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Sub-project Completion Report
on
Techniques Adoption and Formulation of Guidelines for Sustainable Management of Haor and Beel Fisheries

Sub-project Duration
11 July 2018 to 30 December 2021

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

November 2021

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Techniques Adoption and Formulation of Guidelines for Sustainable Management of Haor and Beel Fisheries

Implementing Organization

Department of Aquatic Resource Management
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Bangladesh Agricultural Research Council
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Abbreviation and Acronyms

AA	Abundantly Available
ADG	Average daily gain
AMD	Acid Mine Drainage
ANOVA	Analysis of Variance
APHA	American Public Health Association
BARC	Bangladesh Agricultural Research Council
BCR	Benefit-Cost Ratio
BCSIR	Bangladesh Council for Scientific and Industrial Research
BDL	Below Detection Limit
BDT	Bangladeshi Taka
BOD	Biochemical Oxygen Demand
BSTI	Bangladesh Standard Testing Institute
CA	Commonly Available
CCF	Chief Conservator of Forest
CCME WQI	Canadian Council of Ministers of the Environment Water Quality Index
Cd	Cadmium
CEE	Civil and Environmental Engineering
CEGIS	Centre for Environmental and Geographic Information Services
CPUE	Catch per unit of effort
CR	Critically Endangered
Cr	Chromium
Cu	Cupper
DD	Data Deficient
DE	Decreasing
DO	Dissolved Oxygen
DFO	District Fisheries Officer
DoE	Department of Environment
DoF	Department of Forest
DoF	Department of Fisheries
EC	Electric Conductivity
EMB	Eosin Methylene Blue
EN	Endangered
FC	Fecal Coliform
MAC	Maximum Allowable Concentration
mg/l	milligram per litter
Mn	Manganese
MPN	Most probable number method
NA	Not Available
NATP	National Agricultural Technology Program
NE	Not Evaluated
NGO	Non-Government Organization
Ni	Nickel
NT	Near Threatened
OS	Open site
Pb	Lead
PBRG	Program Based Research Grant
PCA	Principal Component Analysis
PCR	Project Completion Report
PIU	Project Implementation Unit
PI	Personal Interview
PP	Partially protected site
PVC	Polyvinyl chloride
RA	Rarely Available
RCC	Reinforced cement concrete
RU	Rajshahi University
SAU	Sylhet Agricultural University
SCW	Social Work
SD	Standard Deviation
SDDC	Silver Diethyldithiocarbamate
SE	Selenium
SGR	Specific growth rate
SIS	Small Indigenous Species of fish
SPSS	Statistical Package for Social Science
S-R cell	Sedgewick-Rafter counting cell
SS	Sanctuary site
ST	Stable

FCR	Food conversion ratio	SUST	Shahjalal University of Science and Technology
Fe	Ferrous	TC	Total Coliform
FGD	Focus Group Discussion	TCBS	Thiosulfate-citrate-bile salts-Sucrose
GoB	Government of Bangladesh	TDS	Total Dissolved Solids
GI	Galvanized Iron	THB	Total heterotrophic bacterial
HRD	Human Resource Development	TSS	Total Suspended Solids
IEC	Information, Education and Communication	UFO	Upazila Fisheries Officer
IFAD	International Fund for Agricultural Development	UN	Unknown
IN	Increasing	UNO	Upazila Nirbahi Officer
IUCN	International Union for Conservation of Nature	UV	Ultraviolet
Kg	Kilogram	VU	Vulnerable
KII	Key Informant Interview	WB	World Bank
LC	Least Concerned	WHO	World Health Organization
M	Meter	WQI	Water Quality Index
MA	Moderately Available	Zn	Zinc

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Executive Summary

The PBRG sub-project entitled "Techniques Adoption and Formulation of Guidelines for Sustainable Management of *Haor* and *Beel* Fisheries" funded by PIU-BARC, NATP-2 project was a coordinated sub-project implemented jointly by Sylhet Agricultural University (SAU) as component-1, Shahjalal University of Science and Technology (SUST) as component-2 and Rajshahi University (RU) as component-3 under the coordination of Fisheries Division of Bangladesh Agricultural Research Council (BARC). The sub-project started from 11 July 2018 and continued until 10 July 2021. The goal of the sub-project was to ensure sustainable fisheries development for *haor* and *beel* community through improved community-based management approach. The sub-project was implemented in two geographical areas, the north-eastern part of Bangladeh, the *haor* region and the north-western part of Bangladesh, the Chalan *beel*. To achieve the goal of the sub-project similar interventions were made in both the study area as because of the geomorphological characteristics of *haor* and Chalan *beel* is almost similar. Fishing is the main livelihood option for thousands of people in the *haor* and Chalan *beel* region and plays a significant role in food security as well as poverty alleviation.But due to various anthropogenic and natural causes, biodiversity of the *haor* region and Chalan *beel* has been decreasing day by day. Moreover coal mining effluent from upstream rivers of India badly impacted on fish diversity and production which was addressed in the sub-project. By addressing these concerns, the present project was implemented its activities to evaluate the effectiveness of management on aquatic ecosystem through community participation with a view to enhance native fish biodiversity, especially small indigenous species. The sub-project also aimed to find out a sustainable alternate livelihood options of the fishers.

Under the study of component-1 (SAU) there were 5 objectives. To achieve these objectives two sanctuaries were established in the study area to protect brood fish and ensure safe breeding. Two pens were established adjacent to the sanctuaries to enhance nutrient enriched endangered small indigenous species (SIS) of fish mola (*Amblypharyngodon mola*) and dhela (*Osteobrama cotio*). Mola and dhela were collected from different places of Sylhet district and stocked into the pen and rare them until its natural propagation and allow them into the nature by removing the net of the pen. The study was conducted in the Sari-Goyain River and its adjacent areas of Goyainghat and Jainta upazila of Sylhet district and the Kura River of Golapganj upazila were selected as control wetland. During catch assessment highest number of fish species was observed in the Ratargul swamp forest (72) followed by the Kura River (71), the Shari-Goyain River (69), and the Gurukchi River (62). In case of plankton total 40 genera of phytoplankton and 18 genera of zooplankton were identified from the selected sampling spots in the Shari-Goyain River. According to fishers' statement mola, dhela and other small indigenous species (SIS) of fishes were increased remarkably after establishing sanctuaries and pens. According to the catch monitoring data, nine native species which were unavailable in the respective sites were noticed during the present study. Catch data showed that average fish catch (mean ± SD) per fisher was increased in the Ratargul swamp forest area (2.46 ± 2.23 to 3.68±2.97 kg/day) and in the Gurukchi River (1.78±2.11 to 2.98±2.61 kg/day). This study exposed that community-based management approach for sanctuary appeared to be an effective tool for fish diversity enhancement which led to increase in number and amount of various fish species. Cage aquaculture was introduced as an alternate livelihood option. According to the study tilapia and pangus can be the best option for cage culture with a stocking density of 30 fish/m^3 and 60 fish/m^3, respectively considering the growth, production and economic return. The study also suggested that weekly one day gap in feed supply of tilapia is better in respect to economic return in a short period of time. Additionally, using the money getting from fish women were involved with other income-generating activities like goat and sheep rearing, sewing etc. Coal mining pollution also addressed in this study. Every year the hilly flash flood from mid of March to end of May carries coal mining effluents and instantly polluted the river water, resulted instant mass mortality of fishes and other aquatic organisms. Heavy metals like copper, chromium, cadmium, lead, nickel, etc. were detected in the river sediment and fish bodies more than tolerable limit.

In the same study area of SAU, component-2 (SUST) had designed to identify the causes of water pollution, impact of upstream coalmining on water quality, siltation nature and the socio-economic conditions of fishers living in study areas. Baseline survey has been conducted to know the socio-economic condition of fishers, market access, and understanding about the conservation of fish biodiversity. Information, Education and Communication (IEC) materials were developed, printed and circulated among the fishers and local community people for raising awareness for alternative livelihood, importance of biodiversity conservation etc. Motivational campaign, awareness rally with banners and festoon were arranged round the years with the participation of fishers and local community people to ensure protection and preservation of biodiversity in the water bodies of the study areas. Water quality of Shari Goyain River was tested in the laboratory and it was found that the pH of water is almost always low and some heavy metals like Aluminium, Copper, Chromium and Zinc etc. along with Sulphateare at high rate in the water resulted from upstream coal mining effluent. The study tested the water of Kura River as control site as it was found that water quality is almost normal for aquatic life. Siltation level was measured, and it was found that siltation level is high in wet season (highest as 12670.81 gm/day/m^2 or 45020 ton/ day). After the end line survey it was found that due to the involvement of alternative livelihoods arranged by the sub-project their income was increased. Locally extinct fish varieties were started to regain and the production of fishes were increased which impacted upon in increasing their income.

Component-3 (RU) of the sub-project aim to capture the success & failure of the existing fish sanctuaries and to develop appropriate sanctuary and cage fish farming as alternate livelihood options. Findings of baseline survey indicated lacking in monitoring & renovation and lack of improved structure of the existing sanctuary were the main causes of lower performance of sanctuary in Chalan *beel* area. However, construction of sanctuary using potential materials like hexapods and ring pipes result in a new dimension to the conservation of fish diversity in this *beel*. Due to establishment of sanctuary fisheries diversity has increased and become stabilize in both of the study area. Moreover, comparative study showed that species abundance, richness and diversity were higher in present sanctuary sites compared to DoF implemented partially protected site and open site (no sanctuary or any exerted fishing ban). Ten potentially important less available fish species were stocked in the two sanctuary sites and from the next year they were found in higher abundance in the experimental sites than the control area. The technique of using hexapods and ring pipes in the sanctuaries was proved beneficial for increasing fish diversity in Chalan *beel* area. The livelihood status of fishermen also improved around sanctuary sites. Cage farming introduced as alternate livelihood options. According to the trial of cage culture Gulsha tengra was found as the most suitable economically viable fish spices for cage farming in Chalan *beel* area with a stocking density 100 fish/$m^3$and one day feeding gap in a week was a good option for cage fish farming in Chalan *beel* area.

Thus, it can be concluded that these types of activities should be implemented throughout the country to enhance fish biodiversity and production as well as conserving indigenous fish species. A bi-lateral dialogue between Bangladesh and India should be arranged to find out ways for reducing coal mining impacts upon water bodies and aquatic lives.

Keywords: Fish sanctuary, Fish biodiversity, Coal mine effluent, Shari Goyain river, Chalan beel.

PBRG Sub-project Completion Report (PCR)

A. Sub-project Description

1. **Title of the PBRG sub-project : Techniques Adoption and Formulation of Guidelines for Sustainable Management of *Haor* and *Beel* Fisheries**

2. **Implementing Organization(s)**

   - Department of Aquatic Resource Management, Faculty of Fisheries, Sylhet Agricultural University, Sylhet
   - Department of Civil & Environmental Engineering (CEE) and Department of Social Work (SCW), Shahjalal University of Science and Technology (SUST), Sylhet
   - Department of Fisheries, Rajshahi University, Rajshahi.

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

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4. Sub-project budget (Tk)

4.1 Total: (in Tk as approved) : 32,572,000.00

A. BARC Component	:	1,200,000.00
B. SAU Component	:	12,000,000.00
C. SUST Component	:	6,000,000.00
D. RU Component	:	13,372,000.00

4.2 Latest Revised (if any): N/A

5. Duration of the Sub-project

5.1 Start date (based on LoA signed) : 11 July 2018
5.2 End date : 30 December 2021

6. Background of the sub-project

The north-east region of Bangladesh is blessed with a special type of inland water ecosystem called '*haor*' and rich with plenty of fishery's resources from the time immemorial. The *haors* are enriched with aquatic biodiversity along with 141 species (BHWDB 2012) of fish and thus playing a vital role to meet up the growing demand of fish in the country. However, due to various anthropegenic and natural causes' fish production is decreasing day by day. Morover coal mining effluent from the upstream rivers of India badly impacted on fish diversity and production. According to the existing literature very few research works have been made on aquatic ecosystem management, enhancement of aquatic biodiversity and fish production in this region. Therefore, it is necessary to take initiative through conducting need-based research and development program to enhance biodiversity and production of fishes in the *haor* region.

