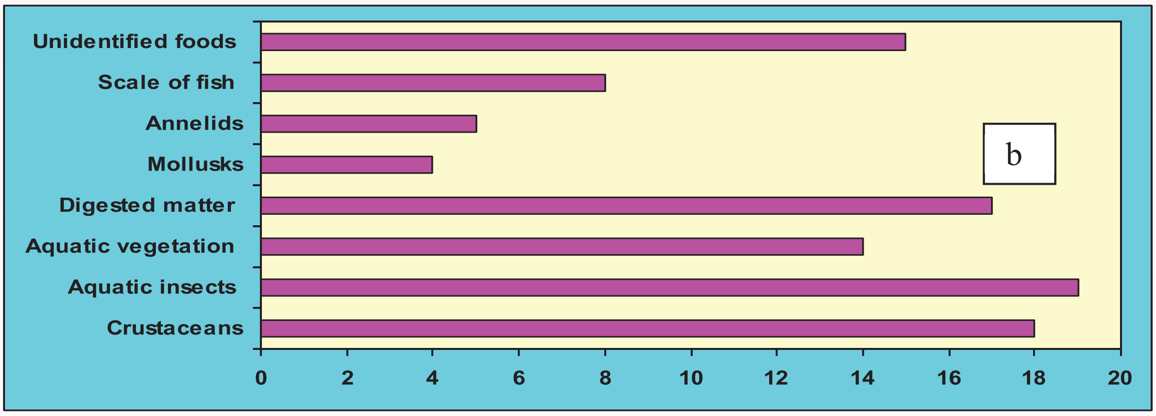


Fig 56. Food items for (a) male (b) female of *P. ticto* collected from Bukvora *Baor*, Jashore.

Despite its popularity and endemic status, fishery science has paid little attention to *P. ticto* in terms of food and feeding patterns. Other modern Puntius species, such as *P. sarana, P. ticto*, and *P. gonionotus*, have detailed information on their feeding habits (Islam et al., 2006; Mondol et al., 2005: Pethiyagoda, 1991). Different types of food items are eaten by *P. ticto* such as crustaceans, mollusks, insects, aquatic vegetation, sand and mud, scale of fish, unidentified foods etc. It's a surface-dwelling fish that eats small insects, algae, and plankton, according to Shafi and Quddus (1982). It was described as larvivorous and herbivorous by Basar (2011), and as omnivore and column feeder by Phukon and Bishwas (2012). According to Mookerjee et al. (1946) its food consists of 40% algae, 15% higher plants, 30% protozoa, and 15% insects,

Feeding habit of *Gudusia chapra*

Fig 57 shows the degree of fullness of fish's stomach during the research period. Highest feeding intensity (FI) was observed from November to January and lowest was seen from June to July.

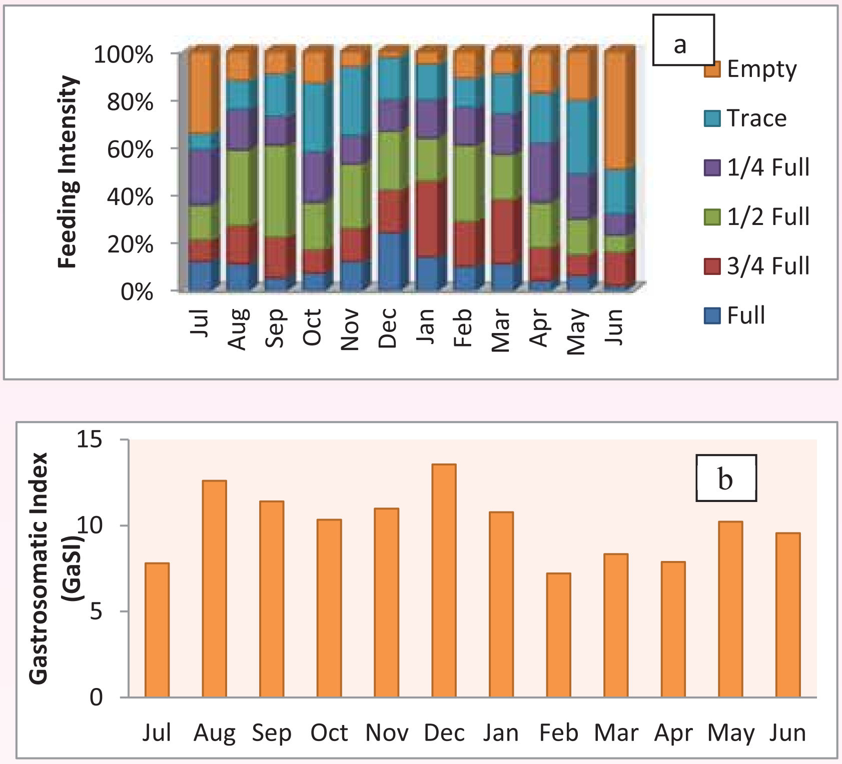


Fig 57. (a) Degree of fullness (FI) of stomach (b) Monthly variations of gastro-somatic index (GaSI) of *G. chapra* from the two selected Baors, Jashore region, south-western Bangladesh.

Gastrosomatic index value of *G. chapra* was ranged between 7.8±34 to 13.55±56. Highest and lowest value was observed in the month of December and February respectively. The monthly measurements of GaSI showed significant ($p < 0.05$) alterations (Fig 57). Food preferences were determined using the electivity index (Table 27). The *G. chapra* favored zooplankton above phytoplankton, according to the overall electivity index data. Bacillariophyceae and chlorophyceae had a positive electivity index, indicating that these groups had a stronger preference than other phytoplankton groups. Rotifers and protozoa were shown to be favoured food items among zooplankton throughout the year. Negative value indicated non-selective feeding in both case of phytoplankton and zooplankton.

Table 27. Ivlev's food preference index/"electivity index" (E_I) calculated of *Gudusia chapra* (Hamilton, 1822) in the Bukvora *Baor*, Bangladesh

Food type	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Bacillariophyceae	0.27	-0.34	-0.27	0.10	0.05	0.04	-0.08	-0.15	-0.25	-0.40	-0.30	-0.23
Cyanophyceae	-0.02	-0.34	-0.15	-0.46	-0.25	0.56	0.32	-0.57	-0.05	-0.78	-0.17	0.65
Chlorophyceae	0.64	-0.42	-0.83	-0.75	0.35	-0.28	-0.56	-0.32	0.72	-0.68	-0.05	-0.17
Dinophyceae	-0.07	-0.45	-0.38	-0.14	-0.41	-0.07	-0.67	0.41	0.82	-0.55	-0.51	0.47
Euglenophyceae	-0.33	-0.43	-0.63	-0.71	-0.85	0.02	0.75	0.35	-0.22	-0.43	-0.66	-0.52
Myxophyceae	-0.16	-0.43	-0.722	-0.55	0.25	-0.67	-0.15	-0.84	-0.31	-0.96	-0.15	0.05
Volvocaceae	0.75	-0.65	-0.32	-0.15	-0.73	-0.23	0.44	-0.72	-0.43	-0.96	-0.13	-0.22
Cladocera	1.00	0.83	0.54	0.32	0.32	0.15	0.05	-0.22	-0.35	-0.52	0.14	0.75
Copepoda	0.95	1.00	-0.91	-0.74	0.65	0.83	0.42	0.40	0.22	0.55	0.36	0.15
Rotifera	1.00	0.87	0.75	0.65	0.53	0.23	0.10	0.05	0.64	0.44	0.41	0.10
Protozoa	0.95	0.74	0.55	0.43	0.21	0.03	0.44	0.21	0.88	0.64	0.05	-0.16

The present study on the feeding intensity (FI) of *G. Chapra* has significant selectivity for a variety of foods, demonstrating that selectivity changes over time. Analysis of the gut content in the present study was shown that of G. *chapra intake* phytoplankton, zooplankton, protozoans along with crustaceans which are supported by Rahmatullah et al. (1995). Rahman et al. (2008) stated the similar trend of observation which supported the present study. Kumari et al. (2020) reported the similar kind of observation on the FI. The highest FI was recorded in December-February and August-September, and the lowest FI was found in October and May-June.

Feeding habit of *Heteropneustes fossilis*

Indexes of 179 guts of *H. fossilis* are given in figure. The observations of their gut gave four guts were categorized indexes such as full empty, ½ full, 1/3 full. During the study period, out of the male and female of were dissected and the observation that most of the guts 35.52% were empty and several of them were full 19.52%, ½ full 23.94% and 1/3 full 21.02% (Fig 58).

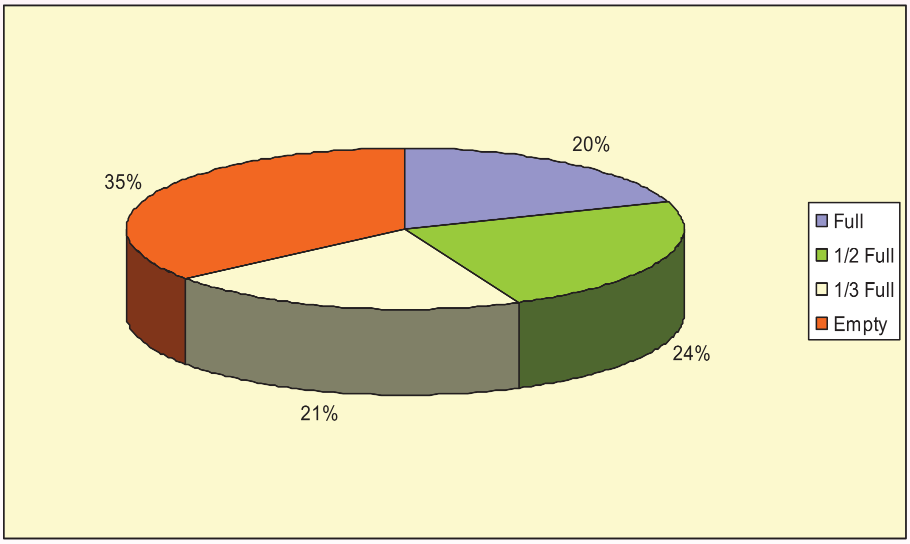


Fig 58. Indexes of the gut content and their percentage of *H. fossilis* collection from Bukvora *Baor*, Jashore.

The main food items that of observed in the guts of *H. fossilis* crustaceans (55%), Plant debris (3%), Animal debris (23%), Scales (1%), Worms (7%), Diatoms (3%), and Insects (8%) were found (Fig 59).

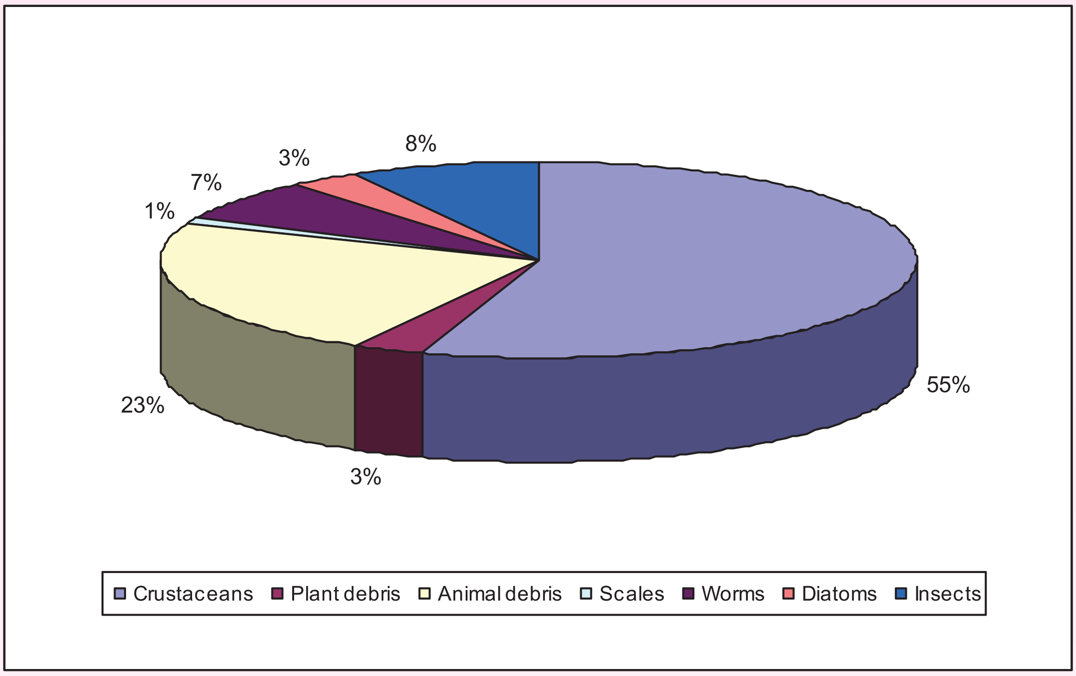
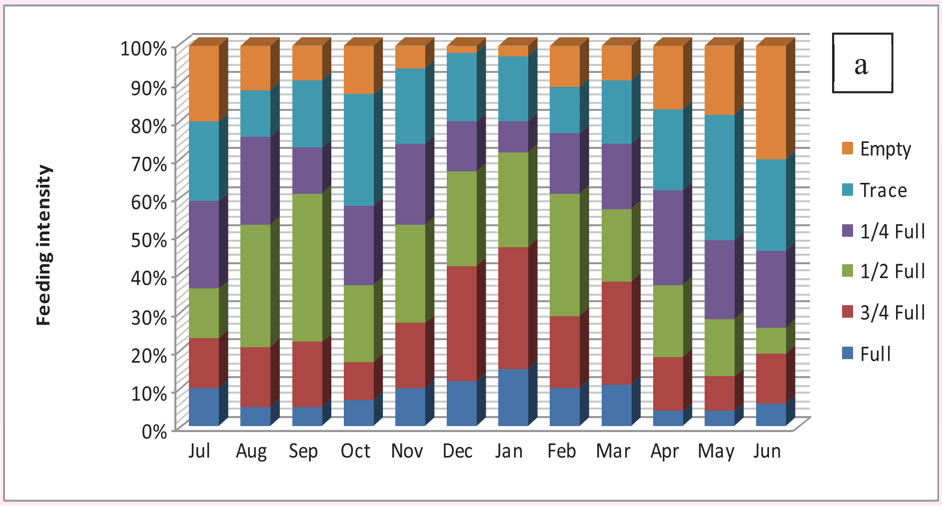


Fig 59. Food items of *H. fossilis* collected from Bukvora *Baor*, Jashore

Despite its popularity and endemic status, fishery science has paid little attention to *H. fossilis* in terms of food and feeding patterns. Different types of food items are eaten by *H. fossilis* such as crustaceans, plant debris, animal debris, insects, scale of fish, worms etc. It was not possible to compare with others due to lack of available literature.

Feeding habit of *Anabas testudineus*

Indexes of 200 no's guts of *A. testudineus* are given in Fig.60. The observations of their gut gave four guts were categorized indexes such as full empty, ½ full, 1/3 full. The fig also shows the degree of fullness of fish's stomach during the research period. Highest feeding intensity (FI) was observed from November to March and lowest was seen from April to June. The main food items that of observed in the guts of *A. testudineus* were crustaceans (38.20%), Debris (1.10%), Protozoan (29.60%), Rotifers (4.40%), Scales of fishes (2.70%), Algae (8.70%), Diatoms (1.60%), and Insects (13.70%) were found (Fig 60). The present study on the feeding intensity (FI) of *A. testudineus* has significant selectivity for a variety of foods, demonstrating that selectivity changes over time. Analysis of the gut content in the present study showed that *A. testudineus intake* phytoplankton, zooplankton along with crustaceans which are supported by Rahmatullah et al. (1995). Rahman et al. (2008) stated the similar trend of observation which supported the present study. Kumari et al. (2020) reported the similar kind of observation on the FI. The highest FI was recorded in November to March and the lowest FI was found in April to June and September to October.



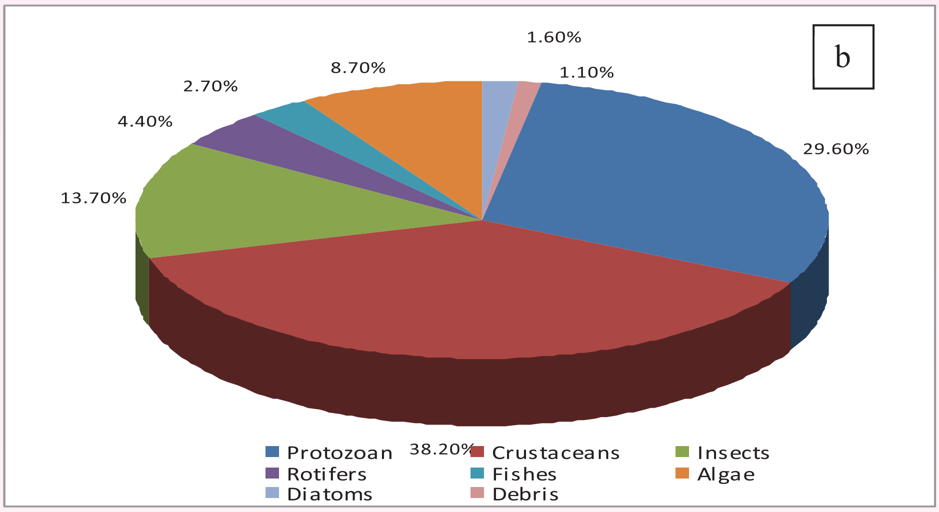


Fig 60. (a) Degree of fullness (FI) of stomach **(b)** Food items of *A. testudineus* collected from Bukvora *Baor*, Jashore.

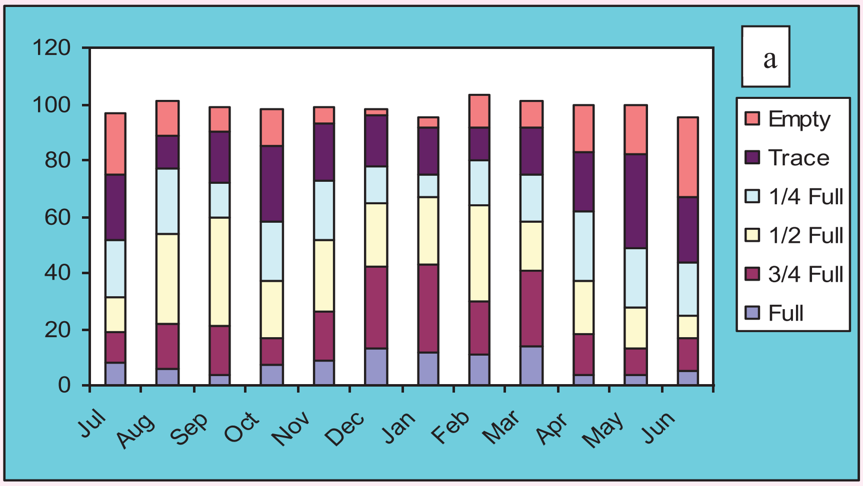
Feeding habit of *Macrognathus pancalus*

Indexes of gut content

Indexes of 210 no's guts of *M. pancalus* are given in figure. The observations of their gut gave four guts were categorized indexes such as full empty, ½ full, 1/3 full. Fig 61 shows the degree of fullness of fish's stomach during the research period. Highest feeding intensity (FI) was observed from November to March and lowest was seen from April to June.

Food items of individuals

The body parts in the gut contents indicate the carnivorous and predatory habits of M. pancalus. The main food items that of observed in the guts of *M. pancalus* were crustaceans (51%), Annelids (19%), Animal vegetation (8%), Molluscs (5%), Scales of fishes (7%), Digested matter (4%), and Aquatic Insects (6%) were found (Fig 61).



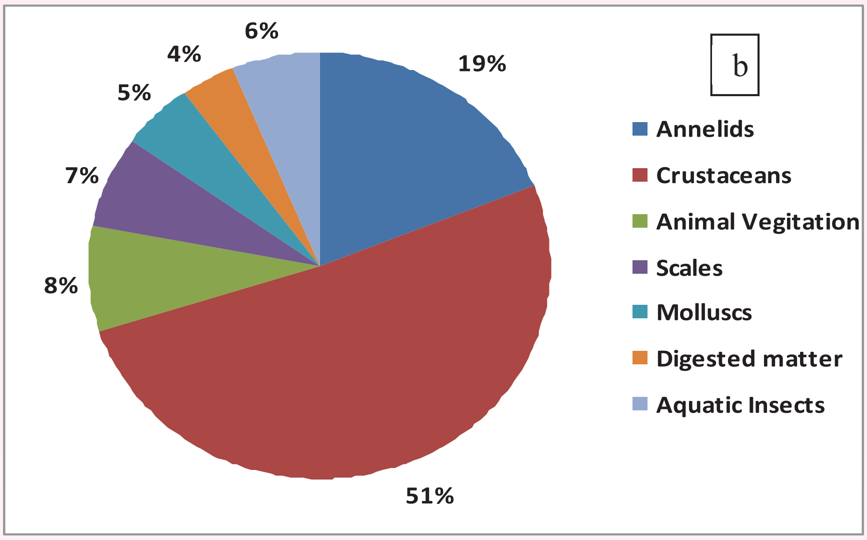


Fig 61. (a) Degree of fullness (FI) of stomach (b) Food items of *M pancalus* collected from Bukvora *Baor*, Jashore.

Different food items

Study revealed the presence of various types and categories of food items in the stomach of different small indigenous fish species where the major component items are included crustacean, mollusks, copepod, insects, sand particles and mud (Plates 13 to 25).

Order: Cyclopoida
Family: Oithonidae
Genus: *Oithona*
Species: *Oithona davisae*

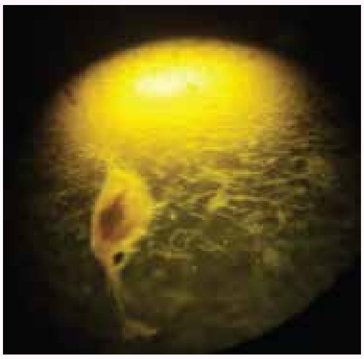


Plate 13. *O. davisae*

Phylum: Arthropoda
Class: Crustacea
Order: Anomopoda
Family: Daphniidae
Genus: *Daphnia*
Species: *Daphnia lumholtzi*

Plate 14. *D. lumholtzi*

Phylum: Arthropoda
Class: Crustacea
Order: Nebaliacea
Family: Nebaliidae
Genus: *Nebalia*
Species: *Nebalia geoffroyi*

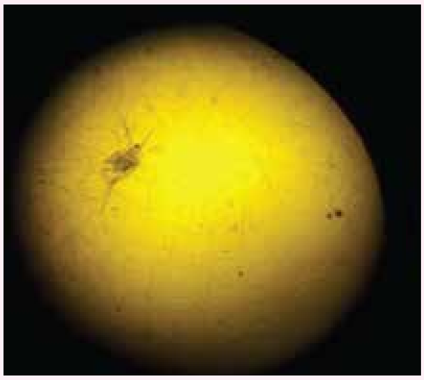


Plate 15. *N. geoffroyi*

Order: Gymnodiniales
Family: Gymnodiniaceae
Genus: *Gymnodinium*
Species: *Gymnodinium catenatum*

Plate 16. *G. catenatum*

Order: Cladocera
Family: Daphniidae
Genus: *Daphnia*
Species: *Daphnia cucullata*

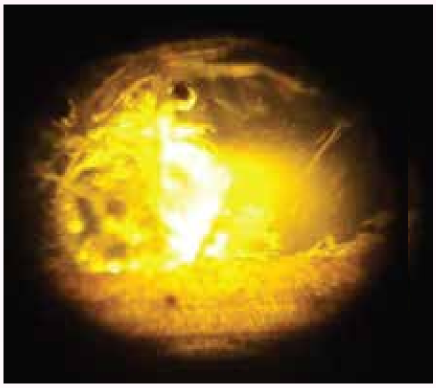


Plate 17. *D. cucullata*

Order: Anomopoda
Family: Daphniidae
Genus: Daphnia
Species: *Daphnia magna*

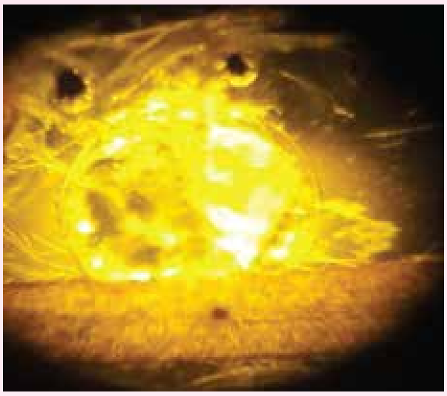


Plate 18. *D. magna*

Phylum: Arthropoda
Class: Crustacea
Order: Mysidacea
Family: Mysidae
Genus: *Mysis*
Species: *Mysis oculata*

Plate 19. *M. oculata*

Phylum: Arthropoda
Order: Heterotrichida
Genus: *Spirostomum*
Species: *Spirostomum ambiguum*

Plate 20. *S. ambiguum*

Phylum: Arthropoda
Order: Hemiptera
Genus: *Plea*
Species: *Plea leachi*

Plate 21. *P. leachi*

Kingdom: Animalia
Phylum: Arthopoda
Sub phylum: Crustacea
Class: *Maxillopoda*
Subclass: *Copepoda*

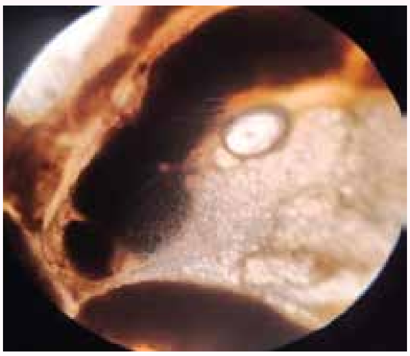
Plate 22. *Copepoda*

Phylum: Arthopoda
Class: Insecta
Order: Diptera
Family: Chironomidac
Genus: *Tanypus*
Type: *Tanypus larvae*

Plate 23. *T larvae*

Unidentified food items

Plate 24. Digested food materials



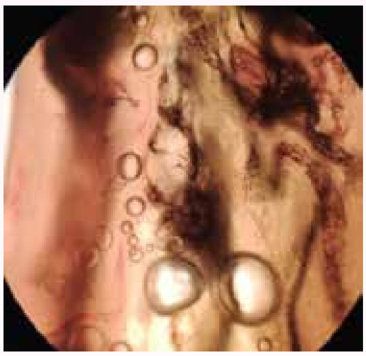


Plate 25. Sand and mud

11.2.14. Identification of co-ownership management problem

Primary data to identify the existing co-ownership management problem collected through survey covering *Baor* fisheries teams (BFT) and a fish farmers group (FFG) managping two selected *Baosr*. Following are the major problems identified that *Baor* beneficiaries had to deal with *Baor* management. Contribution of each cause has been reflected in Fig. 62 where financial problem during fish stocking and inequity of profit distribution occupying the leading position.

- Financial problem during fish stocking
- Inequity of profit distribution.
- Conflict between *Baor* beneficiaries with local agricultural farmers.
- Local political influence during harvesting.
- Physical labour inequity among all *Baor* beneficiaries

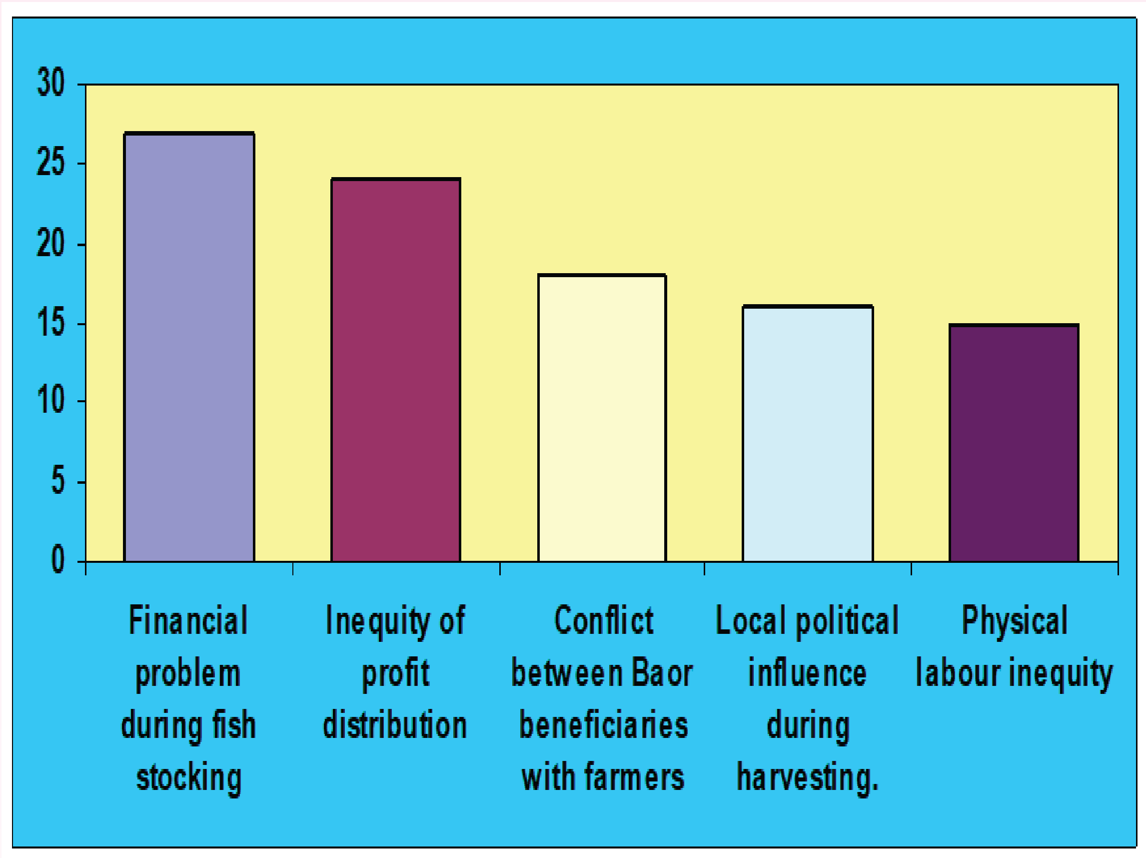


Fig 62. Co-ownership management problem in *Baor*


Ongoing Project


Ongoing Project


Ongoing Project

Plate 25. Field Day observation and monitoring of *Baor* fisheries activities

12. Research highlights

Title of the sub-project

Sustainable Development of Indigenous Fisheries in *Baors* of South-western Bangladesh through Multiple-Functions for Ensuring the Food Security

12.1. Component 1 (RU)

Background

Baors or oxbow lakes are one of the important inland aquatic resources, which are created due to the changed course of the rivers. About 260 species of freshwater fishes are found in the inland water bodies of Bangladesh. However, currently most of the *Baors* fisheries have lost its fashionable characteristics to over exploitation of fish including use of harmful fishing gears, degradation and loss of fish habitats, siltation of water bodies by natural process and water pollution by industry and agrochemicals (Ali et al., 2009).