The Sari-Goyain River is an important river with rich biodiversity originated from Meghalaya, India and comes through Japhlong and Lalakhal area of Jaintapur upazila under Sylhet district of Bangladesh. The river joins with the Surma River near Satak upazila of Sunamganj district. Ratargul swamp forest is one of the largest freshwater swamp forests in Bangladesh situated on the bank of the Sari-Goyain River and plays an important as a breeding and nursery ground of many small indigenous fish species. The forest is fed with water from the river during monsoon and there are few hectares of perennial water in the deeper portions inside the forest. Many fishers' households depend on this river and adjacent wetlands for their livelihood. There is an adverse impact of coal mining comes through run-off from Meghalaya, India which is one of the main reasons of loss of biodiversity. Coal, sand and stone collection from the riverbed inside Bangladesh also badly impacted on the fish biodiversity of this river. Along with this a lot of anthropogenic causes also responsible for the loss of biodiversity of the Sari-Goyain River and adjacent haor aeas. The Kura River is a 15 km long connecting wetland between Aral *beel* and Dhamri *Haor* in Golapganj upazila of Sylhet district. During monsoon the river receives water from the Kushiara River. The Kura River is a perennial canal contains 1.7-3.5 M. water in the dry season. This river was selected as a control wetland for this research has no connection with coal mining pollution.

The Chalan beel is the largest and most important watershed in Northern part of Bangladesh. The watershed serves about 5 million people, predominantly through fisheries and agricultural activities (Hossain *et al.* 2009). It comprises a series of depressions interconnected by various channels to form a continuous vast water body in the rainy season (July-November) when it covers an area of about 400 km^2. During the dry winter and summer, the water area decreases down to 52-78 km2 and looks like a cluster of beels of different sizes (Sahidul 2005) and offers an excellent alluvial crop land in the post monsoon season and and supports livelihoods of millions of people and most of the fish habitats like rivers and beels within this Chalan beel area. Presently the Chalan beel are at the risk of partial or total degradation due to manifold reasons like agricultural encroachment including pesticide usage, siltation along with other anthropogenic activities (Sayeed *et al.* 2008) with significant indications in the reduction in fish biodiversity along with the reduction in the dependency of the fishermen on the beel for their livelihood. Significant reductions in the areal extent of Chalan beel, are pushing many indigenous species to the verge of extinction. Although several efforts like establishment of fish sanctuaries and stocking of fishes in the beel and river system of the country are also made in recent years, but recent situation clearly indicates the necessity of new efforts to sustain the sanctuaries and to increase the fish production towards improvement in fisher's livelihood.

Small indigenous species (SIS) of fishes are nutrient rich and playing an important role in the national diet of Bangladesh. Among those mola and dhela are much more important due to high content vitamin and minerals (Thilsted *et al.* 1997, Kunda *et al.* 2009). These fishes are gradually disappearing from the nature. To ensure food and nutrition security it is essential to enhance SIS diversity in the wetlands. Establishment of sanctuary with its community-based management can be the good option to revive biodiversity and fish production. Illegal fishing is one of the major causes of reduction of fishes from the *haor* basin. Fishing ban should be imposed to protect the illegal catch. As the fishermen are very poor and vulnerable, they need extra income during ban period. Alternative income generative activities during fishing ban period along with awareness building can reduce illegal fishing to a considerable level. Cage aquaculture could be the suitable options for additional income source of the fishers. It will also be a great opportunity for local fisher communities for sustainable development of the ecological biodiversity to improve livelihood through involving them to aquatic ecosystem management.

In the changed environmental conditions, conservation of sufficient brood stock for breeding in the next season along with proper management practices is also the prime need to arrest the decline of open water fisheries. Fish sanctuaries have been considered to be powerful tool for conservation of broods for future propagation leading to fish stock enhancement and increased production. In recent years some sanctuaries have been established mainly under different development projects in Chalan *beel.* After the projects are over, most of the sanctuaries have been reported to be closed or not functioning properly due to lack of proper management. However, the reasons of success or failure have not been properly documented towards the sustainable development and management of the fish sanctuaries. Even proper monitoring of the existing sanctuaries is not also found to assess their impact on fish production/productivity, biodiversity, environment and livelihood of the fishing community of the localities. It is therefore, necessary to have better understanding of the technical and management aspects of the sanctuaries through active participation of the fishers towards sustainability and more effectiveness in terms of increased diversity and production of fishes and improved livelihood. Considering the importance of these wetlands thus the study has been designed to enhance biodiversity and production of fish in Sari-Goyain River and adjacent waerbodies of haor region and Chalan beel of North-western part of Bangladesh through aquatic ecosystem management involving respective communities and also identifying the effect of water pollution caused by coal mining effluent, nature of losses of fish biodiversity for further development of the fisheries sector. It is expected that the lesson learned from this sub-project can be disseminated throughout the country for greater contribution to enhancement of fish biodiversity and production as well as contribution to the economy of the country.

7. Sub-project general objective

To ensure sustainable fisheries development for Haor and Beel community through improved community-based management approach.

8. Sub-project Specific Objectives (component wise)

BARC coordination component

- To ensure smooth and efficient implementation of sub-project activities to achieve desired sub-project outputs within the stipulated timeframe under strengthened capable research management system;
- To coordinate sub-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 sub-project activities;
- To upgrading the level of output of the sub-project through reviewing of yearly technical progress;
- Collect and collate sub-project data, finding and observation and production of compiled Project Completion Report (PCR); and
- Finally, to ensure increased safe fish food production under environment friendly atmosphere with concomitant increase in rural employment, earning and involvement of rural women through effective coordination among the sub project components.

Component-1 (SAU)

- To assess the fish biodiversity in the Shari-Goyain and Kura Rivers;
- To evaluate the effects of management on aquatic ecosystems through community participation.
- To enhance the availability of nutrient-rich small indigenous species (SIS) of fishes in the *haor* region.
- To develop appropriate cage fish farming as alternate livelihood options of fishers; and
- To determine species-specific differences in sensitivity due to coal-mining effect in the Shari-Goyain River.

Component-2 (SUST)

- To assess the water quality of Shari-Goyain and Kura River and their adjacent Haor areas;
- To analyse the impact of coal mining on water quality of Shari- Goyain river;
- To assess the level of siltation of Shari- Goyain river and their adjacent Haor areas;
- To assess the socio-economic conditions and to identify the nature of access to market system of fishers living in the study areas.

Component-3 (RU)

- To capture the success and failure of the existing fish sanctuaries.
- To develop appropriate sanctuary and cage fish farming as alternate livelihood options.

9. Implementing Location (s)

The study areas ares for component-SAU & SUST located at the adjacent areas of Shari- Goyain and Kura rivers of three Upazilas of Sylhet district, Golapganj (24.8581° N, 92.0151° E), Gowainghat (25.1048° N, 91.9686° E), and Jaintapur (24.49° N, 92.14° E). The Shari- Goyain river is a trans- boundary river of Bangladesh with rich biodiversity, originated from the hilly areas of the Meghalaya State of India, enters Bangladesh through the northern part of Jaintiapur Upazila of Sylhet district. It is in 3 Upazilas, namely Jaintiapur, Gowainghat and Chatak of Sylhet region (92.200785– 91.703482°E, 25.254322–24.983024° N). The area of of RU component will cover Shingra Upazila in Natore district and Chatmohar Upazila in Pabna district. (Location map and sampling sites are shown in methodology section).

10. Methodology in Brief (Combined)

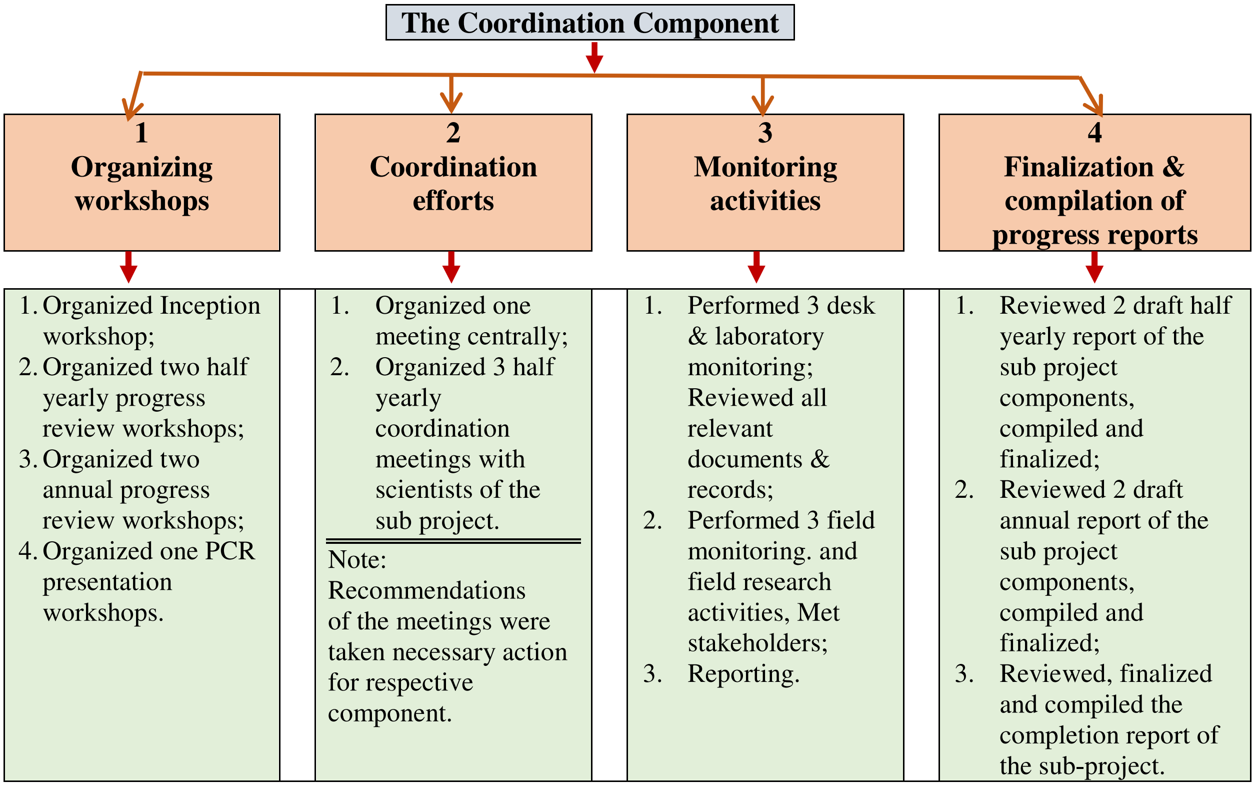
10.1. Activity implementation approach for the Coordination component

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 **Appendices- BARC: A - D.**

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	
H-Y-prog. Review Workshop (Date)	Organized centrally at BARC in March' 2019 & January'2020.	Attended all PI, Co-PI & expert members
Ann. Prog. review Workshop (Date)	Organized centrally at BARC in July' 2019 & in September' 2020	Attended all PI, Co-PI & expert members.
Coordination meeting (No)	03 *07.02.19, 19.10.19 & 25.06.20*	One Coordination meeting held centrally.
Monitoring of field and Lab activities	04 *(SAU, SUST & RU)*	Covered all components under sub-project.
Financial achievement	100% of released money & 99.5% of total approved budget	Delay in Proc. Plan approval and Covid-19 incidence 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 are: • Inception report (1 no); • Compiled half yearly progress report (3 no); • Compiled annual progress report (2 no); • Monitoring reports (3 no);

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

10.2. Research methodology

10.2.1. Selection of study area : The Shari-Goyain River is an important river with rich biodiversity originated from Meghalaya, India, and entered into Bangladesh through its north-eastern part at Jaintiapur upazila of Sylhet district. Six study sites ***under component 1*** were selected in this river *viz.* Lalakhal (S1), Sharighat (S2), Mukhtola (S3), Gowainghat Sadar (S4), Jalurmukh (S5), and Salutikor (S6) (Fig 1). A control site was also selected in the Mukam Bazar Point (S7) of the Kura River in Golapganj upazila where no effect of coal mine drainage is yet reported. The main site selection criteria were the hydro-chemical characteristics of the rivers that ensured adequate coverage in terms of biodiversity and aquatic pollution. Another two sites were selected to establish fish sanctuary, pen and cage aquaculture. The sites are Rangakuri *Beel* (SA1) in the Ratargul swamp forest and the Gurukchi River (SA2) in Gowainghat upazila of Sylhet district (Figs. 1 & 2).