Population structure provides rudimentary data to evaluate stock structure of fish stocks (Vazzoler, 1996). The L_m in fish may depend on environmental condition and can assist to define the minimum catchable size of fishes (Lucifora et al., 1999; Hasan et al., 2021). Determination of the full- and peak-spawning seasons of adult fish is important for conservation and management policies to avoid over harvesting and other impacts (Templeman, 1987). In addition, estimation of fish mortality (natural and fishing) is required that accounts for the loss of fish in a fish stock due to death. The present study attempted to development sustainable management plan of indigenous fishes in the *Baors* to ensure the food security and livelihood of a number of fishers in *Baor* ecosystem of Bangladesh through generation of information on stock, lenth-weight, fecundity, spawing performance and behavior, mortality ant rectuitment pattern of fish species of *Baors.*

Objectives

The study aimed to find out the fish diversity with emphasis on indigenous fish species and to confirm the size and age-at-sexual maturity, spawning- and peak- season of indigenous fishes in *Baors* based on unit-stocks and its status with emphasis on relative abundance (CPUE), longevity, size and age-recruitment, exploitation rate, maximum sustainable yield, biomass after and before the ranching of targeted indigenous. The study also attempted to identify the major man-made and natural causal factors responsible for for declining of indigenous fish species in *Baors*;

Methodology

- The study was conducted in two selected *Baors* namely Saganna and Sarjat covering Jhenaidah district of southwestern Bangladesh
- The baseline survey of the fish biodiversity was conducted through Personal Interview (PI), Focus Group Discussion (FGD), Key Informant Interview (KII) using questionnaire and checklist. Conservation status study of fishes was done in Bangladesh and global aspects of IUCN data and information collected personally on the extinct fish specie those disappears within previous 2-25 years from five studied *Baors*.
- Information about the cause factors which are responsible for the decling of fish population from study areas were done by interview with fishers, fish traders, teachers, students, researchers, government officials and NGO personnel and experienced persons related to fisheries sectors, and from national and international journals.
- Selected 7 indigenous fishes (*Anabas testudineus*, *Channa punctata*, *Heteropneustes fossilis*, *Mystus tengra*, *Mystus vitatus*, *Mystus cavasius* and *Ompok pabda*) were stocked maintained - 10-30 individuals /decimal for each species.
- Monthly increase of stocked fishes observed with the change of total length (TL) and body weight (BW).

- Size at first sexual maturity of seven small indigenous fish species of *Baor* L_m was estimated by (i) TL *vs*. GSI model (GSI %=(GW/BW)*100) (Nikolsky 1963) and Spawning season was estimated through the monthly variations of GSI as GSI (%) = 100 × GW/BW.
- Length at first recruitment, L_r (mean length of first modal group) was estimated through LFDs of 1.0 cm intervals using Excel-add-in-Solver.
- The instantaneous rate of total mortality (*Z*) was estimated by the length converted catch curve method (Pauly, 1983), Natural mortality (*M*) was estimated by Pauly (1980) given as: $log_{10}M = -0.0152 - 0.279\ log_{10}L_\infty + 0.6543\ log_{10}K + 0.4634\ \log_{10}T$. 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): $E = F/Z = F/(F+M)$.
- Beverton and Holt (1966) described yield per recruit model, is the best widely used method for the Estimation of yield per recruit model followed as per Beverton and Holt (1966) expressed as a function of L_c/L_∞ *,F/K,M/K,* and relative fishing mortality *F/M*. Optimum catchable length calculated by the equation of Beverton (1992) as: $L_{opt} = 3L_\infty (3+MK^{-1-1})$ where L_∞ is the theoretical asymptotic length.
- Data analyses done by using Microsoft® Excel-add-in-solver and past 4.03 software.

Key findings

i. A total of 18 indigenous species from Sarjat *Baor*, 3 from Sagana *Baor*, 6 from Fatehpur *Baor*, 1 from Kapashaia *Baor*, 2 from Porapara *Baor*, 3 from Katgora *Baor* have been extinct. Those species were disappeared before 15 to 25 years ago except Saganna *Baor* (2-3 years ago);

ii. Predatory fishes were the major cause for the declining of indigenous fishes in the Saganna *Baor* and introduction of culturable species were key causes for Sarjat *Baor;*

iii. Successful spawning of stocked brood fishes species in the *Baor*;

iv. Hightest length, 32.80 cm (350g) for *O. pabda* and 25.70 cm (170 g) for *M. cavasius recorde in the months of January-februaty*;

v. Size at sexual maturity was calculated minimum was observed 7.20 cm for *M. cavasius* and maximum was 13.00 *cm* for *C. punctata* for Saganna *Baor* and the minimum was observed 7.80 cm for *M. tengra* and maximum was 13.80 cm for *C. punctata* for Sarjat *Baor;*

vi. From GSI variations found that most of the *Baor* fishes spawn in June and July months so fishing ban period should be established during this time;

vii. Minimum size at first recruitment (L_r) was 5.30 cm for *M. vittatus* and maximum was 9.30 cm for *H. fossilis* from Saganna *Baor* and Minimum (L_r) was 5.30 cm for *M. tengra* and maximum was 9.20 cm for *H. fossilis* from Sarjat *Baor*;

viii. Mimimum *Z* was obtained as 1.36 year^{-1} for *M. cavasius* and the maximum was 3.00 year^{-1} for *O. pabda* from Saganna *Baor* and In Sarjat *Baor* the minimum *Z* was 1.53 year^{-1} for *M. vittatus* and largest was 4.79 year^{-1} for *A. testudineus*;

ix. Maximum L_{opt} was 21.20 cm for *O. pabda* and minimum was 8.79 cm for *M. tengra* from Saganna *Baor* and maximum L_{opt} was 21.0 cm for *O. pabda* and minimum was 8.79 cm for *M. tengra* from Sarjat *Baor;*

Keywords: *Baors;* Biodiversity; L_{opt}, Mortality; Size at sexual maturity; Spawning season

12.2. Component 2 (JUST)

Background

In Bangladesh, *Baors* or oxbow lakes are one of the vital inland water assets, which are made due to the changed course of the waterways. Above 600 *Baors* are located in Jashore, Kushtia and Faridpur districts in south-western part of Bangladesh, mostly in greater Jashore district. According to DoF (2020), the current production of *Baor* is 10343 MT. These water-bodies are common properties, which have a high capability of fisheries production.. A total of 253 fish species were recently assessed by IUCN Bangladesh (2015), among them 64 species have categorized as threatened and 189 species were ranked as non-threatened list.

The *Baor* fisheries are highly important because they serve as the breeding ground for small indigenous fish species. Generally, the water depth of *Baor* is higher than the beels. Fish and fisheries sector play an important role in the nutrition, economy, employment and culture of Bangladeshi people. Therefore, proper management and conservation of fisheries resources in Bangladesh is highly crucial to overcome aforementioned situations like nutrition, livelihood and economy.

In recent years fish production from inland freshwater sources is rapidly declining and ostensibly abundance of many fish species are significantly reduced. The major obstacle is that the loss of habitat which is mainly caused by massive siltation, infrastructure development, drying up of water bodies, dewatering, conversion of wetlands, overfishing and aquatic pollution. The declining trends in freshwater fisheries have been created a great concern among researchers, politicians, and civil societies. Moreover, the declining situations in inland open water fisheries directly impact the livelihood to the marginalized people. However, during the last decade, Bangladeshi government has taken efforts for the conservation and management of fisheries resources.

Objectives

To assess the fish diversity index and causal factors for declining of indigenous fish species in *Baor*s of Jashore and to confirm its spawning and peak season and to estimate the stock structure delineation and reproductive potentiality and its success of indigenous fishes after and before the ranching program. Finally, to study the livelihoods of fishers' community in *Baor*s of Jashore district;

Methodology

- The proposed research was conducted in two selected *Baor*s *viz.* Bukvora *Baor* and Khatura *Baor* of Jashore district. Fish sampling was done monthly with the help of traditional fishing nets.The sampled fishes were counted on spot and preserved in 7 to 10% buffered formalin solution for detail identification and further analytical works.
- Selected Indigenous fishes were stocked after marking and tagging to observe the changes of relative abundance by Catch per unit effort (CPUE) and reproductive potentiality through gonadal studies**.** Fish sanctuary was established for facilitating fish breeding and conservation. Koi (*Anabas testudineas*), Taki (*Channa punctata*), Magur (*Clarius batrachus*), Shingee (*Heteropneustes fossilis*), tengra (*Mystus cavasius*) etc. those are considered as the major groups of fishes in *Baor* have high demand also.
- For culture, larger size of fingerlings at the rate of 10-30 individuals /decimal for each species was stocked.
- Morphometric and meristic characters study done following Rahman (1989, 2005) and Talwar and Jhingran (1991). Availability of fish species with particular emphasis to indigenous fish species was determined on the basis of their abundance during sampling

and through interviewing of fishermen with structured questionnaire. Collected fishes were categorized based on IUCN Bangladesh (2015) and IUCN global list (2021)..

To estimate the seasonal diversity of fishes in the study area, month-wise data was collected. Evenness and richness indices were calculated for understanding the status of diversity using the following formulas like Shannon-Weaver diversity index, $H = -\Sigma$ Pi ln Pi (Shannon and Weaver, 1949), Margalef's richness index, D= (S-1)/lnN (Margalef, 1968) and Evenness index, e = H/lnS (Pielou, 1966);

- Livelihood and socio-economic study were conducted based on primary and secondary data. Survey method was used to collect primary data. PRA tool (i.e. FGD) was arranged with fishermen as per Ahmed (1996). FGD implied to get collective issues such as local fishing systems, social and economic status of fishermen with relative challenges etc. Cross-cheek Interviews [CI] was organized with key personals;
- Market survey was conducted based on Focus group discussion (FGD) in two selected *Baor*s along with a questionnaire-based survey;
- All data and information biodiversity threats and management aspects were assessed on the survey information of local fishers, fish farmers, fish businessman, researchers, NGO personnel's, government stake holder as well as other age old related people/persons and secondary literatures;
- In case of stock structure analysis. after proper washing and cleaning each individual was labeled with a specific code of identification. A cyber shoot DSC-W 300 digital camera (Sony, China) was used to capture the digital images, which provide a complete archive of body shape and allowed a repeat of the measurement when necessary (Cadrin and Friedland, 1999).
- Truss distances from the digital images of specimens were extracted by using a linear combination of tpsDig2v2.1 (Rohlf, 2006). A box truss of 16-25 lines connecting these landmarks was generated for each fish species to represent the basic shape of the fish (Strauss and Bookstein, 1982). Then all measurements were transferred to a Microsoft Office Excel spreadsheet software, 2007 and SPSS 21 version software for subsequent analysis. During analysis, the size effect was eliminated from the data set. The variations were attributed to body shape differences and not to the relative sizes of the fish. Size dependent variation was corrected by adapting an allometric method as suggested by Elliot et al. (1995) as follows:
  $M_{adj} = M(L_s / L_o)^b$.
- Approximately 100 mature female of available indigenous fish species were collected randomly from two *Baor*s. All the samples were immediately transported to the laboratory analysis. Total length (TL) and standard length (SL) from each individual of specific species, and body weight (BW) and ovaries weight was weighed by electronic balance. Both left and right lobe weight of ovaries was weighed in the same way. Then sample weight was taken from all parts of ovaries from each lobe. Finally, the number of eggs will directly count with a fine needle. Standard gravimetric method was used to determine the fecundity of SIFS.
  Gonadosomatic Index (GSI) was calculated according to the formula as follows:
  GSI = (gonad mass / somatic mass of the individual × 100%).
  Size ($L_{m50\%}$) at first sexual maturity for fish was estimated by (i) relationship between TL vs. GSI (Khatun et al., 2019) (ii) maximum length-based equation (Binohlan and Froese, 2009).
- For feeding habit analysis, 5 live fish specimen of available fish species was collected from the same location. Fishes under study was dissected and the stomach was carefully cut from the rest of the digestive tract. The condition of feed was assessed by the degree of

distension of the stomach and expressed as full, 3/4 full, 1/2 full, ¼ full, tress and empty. The volume of stomach content was estimated by observation and was recorded on absolute scale. The largest volume was observed in preliminary study and finally allocated 100 points, and each of the stomachs was examined and then rated in one of the following categories 0, 3, 6, 12, 25, 50 and100 points, according to the volume of food present. The stomach contents was emptied into a Petri dish and examined under a binocular microscope with the help of Sedgewick Rafter Counting Cell Slide. Occurrence method was used for the qualitative analysis of food contents. Ecological niches and relation with the feeding behavior were also studied.

- Co-ownership management problem was investigated by using a pre-tested questionnaire survey. There are *Baor* fisheries teams (BFT) and fish farmers group (FFG) at the primary operational level and at the collective level in *Baor* management group (BMG).

Key findings

i. Indigenous fish species in the *Baors* were identified and listed;
ii. Biodiversity parameters of two selected *Baor*s; were estimated
iii. Causes of small indigenous fish's reduction from *Baors* were identified;
iv. Livelihood and socio-economic condition at fishers estimated;
v. Stock structure of 8 indigenous fish were analyzed through truss networking;
vi. Spawning season of 5 species were identified;
vii. Food and feeding habits of 4 species were identified;
viii. Stocking of 8 indigenous species from wild stock were domesticated and took part in spawning;

Keywords : *Baor* sustainable management, Food security, SIFS, Spawning, Feeding habits, Truss-networking

B. Implementation status

1. Procurement (component wise)

1.1.Coordinatio component (BARC)

Description of equipment and capital items	PP Target		Achievement		Remarks
	Physical (No.)	Financial (Tk.)	Physical (No.)	Financial (Tk.)	
(a) Office equipment					Procurement completed as per plan
Procurement of					
Furniture:	2	15800	2	15800	
a) Computer table	6	89400	6	89400	
b) Executive chair	1	99000	1	99000	
c) Sofa	3	74700	3	74700	
d) Wall Cabinet					
Procurement of office					
Equipment's:	1	79200	1	79200	
a) Refrigerator	1	39300	1	39300	
b) Micro Oven	2	298000	2	298000	
c) Air Condition					
(b) Lab & field equipment					
(c) Other capital items					

1.2. Component 1 (RU)

Description of equipment and capital items		PP Target		Achievement		Remarks
		Physical (No.)	Financial (TK.)	Physical (No.)	Financial (TK.)	
(a)	**(a) Office equipment**					
1.	1. Desktop computer	01	60000.00	01	52000.00	Target achieved 100% as per plan
2.	2. Laptop	01	60000.00	01	80000.00	
3.	3. Laser Printer (Black & White)	01	20000.00	01	19800.00	
4.	4. Scanner	01	10000.00	01	7000.00	
5.	5. DSLR Camera	01	45000.00	01	44500.00	
6.	6. UPS (offline)	01	10000.00	01	7000.00	
7.	7. Laboratory Freezer	02	160000.00	02	156000.00	
8.	8. Chargeable Digital Balance	03	30000.00	03	28500.00	
9.	9. Portable Electric Balance	04	32000.00	04	31200.00	
10.	10. Ceiling Fan	02	8000.00	02	7800.00	
	(b) Lab & field equipment					
	1. Multi Meter Water Parameter	01	500000.00	01	487000.00	Target achieved 100% as per plan
	(c) Office Furniture					
	1. Computer Table	01	8000.00	01	7900.00	Target achieved 100% as per plan
	2. Computer chair	01	6000.00	01	5900.00	
	3. Executive Table	01	20000.00	01	13000.00	
	4. Drawer	01	6700.00	01	6700.00	
	5. Executive Chair	01	15000.00	01	14900.00	
	6. Steel Almira	02	60000.00	02	59800.00	
	7. Executive Table (Side Office)	02	20000.00	02	19800.00	
	8. Junior Executive Chair (Side Office)	02	20000.00	02	20000.00	
	9. PVC Chair	12	16800.00	12	16800.00	

1.3. Component 2 (JUST)

Description of equipment and capital items	PP Target		Achievement		Remarks
	Physical (No.)	Financial (TK.)	Physical (No.)	Financial (TK.)	
(a) Office equipment	Lot	**178800**	Lot	**177500**	Target achieved 100% as per plan
1. Computer Table	1	8000	1	8000	
2. Computer Chair	1	6000	1	6000	
3. Executive Chair	2	30000	2	30000	
4. Steel Almeria	2	60000	2	60000	
5. Visitor Chair	3	18000	3	18000	
6. Table (Side Office)	2	20000	2	20000	
7. PVC Chair (Side Office)	12	16800	12	16500	
8. Chair (Side Office)	2	20000	2	19000	
(b) Lab & field equipment		**223000**		**222100**	Target achieved 100% as per plan
1. Laptop	1	60000	1	60000	
2. LaserJet Printer (Black & White)	1	20000	1	20000	

Description of equipment and capital items	PP Target		Achievement		Remarks
	Physical (No.)	Financial (TK.)	Physical (No.)	Financial (TK.)	
3. DSLR Camera	1	45000	1	45000	
4. Scanner	1	10000	1	10000	
5. Laboratory Freezer	1	80000	1	79100	
6. Ceiling Fan	2	8000	2	8000	
(c) Other capital items		**114000**		**113200**	Target achieved 100% as per plan
1. Water Proof tester	1	20000	1	19600	
2. Chargeable Digital balance	2	20000	2	20000	
3. Portable Electronic Balance	4	32000	4	32000	
4. Ice Box	2	20000	2	20000	
5. Dissolved Oxygen Meter	1	10000	1	10000	
6. Digital Slide Calipers	2	12000	2	11600	

2. Establishment/renovation facilities

Not applicable

3. Training/study tour/ seminar/workshop/conference organized

Description	Number of participants			Duration (Days)	Remarks
	Male	Female	Total		
Coordinatio component (BARC)					
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)	68	12	80	2 day	
Orientation on PCR preparatory guideline	12	05	17	01 Day	All PI of the sub project components attended the program
Component-1 (RU)					
Training and motivation to fisher	55	0	48	7 days	
Focus Group Discussion (FGD)	60	0	60		
Seminer	140	20	160	4 days	
Training and motivation to fishers	120	0	120	12 days	
Focus Group Discussion (FGD)	103	0	103		
Field Day	100		100	15 days	

Description	Number of participants			Duration (Days)	Remarks
	Male	Female	Total		
Component-2 (JUST)					
i. FGD	100	0	100	5 days	FGD, Workshop and Field day program held at *Baor* sites. Seminar organized at department of Fisheries building.
ii. Seminar	150	20	170	4 days	
iii. Workshop	125	15	140	5 days	
iv. Filed Day	100	0	100	15 days	

C. Financial and Physical Progress (Combined & component wise)

i. Combined progress

Fig in Tk

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
A. Contractual staff salary	8266548	8266549	8266549	0	100.00	Not applicable
B. Field research/lab expenses and supplies	14460796	14277702	14277702	0	100.00	
C. Operating expenses	1828566	1697591	1697591	0	100.00	
D. Vehicle hire and fuel, oil & maintenance	1270726	1160178	1160178	0	100.00	
E.Training/workshop/seminar etc.	300000	149100	149100	0	100.00	
F. Publications and printing	325000	322000	322000	0	100.00	
G. Miscellaneous	352564	350551	350551	0	100.00	
H. Capital expenses	2313800	2313800	2313800	0	100.00	
Total	**29118000**	**28537471**	**28537471**	**0**	**100.00**	

ii. Coordinatio component (BARC)

Fig in Tk.

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
a. Contractual staff salary	1188333	1188333	1188333	0	100.00	Expenditures made as per plan. No deviation occurred in financial management
b. Field research/lab expenses and supplies	297722	297722	297722	0	100.00	
c. Operating expenses	362866	241241	241241	0	100.00	
d. Vehicle hire and fuel, oil & maintenance	324288	226575	226575	0	100.00	
e. Training/workshop/ seminar etc.	300000	149100	149100	0	100.00	
f. Publications and printing	300000	297000	297000	0	100.00	

g. Miscellaneous	131391	130947	130947	0	100.00	
h. Capital expenses	695400	695400	695400	0	100.00	
Total	**3600000**	**3226318**	**3226318**	**0**	**100.00**	

Component-1 (RU)

Fig in Tk

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
A. Contractual Staff Salary	3558312	3558313	3558313	00	100	No deviation notoced
B. Field Research/ Lab Expenses & Supplies	8593000	8587700	8587700	00	100	
C. Operation Expenses	888323	887381	887381	00	100	
D. Vehicle Hire & Fuel, Oil & Maintenance	631213	630877	630877	00	100	
E. Training /Workshop/ Seminar etc.	0	0	0	00	100	
F. Publications and Printing	25000	25000	25000	00	100	
G. Miscellaneous	104552	102983	102983	00	100	
H. Capital Expenses	1105600	1105600	1105600	00	100	
Total	**14906000**	**14897854**	**14897854**	**00**	**100**	

iv. Component-2 (JUST)

Fig in Tk

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
A. Contractual Staff Salary	3519903	3519903	3519903	0	100	No deviation notoced
B. Field Research/ Lab Expenses & Supplies	5570074	5392280	5392280	0	100	
C. Operation Expenses	577377	568969	568969	0	100	
D. Vehicle Hire & Fuel, Oil & Maintenance	315225	302726	302726	0	100	
E. Training /Workshop/ Seminar etc.	0	NA	NA	NA	NA	
F. Publications and Printing	0	NA	NA	NA	NA	
G. Miscellaneous	116621	116621	116621	0	100	
H. Capital Expenses	512800	512800	512800	0	100	
Total	**10612000**	**10413299**	**10413299**	**0**	**100**	

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

Not applicable for the sub project

E. Information/knowlwdge generated/policy generated

1. 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 diversity with emphasis on indigenous fish species through monthly sampling and later to confirm the size & age-at-sexual maturity, spawning- and peak- season of indigenous fishes in *Baor*s of southwestern Bangladesh based on unit-stocks	Personal interview, Key informant interview & catch assessment L_m was estimated by : TL vs. GSI model (GSI %=(GW/BW)*100) Spawning season was estimated through the monthly variations of GSI as GSI (%) = 100 × GW/BW	Identified the fish species of the *Baor*s of SW, Bangladesh Recorded maturity size of stock fishes Observed spawning and peak spawning season of stock fishes	Baseline status of fish was identified. L_m of fishes help to select permissible mesh size of nets for a specific species. Spawning season help to established fishing bann period
To identify the major man-made and natural causal factors for declining of indigenous fish species in *Baor*s of southwestern Bangladesh.	Personal interview , Key informant interview and FGD	Predatory and culture fish were the key reasons for the declining of indigenous fishes from Saganna and Sarjat *Baor*, respectively.	By find out the major cause specific solution can be applied to reduce the problem
To identify the stocks' status with emphasis on relative abundance (CPUE), longevity, size and age-recruitment, exploitation rate, maximum sustainable yield, biomass after and before the ranching of targeted indigenous.	Total mortality (Z) was estimated by : ln(Nt/Δt) = a + b·t Exploitation rate (E) was calculated: E = F/Z = F/ (F+M). Biomass was calculated by the equation : Nt+1=Nt*exp[-M],	Recorded Mortality, Exploitation and biomass of stock species	Biomass and mortality and exploitation help to get MSY of a certain species and survival rate of stock fishes.

2. Component 2 (JUST)

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)
i) To assess the fish diversity index and causal factors for declining of indigenous fish species in *Baor*s of Jashore and later to confirm its spawning and peak season	Evenness and richness indices were calculated using the following formulas: Shannon-Weaver diversity index, $H = -\Sigma$ Pi ln Pi Margalef's richness index, $D = (S-1)/\ln N$ Evenness index, $e = H/\ln S$	Stocking of SIFS fish and establishment of fish sanctuary Identification of fishes and fisheries status Biodiversity parameters Sampling of Fish and measurement. Causes of *Baor* fish reduction	Stocking of 8 indigenous species from wild stock have been domesticated and took part in spawning. Indigenous fish species in the *Baors* have been listed based on monthly sampling. Biodiversity parameters have been estimated. Causes of small indigenous fish's reduction from *Baors* have been estimated.
ii) To study the livelihoods of fishers' Community in *Baor*s of Jashore district;	The livelihood and socio-economic study was conducted based on primary and secondary data; Market survey was conducted based on focus group discussion (FGD)	Livelihood and socio-economic study; Market survey; Identification of co-ownership management problem; Study of feeding habits;	Livelihood and Socio-economic condition have been estimated. Market survey have been conducted
iii) To estimate the stock structure delineation and reproductive potentiality and its success of indigenous fishes after and before the ranching program.	Size dependent variation was corrected by adapting an allometric method as suggested by Elliot et al. (1995) $M_{adj} = M(L_s / L_o)^b$ Gonadosomatic index (GSI) was calculated according to the formula as follows: GSI = (gonad mass / somatic mass of the individual × 100%).	Study of stock structure analysis Study of reproductive biology	Stock structure of 8 Indigenous fisheries has been analyzed through truss networking. Spawning season of 5 species has been estimated. Food and feeding habits of 4 species has been identified

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)
	Size ($L_{m50\%}$) at first sexual maturity for fish was estimated by maximum length-based equation		

F. Materials development/publication made under the sub-project (combind)

Publication	Number of publications		Remarks (e.g. paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Technology bulletin/ booklet/leaflet/flyer etc.	01	0	বাওড়ে দেশীয় ছোট মাছের প্রজননের মাধ্যমে সহনীয় ব্যবস্থাপনা কৌশল
	01	0	Carp-catfish (Pabda & Gulsa) polyculture in *Baor*
Journal publication	08	04	1. Rahman, M.A., Hossain M.Y., Tanzin, S., Mawa, Z., Hasan, M.R., and Jasmine, S., (2021). Efects of Covid-19 pandemic on *Baor* (Oxbow lake) fisheries: decreased economic livelihoods and food security. *Lakes and Reservoir Management*. 2. Samad, M.A., Rahman, M.A., Mahfuj, M.S.E., Yeasmin, S.M., Sultana, M.F., Rahman, M.H., Ahmed, F.F., Hossain, M.Y. (2021).Life-history traits of ten commercially important small indigenous fish species (SIFS) in the Oxbow lake, (Southwestern Bangladesh): Key for sound management of oxbow lake. Environmental Science and pollution Research. 29:23650–23664. 3. Mahfuj, M.S.E., Samad, M.A., Ahmed, F.F., Elahi, K.S., Rahman, M.A., Adhikary, R.K., Hossain, M.Y. (2020). Differentiation of endangered butter catfish, *Ompok bimaculatus* populations along the selected habitats of South-western Bangladesh: Evidence from morphological characters. Egyptian Journal of Aquatic Biology and Fisheries. 24(6): 135-151. 4. Samad, M.A., Rahman, M.A., Mahfuj, M.S.E., Rahman, M.H., Hossain, M.Y. (2022). Population parameters of ten

			commercially important small indigenous fish species (SIFS) in the Oxbow lake, Southwestern Bangladesh. The 2nd Biennial Conference of the Fisheries Society of Bangladesh 5. Samad, M.A., Mahfuj, M.S.E., Hossain, M.Y. (2022). Intraspecific morphological variations of the vulnerable loach, *Lepidocephalichys annandalei* (Cypriniformes: Cobitidae) in inland water bodies at southwestern Bangladesh. Lakes and reservoirs. 6. Samad, M.A., Rahman, M.A., Yeasmin, S.M., Mahfuj, M.S.E., Rahman, M.H., Sultana, M.F., Hossain, M.Y. (2022). Implications of COVID-19 on oxbow lake (*Baor*s) fisher's community, Bangladesh: Resilience to food security against probable natural calamities. Heliyon. 7. Samad, M.A., Rahman, M.A., Yeasmin, S.M., Rahman, M.H., Hossain, M.Y. (2022). Stock assessments in relation to climate change, foods and feeding habits, nutritional compositions and human health risk assessments of *Gudusia chapra* from Oxbow lake, Bangladesh. Environmental Science and pollution Research
Video clip/TV program	-	04	Channel 24, News-24, VoA on 22/09/20
News Paper/Popular Article		04	The Financial Express on 24/11/2020; Bangla Probaho; Daily Sunshine; Jago News on 08-09/09/2022; Daily Prothom Alo 10/06/2021
Other publications		-	Regular on YouTube & face-book
PhD Thesis	01		Samad, M.A., 2022. Role of Small Indigeous Species for Biological and Socio-economic Sustainability of Oxbow-lake Fisheries in Bangladesh. University of Rajshahi.
MS Thesis	03		i. Khatun, B., (2022). Estimation of Reproductive potentiality of stocked Gangetic nrood (*Mystus cavasius*) in the Sarjat *Baor* (Jhenaidah) in the Southwestern Bangladesh.University of Rajshahi. ii. Khatun, T., (2022). Status of Saganna *Baor* Fisheries: Covid-19 pandemic effect on Economic Livelihoods of Fisheries community. University of

			Rajshahi. iii. Sumi, S.A., (2022). Management approach of the Sarjat *Baor* Fisheries (Jhenidah) in Bangladesh. University of Rajshahi.
Honours Thesis	01		i. Hasan, M.R., (2022). Population morphometry and some aspects of biology of Ticto barb, *Pethia ticto* in oxbow lake, Bangladesh. Jashore University of Science and Technology.

G. Description of generated technology/knowledge/policy

i. Technology fact sheet (*title of the technology, introduction, description, suitable location/ ecosytem, benefits, name and contact address of author***)**

Not applicable

ii. Effectiveness in policy support

Among the available fisheries resources of the country, *Bao*r fisheries are considered as one of the resourceful ecosystems of diversified fish genetic species along with potential natural breeding habitats that allows innumerous fish species to breed and nurse. Unfortunately, due to lack of appropriate management efforts for proper conservation of the ecosystem and protection of fish genetic resources of *Baor* waters, environmental degradation and declining in fish population has emerges as threar for the total *Baor* fisheries. Moreover, whatever management policy, acts/regulations we have at this stage, are not in proper implementation at field level. As a consequences, threats and causal factors of fish population reduction in *Baor* waters are being appears with new dimentions and nature with the passing of time.

The present research findings revealed that particulary for SIFS of *Baors*, establishment of fishing ban period particularly for spawning and nursing of fish species (SIFS) is a very vital issue, now a days, to maintain the sustainibilty of fish stocks and protect them from being extinct from the *Baor* waters

The present study on Baor fisheries identified the spawning season of seven stocked fish species (namely, *A testudineus, C puctaata, M tengra*, *H fossilis, M vittatus, M cavasius* and *O pabda)* applying TL *vs* GSI models, surveyed, reviewed scientific literature related to data analysis on spawning season of other freshwater indigenous species in Bangladesh. Detail and indepth analysis revealed that the *peak spawning season of most of the SIFS species lies within the months of June-July each year*.

Thus, the present rsearch strongly recommend to impose two months (*June – July every year*) fishig banning for SIFS to allow the fish to breed without any interruptionswhich will help to protect the brood fishes and ensure smooth spawning process.

During the proposed banning period, the competent authoriy may take initiative to create alternate livelihood opportunities for fishing communities, provide incentives and foods support that will ultimately encourage the fishers to follow the proposed act/regulation.

So far benefit concer, the proposed seasonal fishing ban will favour sutainability of fish population through smooth and healthy production process; production rate of fish will increase; conservation and extinction of fish genetic resources will be ensured; overfishing will be prevented and bio-ecological balance will be established.

H. Technology/knowledge generation/policy support

i. Immediate impact on generated technology

Not applicable

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

- In case of culture gulsha and pabda with existing carps in the *Baor,* it should be in consideration to maintain their size and density while releasing. It is strongly recommended to culture gulsha and pabda larger than their maturity sizes (L_m>size). According to research result the stocking densities for pabda and gulsha recommended at the rate of 80-90 and 110-120 fishes per decimal, respectively with existing carps. During stocking the suggested fingerling should be 40-50g and 20-30 g for *pabda* and gulsha, respectively.
  The present research suggest more future research at various dimensions to find it as a mature technology/method;
- Banning period imposing during the peak spawning season of SIFS species in the *Baor* to protect the brood fishes and allows them to spawn without any disturbances. Morphometric, meristic and reproductive biology study of more *Baor* fish species are recommended to develop protection and conservation guideline for other fish species;

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

Not as technology as such, but enhancement fish production and income of fishers through practicing polyculture of carp-catfish and by imposing fishing banning period, *Baor* fish production will hope to increase to a significant level within a short time. Increases fish production will ensure the food security and create availability in the market and make the fishes affordable for low-income people of the county and also helps to fulfill the protein intake demand of poor people. Livelihood of *Baor* fishers will also improve.

iv. Policy support

The output of the research on selected *Baor* fish growth and reproductive biology, study on various other parameters like, age-length & length-weight relationship, age at sexual maturity, gonado somaticindex, fecundity, reproductive behavior, spawning and fertilization efficiency etc. as a whole suggest impose of few regulations under the respective policy clause/s related to conservation and protection of *Baor* and openwater fisheries resources, as shown follows:

- Impose proposed banning period (June -July based on research findings) that will help to protect the spawner to ensure the highest production;
- Impose ban on catch of fishes smaller than their optimum catchable length (L_{opt}) which helps to raise the production rate and protect the brood fishes in Baor waters;

- Fixing of a permissible mesh size of nets for the sustainable management of SIFS species in the *Baors*.