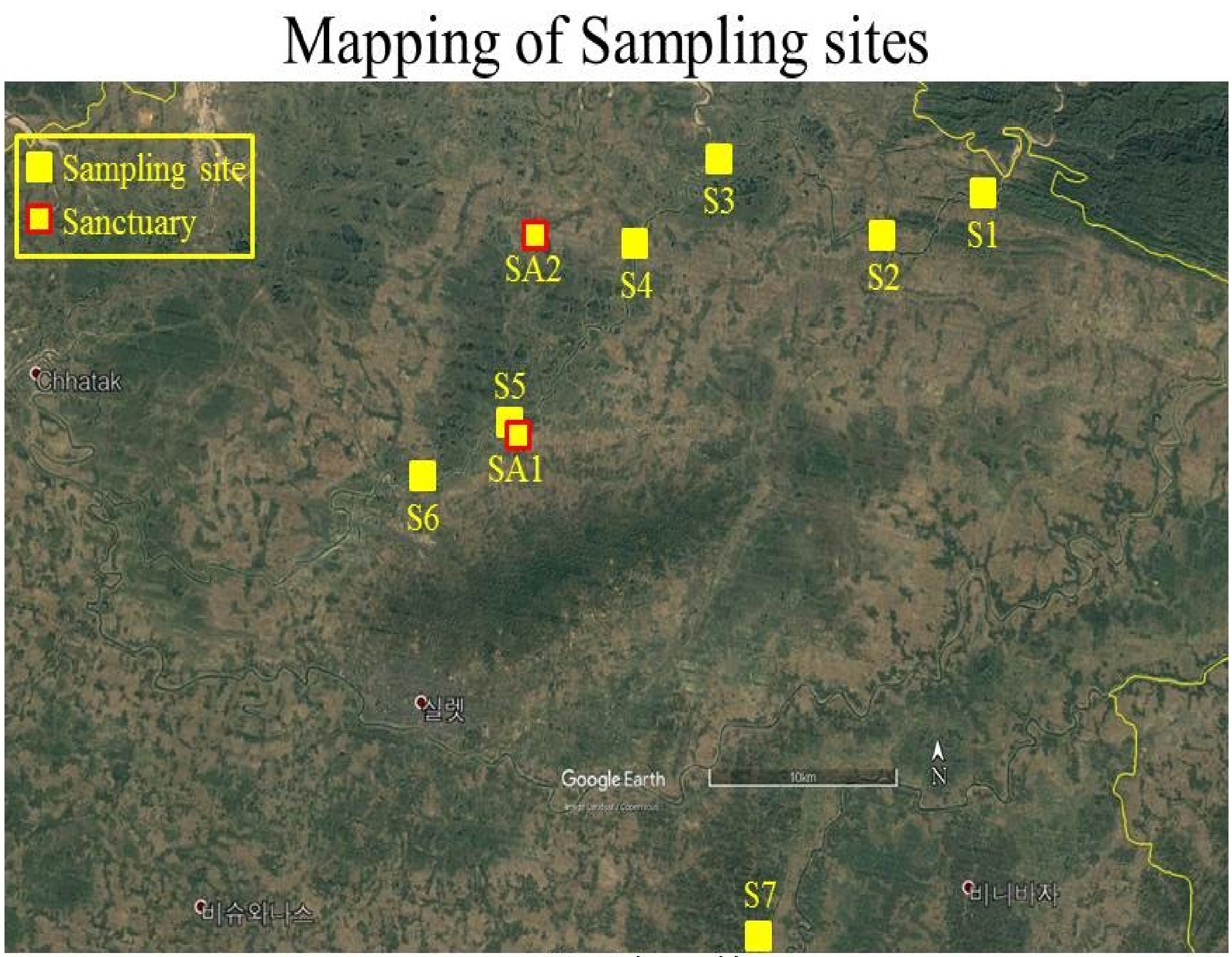


Fig 1. Study areas showing 7 study sites *of comp.-1* in the rivers: Lala Khal (S1), Sharighat (S2), Mukhtola (S3), Gowainghat Sadar (S4), Jalurmukh (S5), Salutikor (S6), the Kura River (S7) (control), and 2 sanctuary sites: Rangakuri *Beel* (SA1), and in the Gurukchi River (SA2).

Fig 2. Sampling sites location under SAU component are shown separately.

10.2.2. Target group selection : Fishermen were randomly selected for the study includes full-time, part-time, and subsistence fishermen. Livelihood of about 5,000 fishers' household depends on the Shari-Goyain River and adjacent wetlands. To ensure community-based sanctuary and pen management 50 fishers from Gurukchi village and 20 fishers of Ratargul village were selected who are very closed to the established sanctuary and willing to dedicate for the management of sanctuary and pen. For data collection and catch assessment about 200 fishers from 5 villages (Salutikor, Jalurmukh, Ratargul, Gowainghat, Gurukchi and Sharighat) were randomly selected for these studies who were directly involved in exploiting fisheries resources for their livelihood. From the control site 50 fishers surrounding Mukamtola Bazar of Golapgonj upazila were selected for data collection and catch assessment.

Existing data sources like voter lists, identity of fishers etc. were used by the ***SUST component*** to select real fishers and their villages from 5000 fishers' household depends on Shari- Goyain River. Concentration of fishers and proximity to Shari-Goyain River is considered to select 7 study villages namely Bolla, Lakkhihaor, Noyakhel, Titkuli Haor, Shialiar Mukh etc. under Gowainghat Upazila as the experimental site of this sub-project.

10.2.3. Baseline survey on fish biodiversity : The baseline survey of the fish biodiversity by the ***SAU component*** was conducted through Personal Interview (PI), Focus Group Discussion (FGD), and Key Informant Interview (KII) using well-structured questionnaire and checklist. The questionnaire and checklist were pretested and corrected accordingly before using for field data collection. All fish fauna were then categorized into five ranks on the basis of more than 50 FGDs, 150 PIs and 20 KIIs. The ranks are Abundantly Available (AA): species plentifully observed throughout the year; Commonly Available (CA): species generally found throughout the year; Moderately Available (MA): species found infrequently in the study area; Rarely Available (RA): species found fortuitously, and Not Available (NA): species disappeared within

10-12 years from the study area. Secondary information was collected from Upazila Fisheries Offices of Jaintiapur, Gowainghat and Golapganj, reports from different non-government organization (NGOs), national and international journals, websites, etc. to cross check and thus authenticate the primary data. The base-line survey includes present status of fish biodiversity, fish production and management system of the rivers.

Plate 1. Data collection by focus group discussions (FGD).

Plate 2. Data collection by personal interviews with fishers.

While ***SUST component*** followed mixed method approach for both baseline and end line survey All fishers age of 18 and above was considered as respondents of the baseline survey. On the other hand, fishers directly involved in the sub-project activities and having knowledge about the project was included as respondents for the end line survey. In-depth interviews, observation, focus group discussions (FGDs) and key informant interviews were the primary sources of data. Before endline survey IEC (Information, Education and Communication) materials like posters, leaflets, documents on legal issues on fishing and leasing practices etc. were developed and printed. Posters were hanged on the walls, leaflets and handouts were distributed among the fishers. Several group discussions, rally and community meetings were organized in the villages to raise awareness and motivate them for exercising legal rights, searching for alternative livelihood, preservation and protection of fish varieties as well as environment etc.

Quantitative data were processes through SPSS software. Qualitative data was transcribed, organized and analyzed using thematic approach of qualitative investigation. The survey explains the socio-economic conditions of fishers as well as it has identified the nature of access to water bodies and market system. It also investigated the understandings of fishers on fish diversity and its importance in promoting animal protein intake in the study area. On the other hand, the end line survey assessed the impacts of the sub-project interventions.

Plate 3. Motivational meetings.

Plate 4. Awareness campaign.

Plate 5. Group discussion on existing rules.

Plate 6. Material distribution for awareness raising

Plate 7. Data collection for end line evaluation.

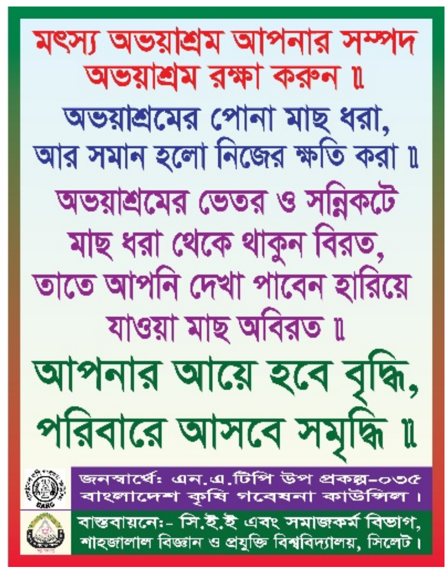


Plate 8. IEC material (poster).

Plate 9. IEC material (poster).

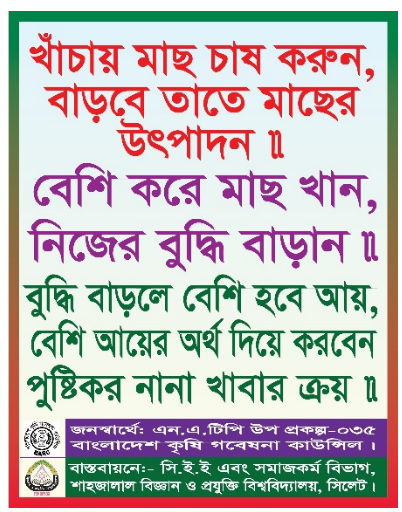


Plate 10. IEC material (poster).

Plates 5-10. Social data collection photograph and IEC materials.

In case *of RU component*, for baseline survey a questionnaire *(Appendix 1, RU)* was developed, and data were collected accordingly. Collection of information about the reasons of success and failure of the existing sanctuaries were also conducted. Samplings for fish catch and species diversity were conducted through catch per unit of effort (CPUE) to analyses catch assessment. Socio-economic conditions of the fishermen were also evaluated to compare the effect of sanctuary before and after the study period

10.2.4. Fish catch and species diversity : During the study period, one DoF established sanctuary site and open site (free from any kinds of exerted fishing protection) were selected by RU to compare fish abundance and diversity with the present sub-project implemented sanctuary site for both the Singra and Chatmohor upazila. Project implemented sanctuary, DoF established sanctuary site and open site were coded as sanctuary site (SS), partially protected site (PP) and open site (OS), respectively. Fishes from the selected study sites were collected using a seine net (10 m × 1.5 m; 0.5 mm mesh). Three, 30-m seine hauls were done at nearer areas of each selected locations on each sampling date. Each haul was from deep water (1–1.5 m) to the bank of the river. The fishes were then sorted and identified according to their morphometric and meristics characters following Talwar and Jhingran (1991), Rahman (2005) and Rahman et al. (2009). After identification, fishes were systematically classified according to Nelson (2006).