I. Information regarding desk and field monitoring

i) Information on desk monitoring (combined)

Consulting meetings, workshops, seminars, coordination meetings etc	Date & Venue	Output
Component 1 (RU)		
1. Inception workshop	22/12/2019; BARC, Dhaka	Review of project document helped to improve the sub-project paln of activity.
2. 1st & 2nd half yearly progress report	20.06.20 and 29.07.21 BARC; DHAKA	Baseline survey report presented in the next progress review meeting
3. 3rd half yearly progress report	02.06.2022; BARC	Proposal with justification for establishment of banning period for indigenous species in Baors developed
4. 1st Co-ordination meeting	07/09/2020 & 12/01/21; BARC, Dhaka	Data collection and analysis completed within June 2022 as per revised activity plan
5. 1st Annual progress workshop	30/09/2020; BARC, Dhaka	Detail information on all parameters as asked for, included in the draft PCR and improvement of the project documemt
6. Meeting with World bank representative	25/08/2021; BARC, Dhaka	Sub-project revision along with activity time plan
7. 3rd & 4th Annual progress workshop	23/11/2021 & 08/10/22; BARC Dhaka	Causes of fish declining in Sarajat baor identified and reported
8. 2nd Co-ordination meeting	12/12/21; BARC Dhaka	Data collection on relative abundance (CPUE), longevity, size and age-recruitment, exploitation rate, maximum sustainable yield, biomass after and before the ranching of targeted indigenous along with GSI and relevant other factors generated
9. Progress meeting on zoom platform	02.05.2021, Virtual platform	Incorporated all review suggestions of PIU-NATP
10. 3rd & 4th Co-ordination meeting		Study of the effectiveness of F-2 generation in spawning completed; Finalized PCR workshop plan
11. Workshop on PCR preparation	11/05/22; BARC Dhaka	Orientation guidelines improves the knowledge of PCR writing
12. Progress meeting on	02.05.2021, Virtual platform	Incorporated all review suggestions of PIU-NATP

Consulting meetings, workshops, seminars, coordination meetings etc	Date & Venue	Output
zoom platform		
13. Draft PCR review workshop	24-25 October'22	Improvement of draft PCR
Component 2 (JUST)		
1. Inception workshop	22/12/2019; BARC, Dhaka	Review of project document done and improved
2. 1st & 2nd half yearly progress report	20.06.20 and 29.07.21 BARC; DHAKA	Baseline completed and shoen in the report. Procurement plan finalized
3. 3rd half yearly progress report	02.06.2022; BARC	Necessary revision completed and activity upgraded
4. 1st Co-ordination meeting	07/09/2020; BARC, Dhaka	Data collection and analysis completed within June 2022 as per revised activity plan
5. 1st Annual progress workshop	30/09/2020; BARC, Dhaka	Data gathered and report updatedf
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 fish declining in Sarajat baor identified and necessary revision done ban period note
8. 2nd Co-ordination meeting	12/12/21; BARC Dhaka	Data collection to estimate the stock structure delineation and reproductive potentiality and to understand the success of indigenous fishes due to ranching continued up to June'2022.
9. Progress meeting on zoom platform	02.05.2021, Virtual platform	Incorporated all review suggestions of PIU-NATP
10. 3rd & 4th Co-ordination meeting	12.12.2 08/10/22, BARC, Dhaka	Analysis of data on all recommended aspects completed by June 2022 as per revised activity plan; PCR workshop plan finalized
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. Draft PCR review workshop	24-25 October'22	Improvement of draft PCR

ii) Information on field monitoring (combined)s

Date	Visit no.	Name/s of visitors	Addresses	Output
8-9 Jan' 20	2	Md. Monirul Islam	Member Director, Fisheries, BARC, Farmgate, Dhaka	Increased awareness among the *Baor* stakeholders
22-25Feb' 22	3	Dr. Nowsher Ali Sarder,	Monitoring & Evaluation Specialist PIU-BARC	Red flag was hosted immediately in the sanctuaries
22-24 Mar' 22	2	1. Dr. Md. Serajul Islam,	(Environmental and Social Safeguard Specialist, PIU-BARC, NATP-2)	All the field and laboratory activities were successfully completed with the pre-scheduled timeframe. Predefined
		2. Munshi Mamunur Rahman	(Documentation Associate, PIU-BARC, NATP-2)	
27 Sept' 20	1	Dr. Shaikh Mohammad Bokhtiar	Executive Chairman, BARC	Reviewed research progress at various stages implementation, lacking and suggestions improved sub-project activities.
27 Sept' 20	1	Dr. Nowsher Ali Sarder,	Monitoring & Evaluation Specialist PIU-BARC	
17 Dec' 20	1	Prof. Dr. Md. Yeamin Hossain	Department of Fisheries, University of Rajshahi	Strengthen activities of sub project.
3-6 Jun'21	1	Dr. Md. Monirul Islam	Member Director, Fisheries, BARC, Farmgate, Dhaka	Increased awareness among the *Baor* stakeholders
22-25' Feb 22	2	Dr. Nowsher Ali Sarder,	Monitoring & Evaluation Specialist PIU-BARC	Placed well informative signboard in each of the fish sanctuaries with red flags. Sampling was conducted with the monitoring of *Baor* samity.
24 Mar' 22	1	Dr. Md. Harunur Rashid	Director, PIU-BARC, NATP-2	Review comments of WB members implemented as per revisewd plan. Marking of all sub project furnitures and equipment done properly.
24 Mar' 22	1	Dr. Md. Sirajul Islam	Environmental and Social Safeguard Specialist	
24 Mar' 22	1	Munshi Mamunur Rahman	Documentation Associate	
17-19 May'22	1	Dr. Saleh Uddin Ahamed	Consultant, PBRGSub project, Fish. Div. BARC	Timely completion of data analysis as per requirement as per revised plan
9-10 Jun'22	1			

iii) Weather data, flood/salinity/drought level (if applicable) and natural calamities

1. Three years average weather information of Jhenaidah region (2019-2021)

Parameters	Seasons						Remarks
	Pre-monsoon (January-April)		Monsoon (May-August)		Post Monsoon (Sept-December)		
	Max	Min	Max	Min	Max	Min	
Av. Rainfall (mm)	78	15	325	210	155	10	
Av. Temperature (^{0}C)	28	19	34	26	31	19	
Flood (year & category)	Not reported						
Av. Salinity	Not applicable						
Natural calamity (year & category)	Amphan (Super Cyclonic Storm) occured on May, 2020						

Ref: Ragional metrological office, Jhenaidahand water development Board office, Jhenaidah

2. Three years average weather information of Jashore region (2019-2021)

Parameters	Seasons						Remarks
	Pre-monsoon (January-April)		Monsoon (May-August)		Post Monsoon (Sept-December)		
	Max	Min	Max	Min	Max	Min	
Av. Rainfall (mm)	68	10	252	145	135	20	
Av. Temperature (^{0}C)	27	18	33	27	30	18	
Flood (year & category)	Not reported						
Av. Salinity	Not applicable						
Natural calamity (year & category)	Amphan (Super Cyclonic Storm) occured on May, 2020						

J. Sub-project auditing

i. 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 on 09-12-2020	No objection raised, found all relevant documents updated as per guideline	1038434.50	Financial management of the component found running smoothly till the end of the project No query or objection raised at	Financial management & project performance found satisfactory in all
Financial audit by FAPAD for the year 2020- 21 on 11-10-2021		95891.00		

Financial audit by FAPAD for the year 2021- 22 on 17-10-22		533255.00	any stage of operation by the audit teams	the audit cases

ii. Component-1 (RU)

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 period 2019-20	No objection raised, found all relevant documents as per guidelines	4970646.00	Financial management of the component run smoothly till the end of the project. No objection or query rose at any stage of the operation by audit teams.	Financial management & project performance found satisfactory
Financial audit by FAPAD for the period 2020-21		4977581.00		

iii.Component-2 (JUST)

Types of audits	Major observation/ issues/objections raised; if any	Amount of audit (Tk.)	Status at the sub-project end	Remarks
Financial audit by FAPAD for the period 2019-20	No objection raised, found all relevant documents as per guidelines	3776380.00	Financial management of the component found running smoothly till the end of the project. No query and objection rose at any stage of operation by the audit teams.	Financial management & project performance found satisfactory
Financial audit by FAPAD for the period 2020-21		2672507.00		
Financial audit by FAPAD for the period 2021-22		9610523.00		

K. Lessons learned

- Improper management and non-cooperation of local people and Baor fihers group member are the main cause of failure in establishing, protecting and conservation of sanctuary in Baor waters.
- Lack of coordination between government and local leaders become a challenge towards sustainable management of *Baor* fisheries.
- Carp-cat fish (Pabda - Gulsha) polyculture in Baor water can be a potential for increasing fish production and income of fishers.

L. Challenges

- ***Regular research sampling and lab work disruption hampered desired progress of the sub project due to Covid-19 pandamic***:

  Nationwide impose of lockdown from 18th March 2020, the research team members could not carried out regular sampling and lab analytical activities smoothly.The overall situation become a challenging for for the research team to complete the research activity as per time plan of the sub project.

- ***Embankment damaged due to cyclone 'Amphan' and stocked brood fishes escaped***:

  Cyclonic Amphan formed over the Indian Ocean on 16 May 2020 and started moving north over the Bay of Bengal, towards north-east India coastal areas and south of Bangladesh. On 20 May 2020, the Bangladesh Meteorological Department (BMD) issued 'great danger' signal number 10 for coastal districts and their offshore islands and chars. In August 2021, due to active monsoon conditions a strong tidal action, the *Baor* flood protection embankments damaged and a large number of stock brood fishes were escaped.

- ***Due to the conflicts between two groups of Baors management has been impediment***:

  Lack of proper coordination between government and local leaders and fishers group, *Baor* management hindered to a greater extend.

M. Suggestions for future planning

- ***Gene-bank & brood bank establishment***:

  Boars should be used as gene-bank & brood bank in future. As the fishes of *Boar* are totally chemical free and they grow up in a natural ecosystem so they have high variability and tolerance range. The hatchery managers will collect them from the *Baor* as seed and brood fish for artificially culture in hatchery. BFRI fish germplasm bank can also be considered as a potential source for quality fish seed;

- ***Marketing channel should be developed***:

  Baor fisheries marketing channel should be developed and established in order to get high profit from sale and distributed fishes throughout the country.

- ***Increase coordinations between government, NGO and other agencies***:

  Government should take initiative to improve the coordination between GO, NGO and local instutions. Occasionally seminar/workshops and coordination meetings on bi-lateral issues of management, share distribution, participation level, role and responsibility etc should be arranged to keep up bonding and understanding among the agencies.

- ***Carp-cat fish polyculture***:

  This initiative should be undertaken to make proper use of all layer to water body and increase production at a time from polyculture of fishes.

- ***Provide complete access to waterbodies to the fishing community*:**
  Most of the *Baors* are managed through the fisher community and supervised by DoF. But recently the local administration is thinking for leasing the water bodies to high bride parties. If that happens, that will an alarming situation for small scale/ poor Baor fishers. Their livelihood will be totally exhausted. Apart from that this will goes against the decleration of the father of the nation Bangobondhu Sheikh Mujibur Rahman that, "Jal Jar Jola Tar ". Therefore, it is highly recommended that the complient authority should look into the matter so that access and right of all poor Baor fisher can be established.

N. References

Adhikary, R.K., Kar, S., Faruk, A., Hossain, A., Bhuiyan, M.N.M., and Asif, A.A. 2018. Contribution of aquaculture on livelihood development of fish farmer at Noakhali, Bangladesh. Asian- Asian-Austra. *J. Biosci. Biotech.,* 3:106-121.

Ahmed, M.N.U., 1996. Reports on the fishermen's socioeconomic survey. Fisheries Survey and Monitoring Program, Department of Fisheries, Tangail, pp: 4.

Ahmed, Z. F., Hossain, M. Y. and Ohtomi, J. 2012. Modeling the growth of silver Hatchet Chela *Chela cachius* (cyprinidae) from the old Brahmaputra River in Bangladesh using multiple functions. *Zool. Stud,* 51 (3): 336–344.

Ahsan, M.R.U. 2008. A study of fish biodiversity and marketing system in Chalan beel. MS thesis, Department of fisheries biology & genetics, Bangladesh Agricultural University, Mymensingh

Akhtar, S., Hossain, M. S., Islam, M. J., Liza, A. A., and Sayeed, M. A. 2018. Consumers profile analysis towards chicken, beef, mutton, fish and egg consumption in Bangladesh. *British Food Journal*, 120 (12): 2818–2831. https://doi:10.1108/BFJ-03-2018-0191

Alam, G.M., and Khatun, M.N. 2021. Impact of Covid-19 on vegetable supply chain and food security: Empirical evidence from Bangladesh. Plos one, 16(3): e0248120.

Alam, M.T., Hussain, M.A., Sultana, S. and Rahman, S.M. 2011. The fecundity and sex-ratio of *Channa punctatus* (Bloch), a small indigenous fish. *Bangladesh Journal Progressive Science and Technology*, *9*(1), pp.41-44.

Ali, M.H., Azad, M.A.K., Anisuzzaman, M., Chowdhury, M.M.R., Hoque, M., and Sharful, M.I. 2009. Livelihood status of the fish farmers in some selected areas of Tarakanda Upazila of Mymensingh district. *Journal of Agrofor. Environ.,* 3: 85-89

Ali, M.H., Hossain, M.D., Hasan, A.N.G.M., and Bashar., M.A. 2008. Assessment of the livelihood status of the fish farmers in some selected areas of Bagmara upazilla under Rajshahi district. *J. Bangladesh Agril. Univ.,* 6: 367–374.

Alok, K.P., Shapon, K.B., Mohammad, S.I., and Hussain, M.A. 2018. Comparative socioeconomic study with a review on fisherman's livelihood around Tulsiganga River, Joypurhat. *Bangladesh. J. Fish. Aquat. Sci*, *13*, 29-38.

Alonso-Fernández, A., Vallejo, A. C., Saborido-Rey, F., Murua, H. and Trippel, E.A. 2009. Fecundity estimation of Atlantic cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefnus*) of Georges Bank: application of the auto diametric method. *Fish Res,* 99:47–54.

Asif, A.A., and Habib, M.A.B. 2017. Socio-economic condition of fish farmers of Jhikargachha upazila in Jessore district, Bangladesh. *Asian J. Med. Biol. Res.,* 3: 462-475.

Asif, A.A., Samad, M.A., Rahman, M.H., Farid, M.A., Yeasmin, S.M., and Rahman, B.M.S. 2015. Socio-economic condition of fish fry and fingerling traders in greater Jessore region, Bangladesh. *Int. J. Fish. Aqua. Stud.,* 2: 290-293.

Azad, K.N., Sarower-E-Mahfuj, M., Iqbal, T., Azad, K.N. and Shafaq, M.A.I. 2020. Differentiation of intraspecific phenotypic plasticity of elongate glassy perchlet, *Chanda nama*: Insights into landmark-based truss morphometric and meristic variations. *Journal of Advanced Veterinary and Animal Research*, *7*(4), p.585.

Basar, M.A., 2011. Spotfin swam barb: *Puntius sorphore*. Bangladesh fisheries information share home. (en.bdfishe. org/2021/01/ Spotfin-swam-barb: *Puntius sorphore*).

Belton, B., and Toufique, K. A. 2014. Is aquaculture pro-poor? Empirical evidence of impacts on fish consumption in Bangladesh. *World Development*, 64: 609–620. https://doi:10.1016/j.worlddev.2014.06.035

Bennett, N.J., Finkbeiner, E.M., Bennett, N.J., Finkbeiner, E.M., Ban, N.C., and Belhabib, D. 2020. The Covid-19 pandemic, small-scale fisheries and coastal fishing. *Coastal Management*, 48: 336–347. https://doi:10.1080/08920753.2020.1766937

Beverton, R.J.H., Holt, S.J., 1966. Manual of methods for fish stock assessment. Part 2. Tables of yield functions. FAO Fisheries Technical Paper.pp. 1: 49.

Beverton, R.J.H. 1992. Patterns of reproductive strategy parameters in some marine teleost fishes. *Journal of Fish Biology*, 41: 137-160.

Binohlan, C. and Froese, R. 2009. Empirical equations for estimating maximum length from length at first maturity. *J Appl Ichthyol,* 25: 611–613

Binohlan, C., and Froese, R. 2009. Empirical equations for estimating maximum length from length at first maturity. *J Appl Ichthyol* 25: 611-613.

Biswas, A., Tripti, J.K., Farid, M.A., Rahman, M.H., and Ghosh, S. 2021. Present status of fish biodiversity and socio-economic conditions of fishermen of the Kannayadaha baor, Jashore, Bangladesh. International Journal of Biosciences. 18(3): 120-126.

Bohnsack, J.A. 1996. Maintenance and recovery of reef fishery productivity. In Reef fisheries (pp. 283-313). Springer, Dordrecht.

Borah, R. and Biswas S.P. 2018. Delineating some of the reproductive aspects of *Macrognathus pancalus* from the river Sessa, Assam, India. An International Journal of environment and biodiversity. 9(2):168-174.

BRAC. 2020. A Rapid Assessment Impact of Covid-19 on Education in Bangladesh. http://www.brac.net/program/wp-content/uploads/2020/07/Rapid-assessment-impact-of-COVID-19-education-in- Bangladesh.pdf?

Cadrin, S. X., and Friedland, K. D. 1999. The utility of image processing techniques for morphometric analysis and stock identification. *Fisheries Research*, *43*(1-3), 129-139.

CGIAR. 2020. Fish and aquatic food systems Covid-19 updates: Bangladesh. Research program on fish. https://fish.cgiar.org/news-and-updates/news/fish-and-aquaticfood-systems-covid-19-updates-india.

Chaklader, M.R., Siddik, M.A.B., Hanif, M.A., Nahar, A., Mahmud, S. and Piria, M. 2016. Morphometric and meristic variation of endangered pabda catfish, *Ompok pabda* (Hamilton-Buchanan, 1822) from southern coastal waters of Bangladesh. *Pakistan Journal of Zoology*, *48*(3).

Chakrobarty, B.K. and Mirza, M.J.A. 2007. Study of aquatic biodiversity of Gharia beel of Bangladesh, West Bengal India, West Bengal science society. *Journal of Crop and Weed*, 3: 23- 24.

Das, B.K., Roy, A., Som, S., Chandra, G., Kumari, S., Sarkar, U.K., Bhattacharjya, B.K., Kanti, A., Das, A.K. and Pandit, A. 2022. Impact of Covid-19 lockdown on small-scale fishers (SSF) engaged in floodplain wetland fisheries: evidences from three states in India. *Environmental Science and Pollution Research,* 29: 8452–8463. https://doi.org/10.1007/s11356-021-16074-9

Das, M.R., Ray, S., Kumar, U., Begum, S. and Tarafdar, S.R. 2015. Livelihood assessment of the fishermen community in the South West region of Bangladesh. *J. Exp. Biol. Agric. Sci.,* 3: 353-361.

Dasgupta, S. 2004. Status of fish marketing in Fulpur upazilla, Mymensingh, MS Thesis, Department of Fisheries Management, Bangladesh Agricultural University, Mymensingh, pp. 62.

Devereux, S., Béné, C., and Hoddinott, J. 2020. Conceptualising Covid-19's impacts on household food security. *Food Security*, 12: 769–72.

DoF (Department of Fisheries), 2014. National Fish week 2020. Compendium (In Bengali). Department of Fisheries, Ministry if Fisheries and Livestock, Bangladesh. 144p.

DoF. 2020. National fish week 2020 compendium (in Bangla). Department of Fisheries, Ministry of Fisheries and Livestock

Doha, S. 1973. Fishes of the districts of Mymensingh and Tangail. Bangladesh Journal of Zoology, 1: 1-10.

Doha, S. and Hye, M.A. 1970. Fecundity of Padma River hilsa, Hilsa ilisha (Hamilton). *Pakistan Journal of Science*, *22*(3), p.4

Dutta, S., and Smita, M. K. 2020. The impact of COVID-19 pandemic on tertiary education in Bangladesh: students' perspectives. Open Journal of Social Sciences, 8(09): 53.

Ehasan, M. A., Hossain, M.S., Razzaque, A. and Alam, M.S. 2000. A usual but important fishing of Chanda beel. *Bangladesh Journal of Zoology*, 28: 69-74.

El-Ganainy, A. and Riad, R. 2008. Population structure of Octopus defilippi (Verany, 1851) from the Gulf of Suez, Red Sea, Egypt. *Egyptian Journal of Aquatic Biology and Fisheries*, 12(2): 81-91.

Elliott, N.G.; Haskard, K. and Koslow, J.A. 1995. Morphometric analysis of orange roughy (*Hoplostethus atlanticus*) off the continental slope of southern Australia. *J. Fish. Biol.,*46(1): 202-220.

Erzini, K., Monteiro, C.C., Ribeiro, J., Santos, M.N., Gaspar, M., Monteiro, P. and Borges, T.C., 1997. An experimental study of gill net and trammel net\'ghost fishing\'off the Algarve (southern Portugal). *Marine Ecology Progress Series*, 158, pp.257-265.

Food and Agriculture Organization (FAO), 2020. How is Covid-19 outbreak Impacting the Fisheries and Aquaculture Food Systems and What can FAO do? Rome: FAO.

Food and Agriculture Organization (FAO). 2021. The Impact of COVID-19 on Fisheries and Aquaculture Food Systems, Possible Responses. Rome: FAO.

Froese, R. 2006. Cube law, condition factor and weight length relationship. History meta-analysis and recommendations. *J. Appl. Ichthyol.*, 22: 241–253.

Froese, R. and Binohlan, C. 2000. Empirical relationships to estimate asymptotic length, length at first maturity and length at maximum yield per recruit in fishes, with a simple method to evaluate length frequency data. *J Fish Biol,* 56: 758–773

Froese, R., Pauly, D. 2020. (Eds.) FishBase, world wide web electronic publication. Available at: http:// www. fishb ase. Org.

FRSS (Fisheries Resources Survey System), 2017. Fisheries Statistical Yearbook of Bangladesh. Fisheries Resources Survey System (FRSS), Department of Fisheries, Bangladesh. Volume 30: 52 pp.

Gulland JA (1965) Estimation of mortality rates. In: Annex to Arctic Fisheries Working Group Report ICES C.M./1965/D:3 (Mimeo) (Reprinted as In: Cushing, P.H. (Ed). Key Papers on Fish Populations. IRL Press, Oxford, pp. 231–241.

Halim, M.A., Salam, M.A. and Hossain, M.S. 2017. Fish biodiversity in Kafrikhal beel under Mithapukur Upazila, Rangpur, Bangladesh. *International Journal of Fisheries and Aquatic Studies,* 5(2): 487-491.

Halls, A.S. 2005. The use of sluice gates for stock enhancement and diversification of livelihoods (R8210). Fisheries Assessment Report. MRAG, London, 75 pp.

Halls, A.S., Hoggarth, D.D., and Debnath, D. 1999. Impacts of hydraulic engineering on the dynamics and production potential of floodplain fish populations in Bangladesh. *Fisheries Management and Ecology,* 6(4): 261–285. https://doi.org/10.1111/j.1365-2400.1999.tb00080.x

Hasan, M. R., Hossain, M. Y., Mawa, Z., Tanjin, S., Rahman, M. A., Sarkar, U. K., and Ohtomi, J. 2021. Evaluating the size at sexual maturity for 20 fish species (Actinopterygii) in wetland (Gajner Beel) ecosystem, north-western Bangladesh through multi-model approach: A key for sound management. Acta Ichthyologica et Piscatoria, 51(1), 29-36.

Hasan, M.K., and Tamanna, M. 2015. Life in a megacity: livelihood strategies and survival mechanisms of rickshaw pullers in Dhaka city. *Millennial Asia* 6(1):44–60. https://doi.org/10.1177/0976399614563224

Hasan, M.R., Hossain, M.Y., Mawa, Z. and Hossain, M.A. 2022. Reproductive biology of *Heteropneustes fossilis* in a wetland ecosystem (Gajner Beel, Bangladesh) in relation to eco-climatic factors: Suggesting a sustainable policy for aquaculture, management and conservation. *Saudi Journal of Biological Sciences*, 29(2): 1160-1174.

Hasan, M.R., Hossain, M.Y., Mawa, Z., Tanjin, S., Rahman, M.A., Sarkar, U.K. and Ohtomi, J. 2021. Evaluating the size at sexual maturity for 20 fish species (Actinopterygii) in wetland (Gajner Beel) ecosystem, north-western Bangladesh through multi-model approach: A key for sound management. *Acta Ichthyologica et Piscatoria*, 51(1): 29-36.

Headey, D. Ruel, M., 2020. The COVID-19 nutrition crisis: what to expect and how to protect, in: J. Swinnen, J. McDermott (Eds.), Covid-19 and Global Food Security, *International Food Policy Research Institute.* https://doi.org/10.2499/p15738coll2.133762

Henry, G.T. 1990. Practical Sampling. Sage Publications, Newbury Park, CA., USA.

Hossain, M. Y., Hossen, M. A. Islam, M. S., Jasmine, S., Nawer, F. and Rahman, M. M. 2017. Reproductive biology of *Pethia ticto* (Cyprinidae) from the Gorai River (SW Bangladesh). *J Appl Ichthyol,* 33:1007–1014.

Hossain, M.A., Asif, A.A., Zafar, M.A., Hossain, M.T., Alam, M.S., and Islam, M.A. 2015. Marketing of fish and fishery products in Dinajpur and livelihoods of the fish retailers. *Int. J. Fish. Aqua. Stud.,* 3: 86-92.

Hossain, M.Y., Ahmed, Z.F., Leunda, P.M., Jasmine, S., Oscoz, J., Miranda, R., and Ohtomi, J. 2006. Condition, length–weight and length–length relationships of the Asian striped catfsh *Mystus vittatus* (Bloch, 1794) (Siluriformes: Bagridae) in the Mathabhanga River, southwestern Bangladesh. Journal of Applied Ichthyology 22(4): 304–307. https:// doi.org/10.1111/j.1439-0426.2006. 00803.x

Hossain, M.Y., Rahman, M.M., Miranda, R., Leunda, P.M., Oscoz, J., Jewel, M.A.S., Naif, A., and Ohtomi, J. 2012. Size at frst sexual maturity, fecundity, length–weight and length–length relationships of *Puntius sophore* (Cyprinidae) in Bangladeshi waters. Journal of Applied Ichthyology 28(5): 818–822. https://doi.org/10.1111/j.1439-0426.2012.02020.x

Hossain, M.A., and Wahab, M.A. 2010. The diversity of cypriniforms throughout Bangladesh: present status and conservation challenges. Nova Science Publishers.(*Accepted article*).

Huang, K.M., Sant'Anna, A.C., and Etienne, X. 2021. How did Covid-19 impact US household foods? an analysis six months in. *PloS one,* 16(9): e0256921.

Hussain, M.G. 2010. Freshwater fishes of Bangladesh: Fisheries, biodiversity and habitat. *Aquatic Ecosystem Health & Management*, 13(1): 85-93.

IFPRI. 2021. Global Food Policy Report: Transforming Food Systems after Covid-19. International Food Policy Research Institute, Washington, DC. https://doi.org/10.2499/9780896293991

Islam, M. Kar, M., Kundu, C., Mondal, G.K., and Khan, M.S. 2018. Current status and barriers to fisheries co-management: Evidence from an oxbow lake of Bangladesh. *Bangladesh Journal of Zoology*, 46(2): 105–116.

Islam, M.K. and Das, M. 2006. Fecundity of Gulsha *Mystus cavasius* (Hamilton) from Brahmaputra and Kongsa rivers. *Journal of the Bangladesh Agricultural University*, *4*(452-2018-3922): 347-355.

Islam, M.M, Asif, A.A., Vaumik, S., Zafar, M.A., Sharif, B.M.N., Rahman, M.H., and Shahriyar. S. 2015. Socio economic status of fry collectors at Sundarban region. *Int. J. Fish. Aqua. Stud.,* 3: 89-94.

Islam, M.M., Asif, A.A., Vaumik, S., Zafar, M.A., Sharif, B.M.N., Rahman, M.H., and Shahriyar, S. 2015. Socio economic status of fry collectors at Sundarban region. *Int. J. Fish. Aqua. Stud.,* 3: 89-94.

Islam, M.S. and Hossain, M.A 1983. An account of the fshes of the Padma near Rajshahi. *Raj Fish Bul* 1:1–31

Islam, S.M., Rahman, M.M., Halder, G.C. and Tanaka, M. 2006. Fish assemblage of a traditional fishery and the seasonal varia-tions in diet of its most abundant species *Wallago attu* (Siluriformes: Siluridae) from a tropical floodplain. *Aquatic Ecology,* 40: 263-272

IUCN Bangladesh, 2015. Red List of Threatened Species. Volume 5: Freshwater Fishes. IUCN, International Union for Conservation of Nature, Bangladesh Country Office, Dhaka, Bangladesh, pp xvi+360.

IUCN, 2021. The IUCN Red List of Threatened Species. Version 2021-3. https://www.iucnredlist.org. Accessed on (3 September 2021).

Janssen, M., Chang, B. P., Hristov, H., Pravst, I., Profeta, A., and Millard, J. 2021. Changes in food consumption during the Covid-19 pandemic: analysis of consumer survey data from the first lockdown period in Denmark, Germany, and Slovenia. *Frontiers in nutrition*, 8: 60.

Jewel, M.A.S., Haque, M.A., Khatun, R., and Rahman, M.S. 2018. A comparative study of fish assemblage and diversity indices in two different aquatic habitats in Bangladesh: Lakhandaha Wetland and Atari River. *Jordan Journal of Biological Sciences*, *11*(4), 427-434.

Jomitol, J., Payne, A.J., Sakirun, S., and Bural, M.O. 2020. The impacts of covid-19 to small scale fisheries in Tun Mustapha Park, Sabah, Malaysia: What do we know so far? Preprints. https://doi: 10.20944/preprints202005.0287.v1.

Kar, S., and Marjit, S. 2009. Urban informal sector and poverty. *International Review of Economics & Finance*, 18(4), 631–642. https://doi.org/10.1016/j.iref.2008.06.009.

Khan, M. A., Miyan, K., and Khan, S. 2013. Morphometric variaton of snakehead fsh, *Channa punctatus* populations from three Indian rivers. *Journal of Applied Ichthyology,* 29, 3, 637-642.

Khan, S., Banu, N. and Isabella, B. 1992. Studies on some aspects of the biology and fecundity of Mystustengra Hamilton-Buchanan 1822. *Bangladesh Journal of Zoology*, *20*: 151-160.

Khatun, D., Hossain, M.Y., Nawer, F., Mostafa, A.A., Al-Askarm A.A. 2019. Reproduction of *Eutropiichthys vacha* (Schilbeidae) in the Ganges River (NW Bangladesh) with special reference to potential influence of climate variability. *Environ Sci Pollut Res*, 26: 10800–10815.