10.2.5. Plankton analysis : Ten liters of water samples were collected from 6 places in each study sites of the Shari-Goyain River by using water sampler and then passed through a plankton net (mesh size 20 µm). Thus, the plankton samples were concentrated to 50 ml and preserved in small plastic bottles by adding 10% buffered formalin. Qualitative and quantitative measurements of plankton were done inside the lab by using a Sedgewick-Rafter counting cell (S-R cell) under a binocular microscope (Olympus, M-4000D) following APHA, 1976. Identification of planktons up to genus level was carried out by using the keys from Ward and Whipple (1959), Prescott (1962) and Bellinger (1992).

The quantitative estimations were done by following the procedure mentioned by Azim *et al.* (2001).

$N = (P \times C \times 100)/L$

Here,
N= Number of plankton cells or units per liter of original water
P = Total number of plankton counted in 10 fields of S-R cell
C= Volume of final concentrated sample (ml)
L= Volume of original water sample (l)

Plate 11. Collection of plankton using plankton net.

10.2.6. Water and sediment quality monitoring

Component 1 (SAU)

Water and sediment samples were collected monthly with three replicates from all the sites. Collected water and sediment samples were instantly stored in plastic containers and plastic bags, respectively, and transported to the laboratory in the Department of Aquatic Resource Management at Sylhet Agricultural University, Sylhet, Bangladesh. Water quality parameters, namely temperature, pH, conductivity, dissolved oxygen (DO), salinity, and total dissolved solids (TDS) were monitored instantly by using a digital multi-sensor (YSI Multi-Sensor, model: Professional Plus, Brand: YSI, Origin: USA). Transparency and water depth are measured by using Secchi disc and weighted rope, respectively. For the convenience of this study we divided the months into 4 seasons, viz. dry season/winter (December-February), pre-monsoon (March-May), monsoon (June-August), and post monsoon (September-November).

Plate 12. Collection of sediments by Ekman dredge and observation of transparency by Secchi disc

Component 2 (SUST)

Water sampling locations of SUST component

Samples were collected over a stretch of 50 km while selecting four important points to monitor the water quality. Sampling point-1 is located at Lalakhal (Zero-Point) (25.120691N, 92.184670E) and Sampling point-2 belongs to Sharighat (25.089258N, 92.11830E) with a distance approximately 10 km from Sampling point-1. Moreover, sampling point-3 is situated near the Gowainghat bridge (25.088829N, 91.981020E) about 26.5 km away from Sampling point-2 and Sampling point-4 is Located at Ratargul (25.012269N, 91.915231E) with a distance approximately 13.5 km from Point-3.

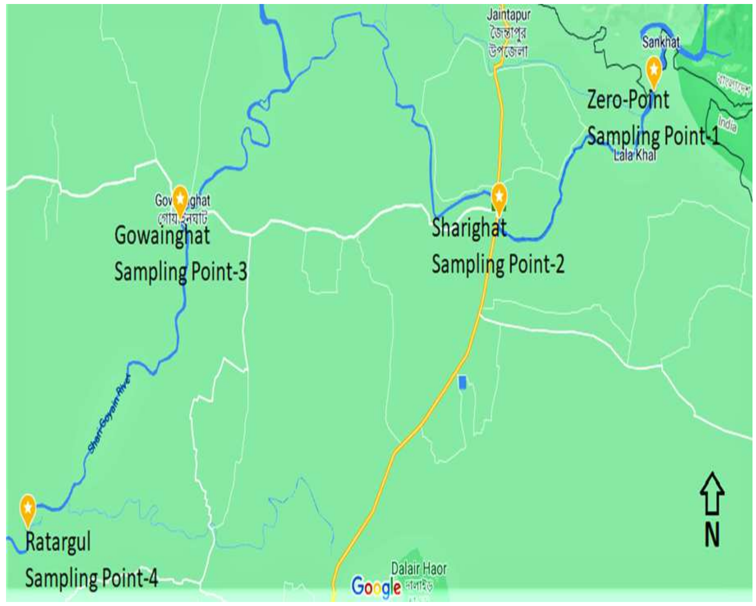


Fig 3. Location of sampling points.

Sampling points are shown in Fig 3. As control site, another point in Kura River of Golapganj was selected, from where water was collected to compare the water quality results.

Sample collection and analysis

There are five parameters of water which are basic to life within aquatic systems. Impairments of these can be observed as impacts to the flora and or fauna with a given water body. These parameters are: Dissolved Oxygen (DO), Temperature, Electrical Conductivity/Salinity, pH and Turbidity (TDS, TSS). Nitrogen (NO_3-N), Coliforms, Chlorides, and Arsenic etc. are also matter of concern for aquatic life. The upstream coal mining process can expose pyrite to weathering, which can release acidity, Iron, Manganese, Aluminium, Sulfate, Potassium, Calcium, Copper, Chromium, Zinc etc. This process is called as Acid Mine Drainage (AMD).

The water samples were collected and analyzed during wet as well as dry season throughout the study from the four selected sampling points shown in Fig 3 according to standard method (APHA, 1976). Tests are conducted in the laboratories of CEE, SUST, Sylhet and in the field. pH, EC and temperature were determined in the field using a calibrated portable pH meter and a thermometer with a precision of 0.1° C. Dissolved oxygen (DO), Biochemical Oxygen Demand (BOD5), Chloride and Hardness were measured by titration method. Similarly, Turbidity and Total Suspended Solid (TSS), Total Dissolved Solid (TDS) were measured using Portable Turbidity Meter and Oven Dry method respectively. Moreover, Arsenic and T.C, F.C were determined by SDDC Method (Silver Diethyldithiocarbamate) and membrane filter method respectively. In addition, Potassium, Iron, Manganese, Nitrate, Sulphate, Copper, Chromium, Aluminium, Zinc and Nickel measured by UV Spectrophotometer (HACH DR 6000) and Atomic Absorption Spectro- Photometer (Varian Spectra 220). For the comparison of results, standard values of water quality parameters for aquatic life are given below in Table 1. It can be mentioned that not all standards for aquatic life are available in Bangladesh.

Table 1. Standard values of water quality parameters for aquatic life

Variables	Standard value	Sources of standard values
DO (mg/l)	5.5-9	CCME Water Quality Guideline for the Protection of Aquatic Life
BOD (mg/l)	2	Department of Environment (DoE) Bangladesh
Temp. (^{0}C)	25	Uddin, M.N., Alam, M.S., Mobin, M.N., & Miah, M.A., 2014. An Assessment of the River Water Quality Parameter: A Case of Jamuna River. J. Evniron. Sci. And Natural Resources
EC (µs/cm)	30-5000	Stone, M.N., Thomford, H.K., Understanding Your Fishpond and Water Analysis Report, Aquaculture/Fisheries, Cooperative Extension Program, University of Arkansas at Pine Bluff
pH	6.5-9	CCME Water Quality Guideline for the Protection of Aquatic Life
Turbidity (NTU)	5	CCME Water Quality Guideline for the Protection of Aquatic Life
TDS (mg/L)	165	Department of Environment (DoE) Bangladesh
TSS (mg/L)	30	PHILMINAQ, Water Quality Criteria and Standards for Freshwater and Marine Aquaculture, Mitigating Impact from Aquaculture in the Philippines
Nitrate (mg/L)	13	CCME Water Quality Guideline for the Protection of Aquatic Life
Hardness (mg/L)	20-300	Bhatnagar, A., Devi, P., Water Quality Guideline for the Management of Pond Fish Culture. International Journal of Environmental Sciences. 2013, Volume 3, No. 6
TC (No/100ml)	30	PHILMINAQ, Water Quality Criteria and Standards for Freshwater and Marine Aquaculture, Mitigating Impact from Aquaculture in the Philippines
FC (No/100ml)	14	Warrington, P.D., Water Quality Criteria for Microbial Indicators. Overview Report. 2001
Chloride (mg/L)	120	CCME Water Quality Guideline for the Protection of Aquatic Life
Arsenic (mg/L)	0.005	CCME Water Quality Guideline for the Protection of Aquatic Life
Iron (mg/L)	0.3	CCME Water Quality Guideline for the Protection of Aquatic Life
Manganese (mg/L)	0.1	CCME Water Quality Guideline for the Protection of Aquatic Life
Aluminium (mg/L)	0.005 if pH$<$6.5, 0.01 if pH$\geq$6.5	CCME Water Quality Guideline for the Protection of Aquatic Life

Variables	Standard value	Sources of standard values
Sulfate (mg/L)	22	Department of Environment (DoE) Bangladesh
Potassium (mg/L)	12	Bangladesh Water Quality Standard
Calcium (mg/L)	36	WQCSFMA (Water Quality Criteria and Standard for Freshwater and Marine Aquaculture)
Copper (mg/L)	0.002-0.004	CCME Water Quality Guideline for the Protection of Aquatic Life
Chromium (mg/L)	0.001	CCME Water Quality Guideline for the Protection of Aquatic Life
Zinc (mg/L)	0.007	CCME Water Quality Guideline for the Protection of Aquatic Life
Nickel (mg/L)	0.025-0.15	CCME Water Quality Guideline for the Protection of Aquatic Life

For all water quality parameters mean values and standard deviations have been calculated (season wise). Some soil samples from the riverbed at Zero point was also collected to check soil texture, soil components, grain size, and presence of toxicity.

Plate 13. Water sample collection, lab analysis and water velocity determination

<u>Component 3</u> <u>(RU)</u>

Monthly monitoring of water quality parameters (temperature, water depth, transparency, dissolved oxygen, pH, alkalinity and ammonia-nitrogen) was conducted. Water temperature (°C) was recorded with a Celsius thermometer. Water depth was measured with a measuring tape. Water transparency (cm) was measured by a Secchi disk. Dissolved oxygen (mg/l) was recorded with digital oxygen meter, pH was measured by portable pH meter and alkalinity (mg/l) and ammonia-nitrogen (mg/l) were determined by HACH kit (FF2, USA). The sediment quality parameters (pH, Organic Matter and Total Nitrogen) were also collected during wet and dry season and subjected to the analysis in the laboratory.

Plate 14. Water and sediment (soil) quality monitoring in sub-project site.

10.2.7. Calculation of water quality index (WQI : Calculation of Water Quality Index (WQI) was done by SUST component to turn complex water quality data into information that is understandable and useable by the public. Therefore, WQI is a very useful and efficient method which can provide a simple indicator of water quality and it is based on some very important parameters. In current study, WQI was calculated using the model of CCME WQI (Canadian Council of Ministers of the Environment Water Quality Index).

The index is comprised of three factors: F_1 (Scope), F_2 (Frequency) and F_3 (Amplitude). The calculation of F_1 and F_2 is relatively straight forward but F_3 requires some additional steps.
F_1 (Scope) represents the extent of water quality guideline non-compliance over the time period of interest.

$$F_1 = \left(\frac{No\ of\ faild\ variables}{Total\ Number\ of\ variables}\right) \times 100 \qquad (1)$$

F_2 (Frequency) represents the percentage of individual tests that do not meet objectives (Failed tests)

$$F_2 = \left(\frac{No\ of\ faild\ tests}{Total\ Number\ of\ tests}\right) \times 100 \qquad (2)$$

F_3 (Amplitude) represents the amount by which failed test values do not meet their objectives. F_3 is calculated in three steps:

i. The Number of times by which an individual concentration is greater than (or less than, when the objective is minimum) the objective is termed an "excursion" and is expressed as follows. When the test value must not exceed the objective:

$$excursion_i = \left(\frac{Failed\ Test\ Value\ i}{Objective\ j}\right) - 1 \qquad (3a)$$

For the cases in which the test value must not fall below the objective:

$$excursion_i = \left(\frac{Objective\ j}{Failed\ Test\ value\ i}\right) - 1 \qquad (3b)$$

ii. The collective amount by which individual tests are out of compliance is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both those meeting objectives and those not meeting objectives). This variable, referred to as the normalized sum of excursions, or *nse*, is calculated as:

$$nse = \frac{\sum_{i=1}^{n} excursion}{Total\ number\ of\ tests} \qquad (4)$$

$F_3$is then calculated by an asymptotic function that scales the normalized sum of the excursions from objectives (*nse*) to yield a range between 0 and 100.

$$F_3 = \left(\frac{nse}{0.01nse + 0.01}\right) \qquad (5)$$

The CCME WQI is then finally calculated as:

$$CCMEWQI = 100 - \left(\frac{\sqrt{F1^2 + F2^2 + F3^2}}{1.732}\right) \qquad (6)$$

The factor of 1.732 has been introduced to scale the index from 0 to 100.CCME-WQI categorization schema is shown in Table- 2.