Khatun, D., Hossain, M.Y., Nawer, F., Mostafa, A.A., and Al-Askar, A.A. 2019. Reproduction of *Eutropiichthys vacha* (Schilbeidae) in the Ganges River (NW Bangladesh) with special reference to potential influence of climate variability. *Environ. Sci. Pollut. Res.* 26, 10800–10815.

Khatun, D., Hossain, M.Y., Nawer, F., Mostafa, A.A., and Al-Askar, A.A. 2019. Reproduction of *Eutropiichthys vacha* (Schilbeidae) in the Ganges River (NW Bangladesh) with special reference to potential influence of climate variability. *Environmental Science and Pollution Research* 26(11): 10800–10815. https://doi.org/10.1007/s11356-019-04523-5.

Khatun, D., Hossain, M.Y., Rahman, M.A., Islam, M.A., Rahman, O., Sharmin, M.S., Parvin, M.F., Haque, A.T.U., Hossain, M.A. and Mawa, Z. 2019. Life-history traits of the climbing perch *Anabas testeudineus* (Bloch, 1792) in a wetland ecosystem. *Jordan J Biol Sci*, 12:175–182.

Khatun, S., Adhikary, R.K., Rahman, M., Sikder, M.N.A., and Hossain, M.B. 2013. Socio-economic status of pond fish farmers of Charbata, Noakhali, Bangladesh. *Int. J. Life Sc. Bt. Pharm. Res.,* 2: 356-365.

Kibria, R., Khan, F.H., Sultana, D., Hasnin, D., and Morshed, M.T. 2020. Impact of Coronavirus on Livelihoods: Rural and Low-Income Population of Bangladesh. Lightcastle Analytical Wing.

Kim, J., Giroux, M., Kim, J.E., Choi, Y.K., Gonzalez-Jimenez, H., and Lee, J.C. 2020. The moderating role of childhood socioeconomic status on the impact of nudging on the perceived threat of coronavirus and stockpiling intention. *Journal of Retailing and Consumer Services*. 59.

Kohinoor, A. H. M., Wahab, M. A., Islam, M. L., and Thilsted, S.H. 2001. Culture potentials of mola (*Amblypharyngodon mola*), chela (*Chela cachius*) and punti (*Puntius sophore*) under monoculture system. *Bangladesh Journal of Fisheries Research,* 5(2): 123–134.

Korten, T. 2020. With boats stuck in harbor because of Covid-19, Will fish bounce back? Smithsonian Magazine, April 8, 2020. https://www.smithsonianmag.com/science-nature/fishstop-covid-19-180974623/.

Kumari, S., Sarkar, U.K., Karnatak, G., Mandhir, S.K., Lianthuamluaia, L., Kumar, V., Panda, D., Puthiyottil, M. and Das, B.K. 2021. Food selectivity and reproductive biology of small indigenous fish Indian River shad, *Gudusia chapra* (Hamilton, 1822) in a large tropical reservoir. Environ Sci Poll Res, 28(9): 11040-11052.

Le Cren, E.D. 1951. The length-weight relationships and seasonal cycle in gonad weight and condition in the perch (Perca fluviatilis). *J. Ani. Ecol.,* 20: 201–219.

Lucifora, L.O., Valero, J.L. and Garcia, V.B. 1999. Length at maturity of the green-eye spurdog shark, Squalus mitsukuii (Elasmobranchii. Squalidae) from the SW Atlantic, with comparisons with other regions. *Ma.r Freshwater Res.,* 50: 629–632.

Mahfuj, M., Khatun, A., Boidya, P., andSamad, M. 2019c. Meristic and morphometric variations of barred Spiny eel *Macrognathus pancalus* populations from Bangladeshi Freshwaters: an insight into landmark-based truss network system. *Croatian Journal of Fisheries*, *77*(1), 7-18.

Mahfuj, M.S., Hossain, M.F., Jinia, S.S., and Samad, M.A. 2019b. Meristic and morphometric variations of critically endangered butter catfish, *Ompok pabo* inhabiting three natural sources. *Int J Biosci*, *14*(4), 518-27.

Mahfuj, S. E., Rahman, M.M., Islam, M., Samad, M.A., Paul, A.K. and Adhikary, R.K. 2019a. Landmark-based morphometric and meristic variations of freshwater garfish, *Xenentodon cancila* from four natural stocks of South-Western Bangladesh. *Journal of Advanced Veterinary and Animal Research*, *6*(1), p.117.

Mahfuj, S. E., Rahman, S. U., and Samad, A. 2019d. Landmark based truss morphometrics delineate the stock structure of *Lepidocephalichthys guntea*. *Journal of Fisheries and Aquatic Science*, *14*, 25-32.

Mahfuj, S.E., M. Ashraful, I. Parvez, M.H. Minar and A. Samad, 2017. Morphological variations of *Labeo bata* populations (Teleostei: Cyprinidae) in six rivers of Bangladesh: A landmark-morphometric contribution. *Iran. J. Ichthyol*., 4: 270-280.

Majumder, L., Riar, M.G.S., Raushon, N.A., Soniya, S. and Mondal, R.P. 2017. Biodiversity of Shorupdah beel, Manirumpur, Jessore. *Journal of Bioscience and Agriculture Research,* 13(02): 1116-1121.

Makmur, S., Rahardjo, M.F., and Sukimin, S. 2003. Biologi reproduksi ikangabus (*Channa striata*) di daerah banjiran sungai Musi Sumatera Selatan. Jurnel of Iktiologi Indonesia 3(2): 57–62.

Margalef, R. 1968. Perspectives in ecological theory. Univ. Chicago Press, Chicago, Ill. 111 p.

Mawa, Z., Hossain, M., Hasan, M., Rahman, M., Tanjin, S. and Ohtomi, J. 2022. Life history traits of *Mystus vittatus* in the Ganges River, Bangladesh: recommendation for its sustainable management considering climate change. *International Journal of Biometeorology*, 66(5): 927-943.

Mawa, Z., Hossain, M., Hasan, M., Tanjin, S., Rahman, M., Sarmin, M. and Habib, K.A. 2021. First record on size at sexual maturity and optimum catchable length of 10 marine fishes from the Bay of Bengal (Bangladesh) through multi-models approach: a key for sound fisheries management. *Environmental Science and Pollution Research*, *28*(28): 38117-38127.

Mazid, M.A., Mortimer, M.A., Riches, C.R., Orr, A., Karmaker, B., Ali, A., Jabbar, M.A. and Wade, L.J. 2005. Rice establishment in drought-prone areas of Bangladesh. *Rice is life: scientific perspectives for the 21st century*, pp.193-195

Mia, M.G.F. 1996. A study of production and marketing of culture fishes by the selected pond owners in Mymensingh district, MS Thesis, Department of Co-operation and Marketing, Bangladesh Agricultural University, Mymensingh. pp. 119.

Mitu, N.R. 2017. Reproductive biology of the female Asian striped dwarf catfsh *Mystus tengara* (Hamilton, 1822) (Siluriformes: Bagridae) in the Ganges River of Rajshahi, northwestern Bangladesh. *Turkish J Fish Aquat Sci*, 17:589–598

Mohammed, E.Y., Ali, L., Ali, S., Hussein, B., Wahab, M.A. and Sage, N. 2016. Hilsa's non-consumptive value in Bangladesh: estimating the non-consumptive value of the hilsa fishery in Bangladesh using the contingent valuation method. *International Institute for Environment and Development*.

Mollah, M., Yeasmine, S., Hossen, M., and Ahammad, A. 2013. Landmark-based morphometric and meristic variations of *Glossogobius giuris* in three stocks. *Journal of the Bangladesh Agricultural University*, *10*(2), 375–384.

Mondal M.A.I., Kader, M.A., Choudhury, A.H., Mustafa, M.G., Nabi, M.R.U., Billah, M.M., Asif, A.A., and Siddiqui, A.A.M. 2018. Socio-economic uplifting analysis of ESBN fishery of the coastal villages, Kumira and Kattoli, Chittagong, Bangladesh. *Int. J. Res. Grant.,* 6: 248-263.

Mondal, M.R., Dewan, S., Hossain, M.A., Asaduzzaman, M., Islam, M.A. and Rozario, U.A. 2005. Food and feeding habits of *Puntius goniotus* (Thai Sarpunti) in rice field, *Pakistan Journal of Biological science*, 8(3): 386-395.

Mookerjee, H.K., Sengupta S.N. and Choudhury, D.N. 1946. Food and its percentage composition of the common adult food fishes of Bengal, Science, & Culture, 12(7): 247.

Murua, H. and Saborido-Rey, F. 2003. Female reproductive strategies of marine fish species of the North Atlantic.

Nayyar, S.K. and Sundararaj, B.I. 1970. Seasonal reproductive activity in the testes and seminal vesicles of the catfsh, *Heteropneustes fossilis* (Bloch). J Morphol, 130:207–226.

Nazrul, S. 2020. How has the Covid-19 pandemic impacted the fisheries sector? Lightcastle Analytical Wing.

Nelson, J.S. 2006. Fishes of the World. 4th Edition, John Wiley & Sons, Hoboken, 601 p.

Ng, H. H., and Tan, H. H. 2004. *Ompok platyrhynchus*, a new silurid catfish (Teleostei: Siluridae) from Borneo. *Zootaxa*, *580*(1), 1-11.

OECD, 2021. Covid-19 and food systems: short- and long-term impacts. https://www.oecd-ilibrary.org/agriculture-and-food/ covid-19-and-food-systems_69ed37bd-en. Accessed 03 Sep 2021.

Okyere, I., Chuku, E.O., Ekumah, B., Angnuureng, D.B., Boakye-Appiah, J.K., and Mills, D.J. 2020. Physical distancing and risk of Covid-19 in smallscale fisheries: a remote sensing assessment in coastal Ghana. *Scientific Reports,* 10:22407. https://doi:10.1038/s41598-020-79898-4

Parvin, M., Hossain, M., Sarmin, M., Rahman, O., Tanjin, S., Samad, M. and Rahman, M. 2022. Reproductive performance of Asian stinging catfish *Heteropneustes fossilis* (Bloch 1794) in the Ganges River (NW Bangladesh) in relation to environmental factors. *Environmental Science and Pollution Research*, *29*(28): 42822-42836.

Pathak BC, Ali R, and Serajuddin M. 2012. Comparative Analysis of Reproductive Traits in Barred Spiny Eel, *Macrognathus pancalus* (Hamilton, 1822) from Lotic and Lentic Ecosystems of Gangatic Basin, India. *World Journal of Fish and Marine Sciences.* 4(5): 470-479.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. *Journal du Conseil International pour1 Exploration de lamer*, 39: 175–192.

Pauly, D. 1983. Some simple methods for the assessment of tropical fish stocks. FAO Fish Tech Pap 234:52

Pe´rez-Escamilla, R., Cunningham, K., and Moran, V.H. 2020. Covid-19 and maternal and child food and nutrition insecurity: a complex syndemic. *Maternal and Child Nutrition*, 16(3). https://doi.org/10.1111/mcn. 13036 PMID: 32458574

Pethiyagoda, R.. (1991). Freshwater fishes of Sri-Lanka. The wildlife Heritage Trust of Sri-Lanka, Colombo, 362 p.

Phukon, H.K. and Biswas, S.P. 2012. Observation on the Maturity Index and Fecundity of *Puntius sophore* (Ham-Buch) from upper Assam. *Asian Journal of Experiment and Bio-logical Science,* 3(1): 247-250.

Pielou, E. C. 1966. The measurement of diversity in different types of biological collections. *Journal of theoretical biology*, *13*, 131-144.

Prasad, L., Dwivedi, A.K., Dubey, V.K. and Serajuddin, M. 2011. Reproductive biology of freshwater murrel, *Channa punctatus* (Bloch, 1793) from river Varuna (A tributary of Ganga River) in India. *Journal of Ecophysiology and Occupational Health*, 11(1/2): 69.

Qambrani, G.R., Soomro, A.N., Palh, Z.A., Baloch, W.A. and Tabasum, S. 2015. Reproductive Biology of *Glossogobius giuris* (Hamilton), in Manchar Lake Sindh, Pakistan. *J Aquac Res Development*, 6: 392.

Rahman, A. K. A. 2005. Freshwater fishes of Bangladesh, 2nd edition. Zoological Society of Bangladesh, Department of Zoology, University of Dhaka, 1000. 263p.

Rahman, A.K.A. 1989. Freshwater fishes of Bangladesh, 1st edition, zoological society of Bangladesh, Department of zoology, University of Dhaka, Dhaka- 1000, pp. 170–171

Rahman, A.K.A. 2005. Freshwater fishes of Bangladesh, 2nd edn. Zoo-ogical society of Bangladesh (ZSB), University of Dhaka, Dhaka, Bangladesh, p 394.

Rahman, A.K.A. 2005. Freshwater fshes of Bangladesh, 2nd edn. Zoological society of Bangladesh (ZSB), University of Dhaka, Dhaka, Bangladesh, p 394.

Rahman, M,A,, Haque, M.M. and Khan, S. 2008. Food and feeding habit of Chapila, *Gudusia chapra* (Hamilton-Guchanan from Rajdhala reservoir. *J Inland Fish Soc India,* 40(2): 13-20.

Rahman, M.M. 2003. Status of fish marketing in Gazipur, Bangladesh. MS Thesis, Department of Fisheries Management, Bangladesh Agricultural University, Mymensingh, pp. 74.

Rahman, M.M., Hossain, M.Y., Ahamed, F., Fatematuzzhura, S.B., Abdallah, E.M. and Ohtomi, J. 2012. Biodiversity in the Padma distributary of the Ganges River, northwestern Bangladesh: recommendations for conservation. *World Journal of zoology*, *7*(4): 328-337.

Rahman, R., Molla, M., SH, C. and MM, S. 2018. Snakehead fish (*Channa striata*) and its biochemical properties for therapeutics and health benefits. *SF J Biotechnol Biomed Eng.,* 1(1): 1005.

Rahmatullah, S.M., Alam, M.T., Hussain, M.M., Amin, M.R. and Haq, M.J. 1995. Study on the food and feeding habits young chapila, *Gudusia chapra*. *Bangladesh J Fish,* 15–18:91–100

Rashid, H., 2020. Problems arising in fish farming due to corona disaster. BonikBarta. Retrieved from https://bonikbarta.net/home/news_ description/229391/.

Raushon, N.A., Riar, M.G., Soniya, S., Mondal, R.P. and Haq, M.S. 2017. Fish biodiversity of the Old Brahmaputra River, Mymensingh. Journal of Bioscience and Agriculture Research, 13(01): 1109-1115.

Richards, T. J., and Rickard, B. 2020. Covid-19 impact on fruit and vegetable markets. Canadian *Journal of Agricultural Economics*. 68(2): 189–94.

Rohlf, F.J. 2006. tpsDig 2.1. Stony Brook, NY: Department of Ecology and Evolution, State University of New York.

Roy, D., Sarker, A.K., Abedin, A.M.M.K., Sarker, S., Begum, K.N. and Latifa, G.A. 2021. Some Biological Aspects of Cultured Ompokpabda (Hamilton, 1822) Collected from A Local Fish Farm in Mymensingh, Bangladesh. *Aquaculture Studies*, *21*(4): 149-159.

Ruzzante, D. E, Taggart, C. T. and Cook, D. 1998. A nuclear DNA basis for shelf and bank-scale population structure in northwest Atlantic cod (*Gadus morhua*): Labrador to Georges Bank. *Mol Ecol*, 7:1663–1680.

Sabbir, W., Hossain, M. Y., Rahman, M. A., Hasan, M. R., Mawa, Z., Tanjin, S. and Ohtomi, J. 2021. First report on reproductive features of the Hooghly croaker *Panna heterolepis* Trewavas, 1977 from the Bay of Bengal in relation to environmental factors. *Environ Sci Pollut R,* 1:1–8.

Sakawat, H.B. 2002. Haor fisheries resources in ItnaUpazila under the district of Kishoregonj and their management practices. M.S thesis, Department of Fisheries Management, BAU, Mymensingh, 48 pp.