Table 2. CCME-WQI Categorization Schema

CCME-WQI Value	Ranking	Comments
95-100	Excellent	Water quality is protected with a virtual absence of threat or impairment, conditions very close to natural or pristine levels. These index values can only be obtained if all measurements are within objectives virtually all the time.
80-94.9	Good	Water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.
65-79.9	Fair	Water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.
45-64.9	Marginal	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.
0-44.9	Poor	Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

10.2.8. Identifying co-relations among water quality parameters : Using the statistical software SPSS (Statistical Package for Social Science, 25.0 version) co- relations among the water quality parameters were identified by SUST component. Besides, important water quality parameters that are mainly responsible for lowering the water quality were also identified. Pearson Correlation Analysis and Principal Component Analysis (PCA) are two tools that were used for this purpose.

Pearson correlation is a worldwide used statistical tool for identifying how they significantly correlate among variables. It ranges from -1 to +1 so that one can easily understand how they correlate to each other. If variables show positive results that means they are linked up with a positive or linear relationship and if show negative, that's mean that they correlate negatively or inversely. The Pearson correlation is also known as the “product-moment correlation coefficient” (PMCC) or simply “correlation”. Pearson's correlation should be used only when there is a linear relationship between variables. It can be a positive or negative relationship if it is significant. Correlation is used for testing in Within Groups studies.

Principal component analysis (PCA) is a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables (entities each of which takes on various numerical values) into a set of values of linearly uncorrelated variables called principal components. This transformation is defined in such a way that the first principal component has the largest possible variance (that is, accounts for as much of the variability in the data as possible), and each succeeding component in turn has the highest variance possible under the constraint that it is orthogonal to the preceding components. The resulting vectors (each being a linear combination of the variables and containing n observations) are an uncorrelated orthogonal basis set. PCA is sensitive to the relative scaling of the original variables.

10.2.9. Assessment of siltation level : Fine Sediments within lakes and rivers originate from the weathering and erosion of rocks. Following rainfall, soil can enter lakes and rivers which cause the finest particles to become suspended in the water, causing it look turbid; this is called siltation. Particles may eventually find their way to the lake or riverbed where they become deposited; this is known as sedimentation.

There are many potential sources of soil and other material which may become suspended or settleable upon reaching a waterway such as, run-off from coal and sand mining areas, Agriculture; cropping too close to watercourses, flooding, bank erosion, wind action, wave or current action, recreational boating and navigation, urban development etc. Excessive siltation or Sedimentation may degrade the spawning grounds, cause behavioral changes in spawning fish, increase egg mortality, decrease larval growth and affect the development rate and survival of larval fish, cause Gill irritation, change blood physiology, alter movement or swimming performance, change foraging behavior and decrease territoriality. That is why it is very important to know the sedimentation rate of a river for the desired fish production.

To determine the rate of sedimentation, two approaches were adopted by the SUST component. One is, using a well-known Hossain's sediment transport equation and the other is, using a device named 'Sediment Trap' is manufactured locally (Fig 4) for measuring sedimentation rate in River Shari-Goyain practically. In addition, Water Current Meter (Vertical Axis Cup Type; made by 'Virtual Hydromet', India) and Depth Finder Device (STRIKER 4 – fish finder; made by 'Garmin', USA) were used to measure water velocity and depth of the river respectively at different places and water discharge, average depth of flow, were calculated from the obtained data, to be used in that equation. River bed materials were also collected by the sampler to perform grain size analysis for median diameter of bed materials (D50), which is required for the equation. Based on the concept of dimensional analysis and similitude argument Hossain (1992) proposed that sediment concentration in a stream of steady water and sediment flow is a power function of: (a) the product of Froude number and slope of energy gradient, (b) the settling velocity ratio and (c) the discharge ratio. The functional form of the equation could be expressed as follows:

$$C_t = A\,[X^a Y^b Z^c] \quad \text{.....(7)}$$

Where,

C_t Total sediment concentration in parts per million (ppm) by weight

$A = 6.946 * 10^5$ for $\frac{B}{H} < 500$; $A = 6.496 * 10^6$ for $\frac{B}{H} > 500$;

$X = \frac{VS}{(gH)^{\frac{1}{2}}}$ and $a = 0.745$; $Y = \frac{\omega_r}{\omega}$ and $b = 0.633$; $Z = \frac{Q}{Q_c}$ and $c = 0.50$

ω_r = settling velocity for a representative sediment size for which D50 = 0.15 mm at ambient temperature = 0.01551 m/sec.

D_{50} = median diameter of bed material. Obtained from grain size analysis of bed materials.

Q = measured discharge. Area velocity method was used to compute the water discharge.

Q_C = assessed discharge

$$Q_C = \left[\left(2.15 + K\frac{B}{H}\right) H (gS)^{\frac{1}{5}}\right]^{\frac{5}{2}} \quad \text{.....(8)}$$

Where,
B = average width of channel
H = average depth of flow. Depth of flow was measured by echo sounder.
g = acceleration due to gravity = 9.81 m/sec^2
S = average water surface slope = 0.019 obtained from Google earth.
The value of K is proposed to be 0.055 when Q< 1500 cumecs and 0.17 when Q> 1500 cumecs.
$\boldsymbol{\omega}$ = settling velocity of the sediment load. Settling velocities of the sediment particles have been computed using Rubbey's equation:

$$\boldsymbol{\omega} = \frac{\left(\frac{2}{3}g(S_s-1)D_{50}{}^3+36v^2\right)^{0.5}+6v}{D_{50}} \qquad (9)$$

Where,
s_s= sediment density = 2.65
D_{50}= median diameter of bed material = 0.00047749 m. Obtained from grain size analysis of bed materials.
v = kinematic viscosity = 0.000000864 m^2/sec
g = acceleration due to gravity = 9.81 m/sec^2

It may be worthwhile to mention that Hossain's equation has successfully been used to estimate sediment transport of many rivers of Bangladesh (Hossain 1992, Alam and Hossain 1988, and Sultana 1989).

However, In terms of sediment trap, two types of sediment traps were employed; one is with deflector inside and the other one is without deflector. The traps were fixed to the river bottom in the littoral zone at a distance approximately 3 m from the shore line at a depth of 1.6 m. the trap were attached to a steel frame which ensured maintenance of traps on the river bottom and stabilized the vertical position (Fig 4). To position the trap vertically, a cross-brace was placed on the upper edge of the trap and a spirit level and pile above the water level was used to achieve the desired position of the trap. The accumulated sediments in the traps were collected at 7-18 days interval depending on the degree of turbid water and transported to the laboratory to determine solid mass. Using obtained data, the rate of sedimentation was calculated through MS Excel of Office 2007 version.

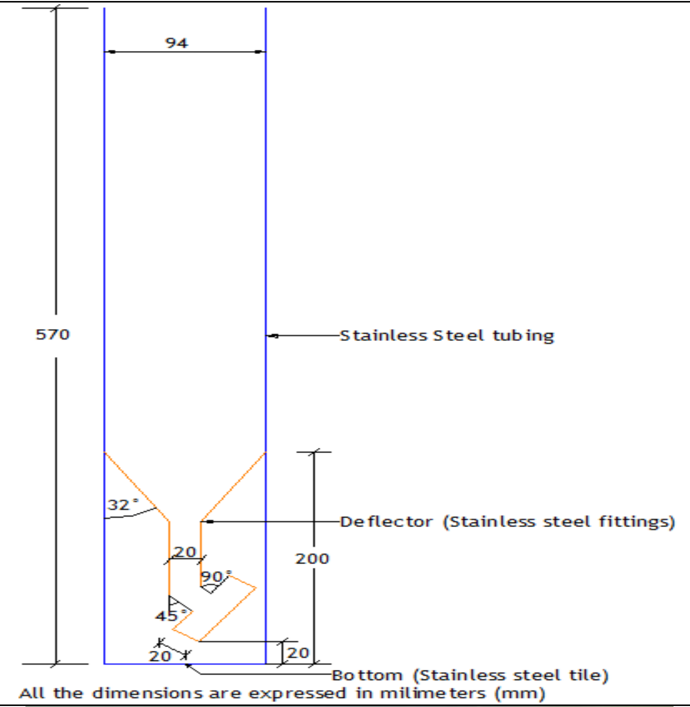
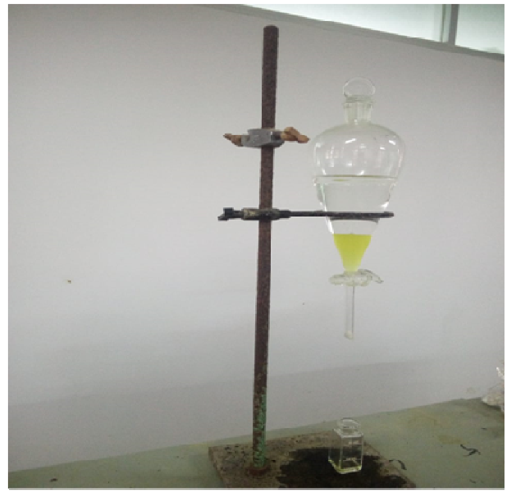


Fig 4.
a) Schematic view;
b) Photo of the 'Sediment Trap'; and
c) Sediment trap under water near Zero point;

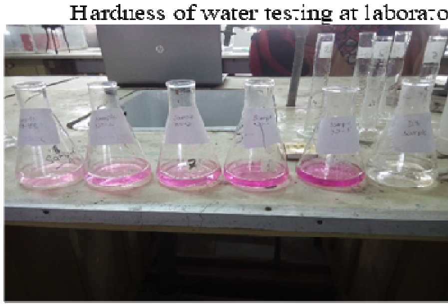
10.2.10. Collection of secondary data, review and analysis : Secondary data like water level fluctuation, water discharge, satellite images of the river, livelihood of fishers etc. were collected by the SUST component from different sources such as- DoF, Bangladesh Water Development Board, CEGIS, Bangladesh Meteorological Department, different NGOs, national and international journals, website, etc.

10.2.11. Analysis of environmental parameters (pollution) : The pollution parameters (heavy metals and bacterial density) were analyzed by the RU component from water, sediment and fish samples collected during wet and dry season from the two study locations. For heavy metal analysis, water samples were collected from two sites at a depth of about 0.3 m below water surface into a 500 ml plastic bottle. Prior to sampling, the bottles were cleaned with 10% nitric acid and rinsed with distilled water. The bottles were rinsed three times with the beel water at the time of sampling. Samples were then collected by direct immersion of the sampling bottle into the beel. Immediately after sample collection, 2 ml nitric acid was added to the water samples to reduce adsorption of metals onto the walls of the plastic bottles.

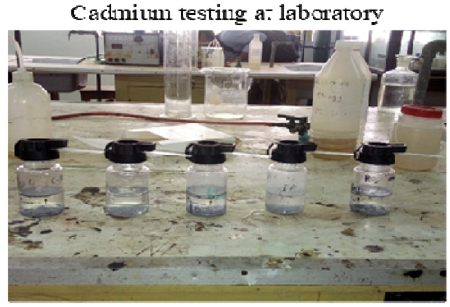
Hardness of water testing at laboratory



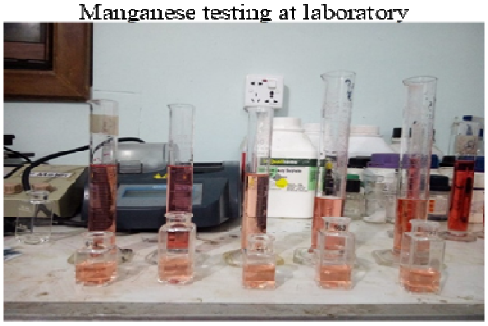
Cadmium testing at laboratory



Manganese testing at laboratory



Arsenic testing at laboratory



Aluminium testing at laboratory

UV Spectrophotometer

Plate 15. Some photographs of laboratory analysis.