Sayeed, M.A. 2010. Fish biodiversity in the challan beel, a natural depression in North West Bangladesh, PhD Thesis, Department of Fisheries Biology and Genetics, BAU, Mymensingh.

Sayeed, M.A., Akter, S., Paul, A.K., Ahashan, M.R,, Miah, M.M. and Hossain, M.A.R. (2009). Development of artificial breeding technique of gutum, *Lepidocephalichthys guntea* (Hamilton, 1822) using carp pituitary gland. *J Agrofor Environ*, (1): 195-197.

Shafi, M. and Quddus, M.A.A. 1982. Bangladesher Matshya Sampad (in Bengeli), Bangla Academy, Dhaka, pp. 314-319.

Shannon, C. E., and Weaver, W. 1949. The mathematical theory of communication. University of Illinois Press.

Sharif, B.M.N., Asif, A.A., Vaumik, S., Zafar, M.A., Islam, M.M., and Samad, M.A. 2015. Socio-economic condition of fish farmer and trader at the village of Pitamborpur in Chaugachha upazilla in Jessore, Bangladesh. *Int. J. Fish. Aqua. Stud.,* 3: 212-217.

Shawki, A. 2020. Shift in consumer behavior silver lining for e-commerce firms. The Business Standard. https://tbsnews.net/economy/industry/shift-consumer-behavio ur-silver-lining-e-commerce-firms-72835.

Siddik, M., Chaklader, M., Hanif, M., Islam, M., Sharker, M. and Rahman, M. 2016. Stock identification of critically endangered olive barb, *Puntius sarana* (Hamilton, 1822) with emphasis on management implications. *J. Aquac. Res. Dev*, *7*(411), p.2.

Siddiq, M.A., Miah, M.I., Ahmed, Z.F. and Asadujjaman, M., 2013. Present status of fish, fishers and fisheries of Dogger Beel in Hajigonj Upazila, Chandpur, Bangladesh. *Journal of Aquatic Science*, 1(2), pp.39-45.

Siddique, M.A. 2001. A study on socio-economic status of fishermen and fish marketing system in Mymensingh district, Bangladesh. MS thesis, Department of Fisheries Management, Bangladesh Agricultural University, Mymensingh, 66pp

Sparre, P., Ursin, E. and Venema, S.C. 1989. Introduction to tropical fish stock assessment. Part 1- Manual. FAO fisheries technical Paper. Rome, FAO. p 337.

Strauss, R.E. and Bookstein, F.L. 1982. The Truss: Body Form Reconstructions in Morphometrics – Syst. Biol. 31(2): 113-135.

Suresh, V.R., Biswas, B.K., Vinci, G.K., Mitra, K. and Mukherjee, A. 2006. Biology and fishery of barred spiny eel, *Macrognathus pancalus* Hamilton. *Acta Ichthyologica et Piscatoria*. 1(36).

Talwar, P. K. and Jhingran, A. G. 1991. Inland fishes of India and adjacent countries, Vol. 1 and 2. Oxford & IBH Publishing Company Pvt. Ltd, New Delhi, India.

Templeman, W. 1987. Differences in sexual maturity and related characteristics between populations of thorny skate (*Raja radiate*) from the northwest Atlantic. *J. Northwest Atl. Fish. Sci.,* 7: 155–167

Thaku, N.K. and Nasar, S.A.K. 1977. Spawning behaviour of an air-breathing catfish *Heteropneustes fossilis* (Bloch). *Physiology and Behaviour*, 19:53–55.

Turan, C., Erguden, D., Turan F., and Gurlek, M. 2004. Genetic and morphologic structure of *Liza abu* (Heckel, 1843) populations from the rivers Orontes, Euphrates and Tigris. *Turk. J. Vet. Anim. Sci.,* 28: 729-734.

U.S. Bureau of Labor Statistics (UCBLC), 2020. Consumer Price Index for All Urban Consumers: Food at Home in U.S. City Average retrieved from Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/ CUSR0000SAF112020

Uddin. S., Hasan, M.H., Iqbal, M.M. and Hossain, M.A. 2017. Study on the reproductive biology of Vietnamese climbing perch (*Anabas testudineus*, Bloch). *Punjab Uni J Zool.* 32:001–007.

Vaumik, S, Sarker, S.K., Uddin, M.S., Alam, M.T., Satter, A., and Asif, A.A. 2017. Constraints and prospects of fish farming in Lalmonirhat District. *Inter. J. Bus. Soc. Sci. Res.,* 5: 201-210.

Vazzoler A.E.A.M. 1996. Reproduction biology of teleostean fishes.Theory and practice. Maringá, EDUEM, p 196.

Wilding, T.,Yong, K. and Pitkethley, R. 2000. Bay of Plenty freshwater fish calendar, In: environmental report 00/26. Environment Bay of Plenty, Whakatane.

Zabir, A. A., Mahmud, A., Islam, M. A., Antor, S. C., Yasmin, F., and Dasgupta, A. 2020. COVID-19 and food supply in Bangladesh: a review. *South Asian Journal of Social Studies and Economics*, 10(1): 15-23.

Zahid, M., Malik, S. and Rani, S. 2013. Spawning behaviour of barred spiny eel, *Macrognathus pancalus*, in the River Gomti, India. *Journal of Applied Ichthyology*. 29(5): 1109-1113.

Zurayk, R., 2020. Pandemic and food security: A view from the global south. *Journal of Agriculture, Food Systems, and Community Development,* 9(3): 1–5. https://doi.org/10.5304/jafscd.2020.093.014

Signature of the Coordinator	**Counter signature of the Head of the organization/authorized representative**
 ***(Dr. Md. 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***

Annexures

1. Coordination component (BARC)

Annexure – BARC: A

Recommendations of the inception workshop and status of action taken

Recommendations	Action taken
Component 1 (RU)	
• In case of fish biodiversity study, in addition to direct fish sampling from Baors, secondary information from relevant reports and local market survey findings emphasized;	Secondary information from relevant reports and local market survey findings collected;
• Climate change impact study methodology on change of fish population of Baor should be stated clearly;	Necessary aamendment done
• Rethinking the possibility of study the sexual maturity of Baor larger fishes belongs to longer life span group within the project period;	Species only covered considering the sub project objectives
• Establishment of fish sanctuaries for Baor fishery management can be a vital tool for facilitating fish breeding and conservation- the component project may include this under the present activities;	Complied accordingly
• Suitability of proposed data analysis models should be re-examined for the present study;	Re-examined and additional tool implied as suggestion of the world Bank expert
• Suggested to shift output no-5 under the list of outcomes;	Correction done
Component 2 (JUST)	
• Causes of Baor fish reduction should be re-examined and justified;	Re-examined and varified
• Ecological niches and relation with the feeding behavior of fishes should be studies;	This is a separate study not relevant with the present research objectives.
• Number of fish species/types to be studied for feeding behaviour - should be specify clearly;	Followed accordingly
• Existing co-ownership management problems should be considered in case of Baor fishery development and management operation under the research activity	Co-ownership and problems therein recorded accordingly

Annexure – BARC:B

Recommendations of the half yearly workshops

Recommendations of the first half yearly workshop	Action taken
General comment	
• Baseline survey informatin are yet completed by any of the component. Initially emphasize should be given for a completed baseline report development.	Baseline survey report presented in the next progress revieqw meeting

• Preparation and submission of a procurement plan of the respective year by all components are urgently needed	Complied accordingly
General comment	
• Data on available fish species in the baor water, their bioloy, breeding, growth survival and management practices should be properly reviewed and compare with the available literature and secondary data.	Recommendation followed accordingly
Recommendations of the 2nd & 3rd half yearly workshops	**Action taken**
Component 1 (RU)	
• Proposed "Establishment of banning period for indigenous species in Baors, SW Bangladesh" placed under the technology generation section should be placed under more relevant information generation section;	Done accordingly
• Change the title "Introduction of catfish (Pabda & Gulsa) culture with existing carp polyculture" to "Introduction of carp-catfish (Pabda & Gulsa) plycuture in Baors"	Modified accordingly
• List of information/knowledge generation shown in the respective table are not self-explanatory. Needs rewriting of the list;	Revision done
• Output/results of the research that effective existing policies suggesting new policy development should be explained with proper justification;	Followed as and where necessary
• Presentation on contribution of research output in increasing fish production and farmer's income is not done in proper way. There should be a para with describing proper justification and information in favor.	Followed accordingly
• Suggesting inclusion of updated information on desk and field monitoring;	Necessary formation incorporated and upgradation done
• Weather information table and audit information tables are not presented properly. Need more specific information.	Necessary correction done
• First three points under the table "Challenges" can be put under a single point,	Necessary changes done.
Component 2(JUST)	
• 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.	Revision done in the draft PCR
• Avoid duplication of presentation in all cases (such as data table and graph on the basis of same data etc);	Complied accordingly
• Outputs of desk and field monitoring activities are not discussed	Included as per need
• Information on auditing not presented with required information;	Audit information updated and shown in the draft PCR
• Materials development/publications should be presented as per PCR format	Complied accordingly

• First three points under "suggestion for future research planning" not properly written- need modification;	Necessary revision done

<u>Annexure – BARC: C</u>

Recommendation of the annual workshop

recommendations of the first annual workshop	**Action taken**
Component 1 (RU)	
• Detail information on estimation of monthly collected fish species, their size and age at sexual maturity, spawning and peak -spawning season and GSI values was not presented in detail. Particularly for review sessions, detail presentation with information rich handout should be ensured to perform the review activity thoroughly and critically. Immediate monitoring of research progress is necessary;	Detail information on all parameters as asked for, included in the draft PCR
Component 2(JUST)	
• In Bangladesh, use of agri-pesticides in crop fields consider as an important source of aqua-environment pollution and animal reduction. This activity was ignored under causes of SIS fish species reduction; However, available secondary information with relevant agencies may fulfill the information gap	Data gathered and presented in the reports
Recommendations of the second annual workshop	**Action taken**
• Causes of fish declining in Sarajat baor (under objective -2 of RU) shown in the graphical presentation need to be revised. The cause mentioned should be replaced by appropriate text language in the report/PCR etc.	Necessary revision done
• Information mentioned under technology development (by RU & JUST components), focused fattening of Pabda, Gulsa, Koi and Shing under the sub-projects activity which is not to be presented as such, rather it will be wiser to discuss this finding under production data analysis (immediate impact of the research). • Similarly, fish ban period should be presented in policy section with proper legal aspects and reasons for amendment or new addition.	Suggestion followed Necessary revision done accordingly
• A model questionnaire can be implied by RU component to quantify the fish (newly release-reproduced F-2 generation) harvested and marketed by baor fishers from the third projection year of the sub-project	Done everything as per recommendation
• The term "Climate change" mentioned by the JUST component is one of the important causes of fish decline in the Baor fishery. Detail explanation of the method of climate change impact on fish decline analysis and determination (how) with justification should be	Discussed in summary form

discussed in the PCR	
• Re-examination of inclusion of activity 7 of the revised activity plan suggested (as the part already completed, by the respective component (JUST) in the previous years).	Revision done

Annexure – BARC: D

Recommendation of the coordination meetings

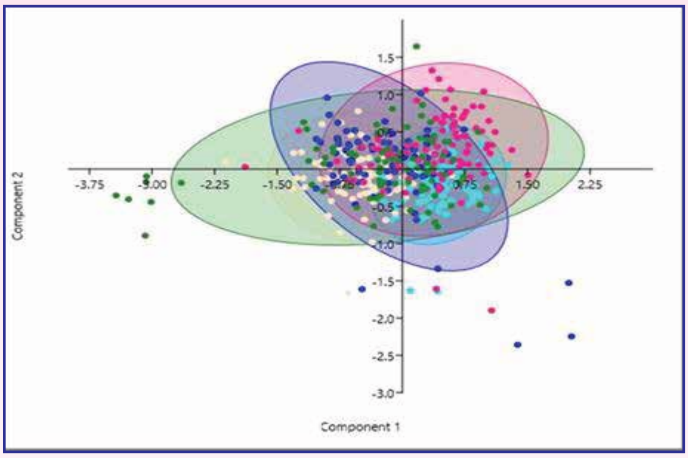
Centrally organized two (1st & 2nd) virtual coordination meetings at BARC	
Recommendations	**Action taken**
Component 1 (RU)	
• Suggesting continuation of present data collection on fish diversity with particular emphasize on indigenous species through monthly sampling and then to confirm the size & age-at-sexual maturity, spawning- and peak- season of fishes in the study *Baors* and completion of its total analysis by December'20**;**	Data collection and analysis completed within June 2022 as per revised activity plan (due to Covid interruption)
• Remaining part of the survey work to identify the major man-made and natural causal factors for declining of indigenous fish species in study *Baors* (under objective 2) should not continue beyond August;20;	
• Data collection on relative abundance (CPUE), longevity, size and age-recruitment, exploitation rate, maximum sustainable yield, biomass after and before the ranching of targeted indigenous along with GSI and relevant other factors must be completed by November'20. As winter months will start from December and continue up to February;21, therefore, no time space will be available for further study the same parameters in the next year as the project will close down in June, 21 next;	
Component 2 (JUST)	
• More relevant information to be added to enrich the base line report to a full form (this report to be shown in the first annual report);	Added accordingly
• Emphasize immediate starting of fish biodiversity study and identification of causal factors responsible for declining of particular fish population within the remaining part of this season By October'20);	Data collection and analysis completed within June 2022 as per revised activity plan (due to Covid interruption)
• Completion of survey on livelihoods of fishers' community in *Baors* of Jashore and analysis of data by September'20;	
• Data collection to estimate the stock structure delineation and reproductive potentiality and to understand the success of indigenous fishes due to ranching suggested to continue up to November'20. Analysis of data of this part should not take more than two months thereafter;	

3rd Coordination meeting	
Component 1(RU)	
• Emphasize should be given on study of the effectiveness of F-2 generation taking in spawning which will be expected to be sustained in the existing habitat and will continue. This is the focus of the sub project for the RU component. There should be an effective sustainable management approach for indigenous fishes in *Baors* (wetlands) which will be ensured food security & develop livelihood of fishers depended in *Baors* or in any other wetlands. Therefore, the activities under this part within the remaining period should cover the activities like: sampling of fish, measurement of fishes, species identification and sexing, monthly collection of ovary and their preservation, monthly examination of maturity stages microscopically, collection of data on threats to fishes and fishers through survey and FGD and data input, compilation & analysis.	Completed by June 2022 as per revised activity plan
Component 2 (JUST)	
• Sampling of fish, species identification and sexing, measurement of fishes, stocking of selected indigenous brood fishes with marking & tagging, monthly collection of ovary and their preservation, collection of data on threats to fishes and fishers through survey and FGD, data analyses for delineation of stock structure, food and feeding habits, data collection on fish biodiversity, survey on socio-economic status of fisherman, monthly obserrvation of fishes and water quality, eestimation of size at first sexual maturity and data input, compilation & analyses to be finish as per project time plan.	Completed by June 2022 as per revised activity plan
4th Coordination meeting on organizing of PCR review workshop	
• Decision was taken to organize the two days workshop by the Coordination component within the first half of Oct'22; • The sub-project will be presented by Prof. Dr. Yeamin Hossain of RU, 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;	PCR workshop held smoothly on 24-25 Oct'22 under the organizership of 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)	
• Different statistical tools applied for analysis of different morphometric, meristic and biological parameters and their findings shown in different locations of the report need to be revisited for a concistent report presentation	Checked and corrected
• Under the "sugession" section, incase of releasing of fish fingerlings in the *Baors,* BFRI fish germplasm bank can be considered as a potential source for quality fish seed.	Suggestion rewritten
Recommendations of the second half yearly workshop	
Component 2 (JUST)	
• Under section 11.2.11 "Study of stock structure analysis" few sentences on background information need to be added here.	Done accordingly
• Co-ownership management problems under section 11.2.14 need to be enriched with data and more information	Data/information added



Ministry of Agriculture

THE WORLD BANK
IBRD • IDA | WORLD BANK GROUP

IFAD
Investing in rural people