Sample bottles were then labeled to indicate sampling date and site. Samples were transported in an ice-box to the laboratory and stored at 4 ^{0}C awaiting the analysis. Sediment samples were taken from the bottom surface (1-2 cm thick) using a PVC tube. For each sample, three sediment grabs were randomly taken, homogenized in a plastic bucket and kept in clean polyethylene bags. The polythene bags were then labeled to indicate sampling station and date of sampling. Samples were then stored in ice box for transportation to the laboratory. Fish samples were also collected from the sites and transported to laboratory in coled condition. Heavy metals from the samples (water, sediment & fish) were analyzed in the laboratory of Atomic Energy Commission, Dhaka.

For the bacteriological analysis, 500 ml of water samples and required amount of sediment and fish samples were sampled from the selected representative sampling points. The materials used in sampling were sterile glass bottle, ice box i.e. a lightproof insulated box containing melting ice or ice-packs and marker. The fish samples were collected from the fisherman. The sample was delivered to the laboratory as quick as possible i.e. the time gap between sampling and the analysis was maintained below 3 hrs. Total heterotrophic bacterial count was determined by spread plate method using nutrient agar medium. Counting of *E. coli* from water sample was carried out by most probable number method (MPN) and by spread method for sediment and fish sample in EMB agar plate. Determination of *Vibro cholerae* from water, sediment and fish sample were carried out by spread plate method using TCBS agar medium.

10.2.12. Establishment of sanctuaries : To enhance the aquatic biodiversity, it is essential to prevent fishing during breeding season as well as during lean period. Therefore, two fish sanctuaries were established (March, 2019) by the ***SAU component*** in the Ratargul swamp forest and in the Gurukchi River considering breeding ground and nursery ground for the most valuable fish species. Each of the sanctuaries covers an area of around 0.50 hectare. Locally available *hizol* trees, bamboo branches, branches and roots of other available trees were used to establish the sanctuaries. Sanctuary management was done through community participation as well as replacement and addition of new materials time to time in order to replenish the loss of those sanctuary materials by natural decomposition. A total of 50 cluster meetings were conducted to increase awareness among fishers about the benefits of the establishment of sanctuary and pen and its management techniques.

Plate 16. Sanctuary and cage culture activities in the Ratargul swamp forest.

In case of ***RU component***, based on the questionnaire survey, failure of the performance of sanctuary was addressed and potential sites, materials and species for sanctuary were selected with the utilization of the experience of fishers involved in sanctuary management. Two sanctuaries were established, one in Singra Upazila (coded as Site 1) and another in Chatmohor Upazila (coded as Site 2). Two committees were also formed in two Upazilas for the management of the two sanctuaries. Minimum100 beneficiaries (fishers) from each Upazila have been selected for management of the sanctuary (Fig 5).

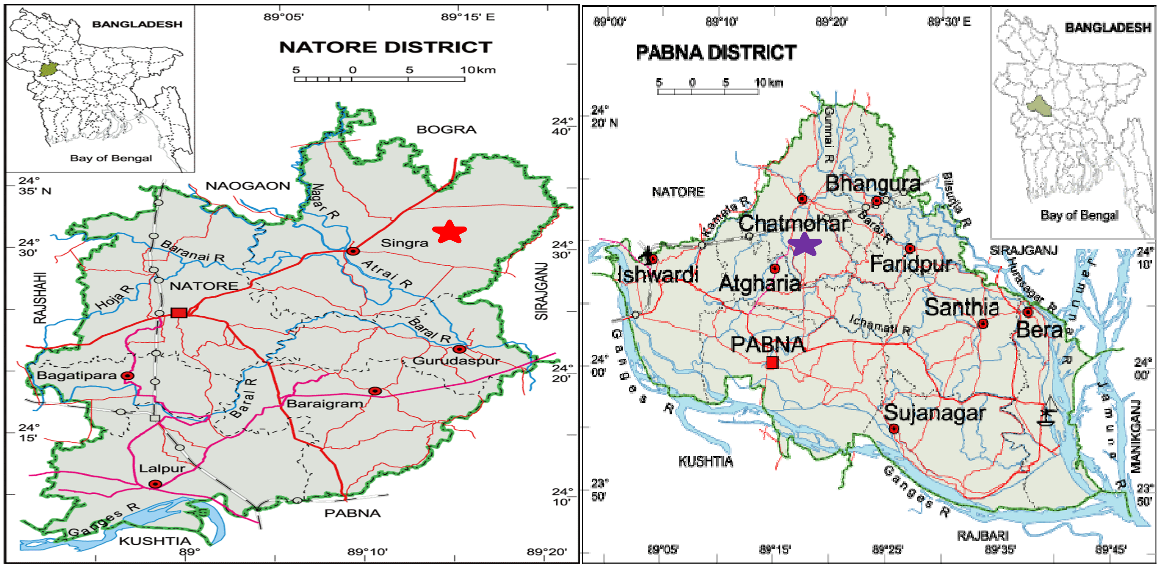


Fig 5. Map showing the sub-project areas (a) Natore district and (b) Pabna district of Bangladesh.

10.2.13. Establishment of pen and stocking of SIS by Comp- 1 : To ensure nutrient security and increased income for fishers' community it is essential to enhance the nutrient-rich small indigenous species (SIS) of fish, some of which become endangered in localities. For instance, mola (*Amblypharyngodon mola*) and dhela (*Osteobrama cotio*) is highly micro-nutrient rich SIS which are now a days very scarce in the natural waterbodies. For this reason, mola and dhela were stocked by the ***SAU Component*** in the both the selected sanctuary sites. Mola and dhela were collected from different sources and stocked in some hired ponds during March-April 2020 and rared on commercially available nursery feeds for 20 to 30 days before stocking in the previously established two pens in sites SA 1 (Singra) and SA 2 (Chatmohor). The size of each pen was around 0.1 hectare. Finally, about 60 kg mola and 10 kg dhela were stocked in each pen and kept two months. After few days of breeding all the fishes with offsprings were allowed to leave the pen and spread in the adjacent *beels*, *haors* and rivers by removing the nets of the pens.

10.2.14. Impact of banning and catch assessment

a) Banning on fishing : Fishing was banned during peak breeding season, May to August, in the study area to ensure safe breeding of the indigenous fishes and until attainment of juvenile stage. In this regard several trainings and motivational meetings were arranged involving Upazila Fisheries Officer (UFO) of Gowainghat. Upazila Nirbahi Officer (UNO) also visited the sanctuary area and took part in a motivational meeting with the fishers. He also found out and destroyed few of the illegal nets from the river during his visit. Notably, year-round ban on fish catch was imposed in and around the sanctuaries and the fishers themselves protect the area.

b) After intervention data collection : Survey was continued in the Shari-Goyain River and adjacent waters to assess the changes in fish diversity and production after establishment of sanctuaries, stocking of SIS fishes, and successful implementation of banning. The survey was continued throughout the project period. Data were collected from fishermen and fish traders from local fish market in the project area. During data collection Personal Interview (PI), Focus Group Discussion (FGD) and Key Informant Interview (KII) were made.

c) Catch assessment : To know the present fish biodiversity and production status, direct catch assessments were performed to assess the impact of fish sanctuaries. PhD fellow, Field Assistant, and Data Enumerators under this project are continuously visiting all the study sites to carry out the catch assessment survey. The fish samples were identified up to species level and compared with the recent IUCN Red List (IUCN, 2015) and other published books and literatures. During catch assessment photograph of different fishes were taken and some samples of each species were taken to the laboratory for preservation.

Plate 17. Angling fishing in the adjacent floodplain of the Ratargul swamp forest.

Plate 18. Fish sampling in the river bank of the Gurukchi River.

10.2.15. Cage fish farming as alternate livelihood options

10.2.15.1. Component– 1 (SAU) : The sub-project introduced alternate livelihood option through appropriate cage fish farming to reduce the fishing pressure during ban period on fishing and also to ensure community-based sanctuary management activities properly. All the cost incurred for cage culture activities were borne from the sub-project as incentive to the fishers. For this purpose, two fishers' communities were selected by the *SAU component* from Ratargul and Gurukchi villages of Gowainghat upazila. In Ratargul and Gurukchi villages 30 and 50 fishers', respectively were involved in cage fish farming who were responsible for sanctuary and pen management and also actively participated to ensure ban on fishing. To find out a suitable cage aquaculture technique three different experiment trials were made with different species. For this purpose, three experiments in each study site were successfully completed during the study period. All the experiements consisted of 3 treatments with 3 replications each.

Expt.- 1. Determination of suitable species for cage farming

Cage culture has been successfully practiced in most Asian countries such as China, Vietnam, Thailand, Taiwan and Malaysia. These countries have increased their national fish production by several folds and leading the international tilapia market and are producing better sized tilapia. As like as Bangladesh has high population density and regularly loosing agricultural lands for urbanization where closed water bodies to produce fish are limited, but production has reached to high enough of its capacity. Now it is the time to introduce cages in flowing river water to increase the fish production promptly. Cage culture or any other intensive culture system, selection of species is also important since all species are not suitable for all culture systems. Some of the fish showed consistently successful culture in cages which are Thai sharpunti (*Barbodes gonionotus)*, tilapia (*Oreochromis niloticus*), grass carp (*Ctenopharyngodon idella*), thai pangas (*Pangasias hypopthalmus*), prawn (*Machrobrachium* sp), koi (*Anabas testudineus*) and mrigal (*Cirrhinus mrigala*). Among these tilapia is the most common (56%). Moreover pangas (12%), sharpunti (11%), grass carp (8%) and others (13%) (CARE, 2000). This experiment was performed to find out the suitable fish species for cage farming in the *haor* region. However, magur, pabda and pangas were selected for this trial to consider good taste, high market demand and economics.

Cage preparation and set up : Medium size cages (6m×3m×2m) were used for cage aquaculture. A total of 9 cages were installed in each of the sanctuary sites. The cages were made of galvanized iron (GI) pipe frame and covered by nylon net tied with nylon twine. The mesh size of the net was about 2.5 cm to protect experimental fish fry escaping from the cage and also to allow large amount of water to easily pass through the cages. To keep the cages floating 20 empty metallic drums each of 200 L capacity were used in both sides of the cages. Drums were fixed with the cages using GI pipe and bamboo. Two anchors fixed in the bottom of the waterbody and tied up with rope at both side of the series of 9 cages, so that the water current and wave action could not be displaced the cages. To prevent floating feeds escaping from the cages by the natural flow of water all the cages were covered with fine meshed net to a length of 15 cm from the water surface to downwards. Cage nets were cleaned once in a week to allow smooth flow of water.

Study design and stocking of fish : The study conducted three treatments with three replications. Magur was stocked in treatment-I (T_1), Pabda was stocked in treatment-II (T_2) and Pangas was stocked in treatment-III (T_3). Stocking density of Magur, pabda and pangas were 1080/per cage (40/m^3), 1620/per cage (60/m^3) and 1080/per cage (40/m^3), respectively. Fish fry were collected from Mymensingh from the same stock. Fries were transported with oxygenated drums by truck from Mymensingh to Ratargul and Gurukchi of Goyainghat. Then fries were transported to study sites by boat with large plastic drums and stocked early in the morning.

During transportation water in the plastic containers were agitated manually to add oxygen from the air. Before stocking length and weight of 50 fries of each species were recorded randomly.

Feeding management : Feeding was started with commercial feed at 10% of body weight of fish initially and gradually decreased up to 5% body weight until the end of the study. Feeds were spreaded over the cages through the upper opening. Total feed for a day were divided into two equal half and supplied in the morning between 8.00-9.00 am and in evening at 5.00-6.00 pm for pangas. Due to nocturnal habit feeding of magur and pabda was done in the evening between 7.00 to 8.00 pm and in the early morning between 4.00 to 4.30 am. Feeding rates were adjusted every 7 days interval depending on the mean body weight.

10.2.15.2. Component-3 (RU) : The sub-project has developed alternate livelihood option through appropriate cage fish farming to reduce the fishing pressure during ban on fishing for sanctuary operation. Fish farming groups for cage culture was selected from one upazila (Singra upazila under Natore district). Connection of beel to the river water and water current was given major considerations during selection of site. For first year experiment, 4 species (Pangus, Pabda, Magur and Gulsha Tengra) were selected for trial of cage culture. Fry of selected fishes has been released in experimental cages and feeding and growth monitoring was done. Medium sized cage (6 m x 3 m x 2 m) was used for this trial. A total of 12 cages have been installed for this experiment. The cages were stocked with 100 fish/m^3 and that the total fish in each cage were 3500 (Table 3).

Table 3. Experimental design layout

	T_1	T_2	T_3	T_4
Replication I (R_1)	T_1R_1 (3500 fish/cage)	T_2R_1 (3500 fish/cage)	T_3R_1 (3500 fish/cage)	T_4R_1 (3500 fish/cage)
Replication II (R_2)	T_1R_2 (3500 fish/cage)	T_2R_2 (3500 fish/cage)	T_3R_2 (3500 fish/cage)	T_4R_2 (3500 fish/cage)
Replication III (R_3)	T_1R_3 (3500 fish/cage)	T_2R_3 (3500 fish/cage)	T_3R_3 (3500 fish/cage)	T_4R_3 (3500 fish/cage)

T_1=Pangas, T_2=Magur, T_3=Pabda, T_4=Gulsa tengra

After the successful completion of the first experiment of selection of suitable fish species for cage fish farming in Chalan beel area, among the 4 species (Pangus, Pabda, Magur and Gulsha Tengra), the second experiment was designed to evaluate the most effective stocking density of selected fish species in cage farming system in Chalan beel area. 4 types of potential stocking density (50, 100, 150 and 200 fish/m^3) were selected and stocked in the experimental cages (Table 4). Therefore, the number of fish in each cage was 1750, 3500, 5250 and 7000 pieces in T_1, T_2, T_3 and T_4, respectively. The initial body weight was kept fixed for all the treatments and the value was around 5.55±0.49 g.

Table 4. Experimental design layout

	T_1	T_2	T_3	T_4
Replication I (R_1)	T_1R_1 (1750 fish/cage)	T_2R_1 (3500 fish/cage)	T_3R_1 (5250 fish/cage)	T_4R_1 (7000 fish/cage)
Replication II (R_2)	T_1R_2 (1750 fish/cage)	T_2R_2 (3500 fish/cage)	T_3R_2 (5250 fish/cage)	T_4R_2 (7000 fish/cage)
Replication III (R_3)	T_1R_3 (1750 fish/cage)	T_2R_3 (3500 fish/cage)	T_3R_3 (5250 fish/cage)	T_4R_3 (7000 fish/cage)

After the successful completion of the first and second experiment on selection of suitable catfish species and optimal stocking density for cage fish farming in Chalan beel area, the third experiment was designed to minimize the feed cost through different levels of restriction on feeding ration (Table 5). 4 different treatments were assigned for this experiment, whereas fish were distributed among regular feeding, 1 restriction and 6 day feeding, 2 day restriction and 5 day feeding; and 3 day restriction and 4 day feeding, respectively in one week period. Thus, over the culture period 120 days, regular feeding was maintained at T_1, 18 day restriction at T_2, 36 day restriction at T_3 and 52 day restriction at T_4. Stocking density (100 fish/m^3) was similar in all the treatments. Initial weight of the stocked fish was 8.00±0.35g.

Table 5. Experimental design layout

	T_1	T_2	T_3	T_4
Replication I (R_1)	T_1R_1 (Regular feeding)	T_2R_1 (1 day restriction in a week)	T_3R_1 (2 day restriction in a week)	T_4R_1 (3 day restriction in a week)
Replication II (R_2)	T_1R_2 (Regular feeding)	T_2R_2 (1 day restriction in a week)	T_3R_2 (2 day restriction in a week)	T_4R_2 (3 day restriction in a week)
Replication III (R_3)	T_1R_3 (Regular feeding)	T_2R_3 (1 day restriction in a week)	T_3R_3 (2 day restriction in a week)	T_4R_3 (3 day restriction in a week)

Sampling of caged fishes : Feeding status was monitored regularly on daily basis. However, health conditions of fishes and condition of cage were checked fortnightly during sampling, whether getting damage or not. Length and weight of randomly selected 20 individuals were measured and recorded from each of the cages at monthly basis throughout the study period. Length of fish was measured by wooden scale and weight of fish was measured by digital weighing machine. Initial individual body weights of fishes were recorded at the time of initiation of the experiment and until the end of the study.

Estimation of fish growth, survival & yield in cage culture : Fish has been sampled monthly to assess the growth and to adjust the feeding ration. 50 fishes from each cage of the stocked fishes were measured in each sampling using scope net in each experimental cage. The following growth parameters were recorded:

Initial weight (g) = Weight of fish at stock
Final weight (g) = Weight of fish at harvest
Weight gain (g) = Mean final weight- Mean initial weight

$$\text{Percent weight gain (\%)} = \frac{\text{Final weight (g)} - \text{Initial weight (g)}}{\text{Initial weight (g)}} \times 100$$

$$\text{Specific growth rate (SGR, \% bwd}^{-1}) = \frac{L_n \text{ final weight} - L_n \text{ initial weight}}{\text{Culture Period}} \times 100 \text{ (Brown 1957)}$$

$$\text{Survival rate (\%)} = \frac{\text{No. fish harvested}}{\text{No. fish stocked}} \times 100$$

$$\text{Food conversion ratio} = \frac{\text{Feed given (dry weight)}}{\text{Total wet weight gain}}$$

Yield (Kg/cage): Fish biomass at harvest – Fish biomass at stocking

Economics of cage fish farming : At the end of the piloting, fishes were harvested and sold to local market. Cost-benefit analysis of different treatments were calculated on the basis of the cost of inputs and labor to be used; and the income from the sale of fishes. The following equation were used for the calculation of net return:

$$R = I - (Fc + Vc + Ii)$$

Where, *R refers to* net return; *I*, total income from fish sold; *Fc for* Fixed costs, *Vc for* variable costs and *Ii for* interests on input costs.

The prices will be expressed in Bangladesh Taka (BDT). All inputs and fish fingerlings will correspond to wholesale market prices of the project areas. Net benefit will be calculated by deducting the total cost from total income from fish sale. The cost-benefit ratio (CBR) will also be calculated using following formula:

BCR = Total revenue / Total cost

Statistical analysis for cage farming : All the data collected during the experiment were recorded in a data note book and then regularly inputted in a computer. At the end of the experiment all data were analyzed statistically using one way analysis of variance (ANOVA). The mean values were compared DMRT. SPSS statistical software (20.0 version) was used for all the analysis. Standard deviation (SD) of treatment means were calculated from the residual mean square in the analysis of variance. Probabilities of $p<0.05$ were considered to test significance level.

Plate 19. Repairing activities of cage nets.

Expt.- 2. Optimization of stocking density for cage fish farming (SAU)

Stocking density is an important factor in aquaculture as well as for cage fish farming. Higher stocking density caused a series of biochemical and physiological changes in fish (Conceiçao *et al.*, 2012). The negative impact of density on growth, survival, size heterogeneity, immune function, disease resistance and final products of farmed fish has been widely reported when raising catfish (Telli *et al.*, 2014). Density stress also known to affect the functioning of liver and kidneys and modulates metabolic activities in fish (Pakhira *et al.*, 2015). Stocking density also influences the economics of cage fish farming. This experiment was performed for finding out the appropriate stocking density of pangas, the best performing species from the previous experiment and tilapia, the widely cultured species in cage farming. All the methodologies followed as the experiment-I. In Ratargul Swamp Forest three stocking densities of pangas under the experiment were maintained *viz.* 30, 40 and 50 fish/m^3 and designated as treatment 1 (T_1), treatment 2 (T_2) and treatment 3 (T_3), respectively. On the other hand, tilapia was introduced in Gurukchi River maintained the stocking densities 40, 60 and 80 fish/m^3 with triplicate and designated as treatment 1 (T_1), treatment 2 (T_2) and treatment 3 (T_3), respectively. Feeding strategy remained same for all treatments in both study sites. Commercial floating feed was supplied starting with 10% body weight of fish and gradually reduced up to 3% body weight. Fish sampling were done every 15 days interval.

Plate 20. Fish samplings in cages.

Expt.- 3. Effects of supplementary feed on the production and economics of cage farming by Component 1

According to the fish farmers perception due to high price of supplementary feed profit margin in cage aquaculture is very low. This is why this experiment was designed as how to minimize the use of feed in a cost-effective way. Starving of fishes for few days within the culture period can be effective to reduce feed cost and to increase profit margin (Gaylord and Gatlin, 2000). Starving of fishes is a familiar strategy applied by fish farmer to reduce feed cost in fish in aquaculture as because being an important factor in commercial fish farming feed costs account for 40-60% of the production cost in fish culture (Marimuthu et al., 2011). Adequate feeding can overcome the effect of starvation and was also known to give faster growth than the continuously fed fish, which is called growth compensation. Based on the overall performance of the previous experiment's tilapia was considered for this trial. All the methodologies followed as the experiment-I only feeding strategy was different. There were three treatments with three replications each; daily feeding ratio (% body weight of fishes) was same but feeding frequency varies from treatments to treatments. In treatment-1 regular feeding were done, in treatment-2 fishes were unfed once in week and in treatment-3 fishes were unfed every three days interval.

Plate 21. Harvested fish from the cages.

10.2.16. Determination of coal mining effects on fishes

During April-May mass mortality occurred in Shari-Goyain River due to coal mining effluent comes from Meghalaya, India. To find out the effect of coal mining effluent immature post-spawnings and adult fishes were also collected from the Shari-Goyain River. Water and sediment samples were also collected for heavy metals and coal mine effluent analysis. After harvesting fishes were kept in secured enclosures overnight. In the next morning the fish samples were transported (up to 0.5 h) to the sampling stations and were kept in oxygenated bins until sampling in the same morning. Collected samples were kept in oxygenated bins and transported to the laboratory of the Department of Aquatic Resource Management, SAU. Fishes were then anesthetized with MS-222 (0.1 g L^{-1}), blood samples were collected from the caudal blood vessels and sacrificed by spinal transection. Plasma for cortisol, glucose, triodothyronine (T_3) and thyroxine (T_4) analyses were recovered (blood centrifuged for 5 min at 16,000 g) and flesh samples were frozen in liquid nitrogen. Carcasses were kept on ice (maximum 4 h) until dissection. Fork length, fish weight, sex, maturity and liver weight were recorded before colleting those samples. Condition factor [K = (weight×100)/length^3] and liver somatic index [LSI = (liver weight/body weight) ×100] were also calculated. Gills (Na^+/K^+ ATPase activity) were removed and were frozen in liquid nitrogen. Muscle samples taken from the left side of the fish body under the dorsal fin were analyzed for Mn, Zn, Fe, Pb, Cu, Cr, Cd and Se contents. All dried samples were analyzed in the Interdisciplinary Institute for Food Security, BAU, Mymensingh; Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka and SGS Bangladesh Limited, Dhaka.

Plate 22. Dissection and separation of different fish organs for heavy metal analysis.

10.2.16.1. Biochemical analyses : For biochemical analysis blood samples for Boal (*Wallago attu*) were collected directly from the river and kept into appendrop tube and taken to the laboratory using a icebox. Cortisol, total T_3 and total T_4 were measured with radioimmunoassay kits (Medicorp, Montréal, Québec, Canada). Glucose was determined by incubating (60 minutes at 23°C) the samples with GOD-PAP reagent (Roche Diagnostic, Laval, Québec) and the absorbance was measured at 510 nm. All the sample were tested in the Microbiology Laboratory of Faculty of Veterinary, Animal and Biomedical Sciences, SAU.

11. Results and discussion (combined)

11.1.1. Status of fish biodiversity in the Shari-Goyain River and adjacent waters

During the sub-project period 88 species of indigenous fishes belonging to 26 families and 11 orders were identified in the Shari-Goyain River and adjacent waters where the Shari-Goyain River, the Gurukchi River and Ratargul swamp forest contributed 69, 62 and 72 species, respectively. A total of 126 fish species covering 39 families were recorded from Sunamganj district (Mahalder & Mustafa, 2013) which was much more higher fish diversity comparing with the present study. However, this study covers 62.41% indigenous fish species living in the *haor* basin (141) of Bangladesh (BHWDB, 2012). List of available fish species with their taxonomic position (order and family name), scientific name, English name, local name, present status, conservation status, and population trends in Bangladesh and global aspects are presented in Table 6.

Table 6. List of recorded fish species in the Shari-Goyain River

Sl. no.	Taxonomic position	English name	Local name	Present status	Conservation status		Population trend	
					BD	Global	BD	Global
	Beloniformes							
	Belonidae							
1	*Xenentodon cancila*	Freshwater garfish	Kaikya, kakila	RA	LC	LC	UN	UN
	Clupeiformes							
	Clupeidae							
2	*Corica soborna*	The Ganges river sprat	Kachki	MA	LC	LC	UN	UN
3	*Tenualosa ilisha*	Hilsa	Ilish	MA	LC	LC	IN	DE
4	*Gudusia chapra*	Indian river shad	Chapila	CA	VU	LC	DE	DE
	Cypriniformes							
	Cyprinidae							
5	*Amblypharyngodon mola*	Mola carplet	Mola	CA	LC	LC	DE	ST
6	*Esomus danricus*	Flying barb	Darkina	MA	LC	LC	DE	ST
7	*Osteobrama cotio*	Cotio	Dhela	MA	NT	LC	DE	UN
8	*Megarasbora elanga*	Bengala barb	Elong	RA	EN	LC	DE	UN
9	*Salmophasia bacaila*	Large razorbelly minnow	Katari chela	CA	LC	LC	DE	ST
10	Salmophasia phulo	Finescale razorbelly minnow	Fulchela	AA	NT	LC	DE	UN
11	*Gibelion catla*	Catla	Catla	MA	LC	LC	DE	UN
12	*Cirrhinus cirrhosis*	Mrigal carp	Mrigal	MA	NT	VU	DE	DE
13	*Cirrhinus reba*	Reba carp	Laccho	AA	NT	LC	DE	ST
14	*Devario devario*	Sind danio	Chapchela	RA	LC	LC	DE	UN
15	*Labeo angra*	Angra labeo	Kharish	RA	LC	LC	UN	ST
16	*Labeo bata*	Bata labeo	Bata	CA	LC	LC	UN	UN
17	*Labeo calbasu*	Black rohu	Kalibaosh	AA	LC	LC	IN	UN
18	*Labeo gonius*	Kuria labeo	Gonia	CA	NT	LC	DE	UN
19	*Labeo pangusia*	Pangusia labeo	Ghora maach	RA	EN	NT	DE	DE
20	*Labeo rohita*	Rohu	Rui	MA	LC	LC	DE	UN
21	*Pethia conchonius*	Rosy barb	Kanchan punti	RA	LC	LC	UN	UN
22	*Pethia guganio*	Glass barb	Mola punti	RA	LC	LC	UN	UN
23	*Pethia phutunio*	Spottedsail barb	Phutani punti	MA	LC	LC	UN	UN
24	*Systomus sarana*	Olive barb	Sarpunti	CA	NT	LC	DE	UN
25	*Puntius sophore*	Spotfin swamp barb	Jat punti	AA	LC	LC	UN	UN

Sl. no.	Taxonomic position	English name	Local name	Present status	Conservation status		Population trend	
					BD	Global	BD	Global
26	*Pethia ticto*	Ticto barb	Tit punti	RA	VU	LC	DE	UN
	Balitoridae							
27	*Acanthocobitis botia*	Sand loach	Balichata	MA	LC	LC	UN	UN
28	*Acanthocobitis zonalternans*	River loach	Bali gutum	MA	LC	LC	UN	UN
	Cobitidae							
29	*Botia Dario*	Queen loach	Rani mach	MA	EN	LC	UN	UN
30	*Lepidocephalichthys annandalei*	Annaldale loach	Gutum	MA	VU	LC	DE	UN
31	*Lepidocephalichthys guntea*	Guntea loach	Gutum	CA	LC	LC	DE	ST
32	*Canthophrys gongota*	Gongota loach	Ghora gutum	CA	NT	LC	DE	UN
	Cyprinodontiformes							
	Aplocheilidae							
33	*Aplocheilus panchax*	Blue panchax	Kanpona	RA	LC	LC	UN	UN
	Mugiliformes							
	Mugilidae							
34	*Rhinomugil corsula*	Corsula	Corsula	MA	LC	LC	UN	UN
	Osteoglossiformes							
	Notopteridae							
35	*Notopterus notopterus*	Grey featherback	Kanla	CA	VU	LC	DE	ST
	Perciformes							
	Gobiidae							
36	*Glossogobius giuris*	Bareye goby	Baila	MA	LC	LC	UN	UN
	Channidae							
37	*Channa punctate*	Spotted snakehead	Lati	RA	LC	LC	DE	ST
38	*Channa striata*	snakehead murrel	Shol	MA	LC	LC	DE	ST
	Badidae							
39	*Badis badis*	Blue perch	Napit koi	RA	NT	LC	UN	UN
	Ambassidae							
40	*Chanda nama*	Elongate glass perchlet	Lomba chanda	CA	LC	LC	DE	DE
41	*Parambassis lala*	Highfin glassy perchlet	Ranga chanda	MA	LC	NE	UN	DE
42	*Pseudambassis ranga*	Indian glassy fish	Gol chanda	AA	LC	LC	UN	ST
	Sciaenidae							
43	*Johnius coitor*	Big-eyed jewfish	Poa	MA	LC	LC	UN	ST
	Nandidae							
44	*Nandus nandus*	Mud perch	Bheda	RA	NT	LC	DE	UN

Sl. no.	Taxonomic position	English name	Local name	Present status	Conservation status		Population trend	
					BD	Global	BD	Global
	Anabantidae							
45	*Anabas testudineus*	Climbing perch	Koi	MA	LC	LC	UN	ST
	Siluriformes							
	Schilbeidae							
46	*Eutropiichthys vacha*	Batchwa vacha, bacha	Bacha	MA	LC	LC	DE	DE
47	*Neotropius atherinoides*	Indian potasi	Batasi, bashpata	AA	LC	LC	DE	UN
48	*Ailia coila*	Gangetic ailia	Kajuli, bashpata	MA	LC	NT	UN	DE
49	*Clupisoma garua*	Garua bacha	Ghaura	RA	EN	LC	DE	DE
	Bagridae							
50	*Batasio batasio*	Tista batasio	Bali tengra	MA	NT	LC	DE	UN
51	*Hemibagrus menoda*	Menoda catfish	Ghagla	AA	NT	LC	DE	UN
52	*Mystus bleekeri*	Bleeker's mystus	Gulsha tengra	MA	LC	LC	UN	UN
53	*Mystus cavasius*	Gangetic mystus	Golsha	AA	NT	LC	DE	DE
54	*Mystus tengara*	Tengara mystus	Bujuri tengra	CA	LC	LC	UN	UN
55	*Mystus vittatus*	Asian striped catfish	Tengra	MA	LC	LC	UN	DE
56	*Rita rita*	Rita	Rita, rida	MA	EN	LC	DE	DE
57	*Sperata aor*	Long-whiskered catfish	Ayre	CA	VU	LC	DE	ST
58	*Sperata seenghala*	Giant river-catfish	Guijja ayre	AA	VU	LC	DE	UN
	Siluridae							
59	*Ompok bimaculatus*	Butter catfish	Kani pabda	CA	EN	NT	DE	UN
60	*Ompok pabda*	Two stripe gulper catfish	Madhu pabda	CA	EN	NT	DE	DE
61	*Wallago attu*	Freshwater shark	Boal	AA	VU	VU	DE	DE
	Sisoridae							
62	*Bagarius bagarius*	Gangetic goonch	Baghair	RA	CR	NT	DE	DE
63	*Gagata cenia*	Indian gagata	Konkot	CA	LC	LC	UN	UN
	Chacidae							
64	*Chaca chaca*	Squarehead or angler catfish	Chaka	CA	EN	LC	DE	DE
	Synbranchiformes							
	Mastacembelidae							

Sl. no.	Taxonomic position	English name	Local name	Present status	Conservation status		Population trend	
					BD	Global	BD	Global
65	*Macrognathus aral*	One-stripe spiny eel	Tara baim	MA	DD	LC	UN	ST
66	*Macrognathus aculeatus*	One-stripe spiny eel	Tara baim	MA	NT	NE	UN	UN
67	*Mastacembelus armatus*	Spiny eel	Sal baim	AA	EN	LC	DE	ST
68	*Macrognathus pancalus*	Stripped spiny eel	Chikra baim	MA	LC	LC	DE	UN
	Tetraodontiformes							
	Tetraodontidae							
69	*Tetraodon cutcutia*	Ocellated puffer fish	Potka	AA	LC	LC	UN	UN

*NE = Not Evaluated, NT = Near Threatened, LC = Least Concerned, VU = Vulnerable, EN = Endangered, DD = Data Deficient, CR = Critically Endangered, IN = Increasing, ST = Stable, DE = Decreasing, UN = Unknown

In the Shari-Goyain River, a total of 69 species of indigenous fish species covering 22 family and 10 oreders were documented during catch assessment. Chowdhury *et al.* (2019) reported 51 indigenous fish species under 16 families from the Surma River which is lower than the present study. Hossain *et al.* (2017) and Islam *et al.* (2019) enlisted 74 fish species of 22 families and 75 fish species of 25 families in the Kushiyara and the Juri Rivers, respectively which are almost similar to the result of the present study. The possible reasons behind the lower number of fish species in the river are due to the geographical location, and poor water quality of the river.

11.1.2. Seasonal variation of fish species diversity in the Shari-Goyain River

Seasonal variation of species diversity was observed in the Shari-Goyain River where maximum number of fish species was found during the post monsoon season (48-50 species) followed by monsoon (40-46 species), winter (35-39 species), and pre-monsoon (25-39 species) (Fig 6). In Sylhet region rain usually begins in the pre-monsoon season, and thus this is the peak breeding time for most of the fish species. There is a familiar concept that fish diversity increases with increasing water depth but maximum number of fish species harvested by the fishers in the post monsoon season. For this reason highest biodiversity (catch data based) was observed in the post monsoon season. The lowest number of fish species in the Shari-Goyain River was found in pre-monsoon season. It is supposed to be due to acute exposure of chemicals comes with the coal mining effluent from upper stream of Meghalaya, India and fish kill incidences happened during April and May every year. In April-May 2019 and 2020, we found excess amount of coal mine drainage made the aquatic habitat toxic results mass mortality of fishes and the local people including fishers harvested the dead and moribund fishes easily. On the other hand, a lot of moribund fishes are found floating on the water surface and moving downstream with the flow of water.

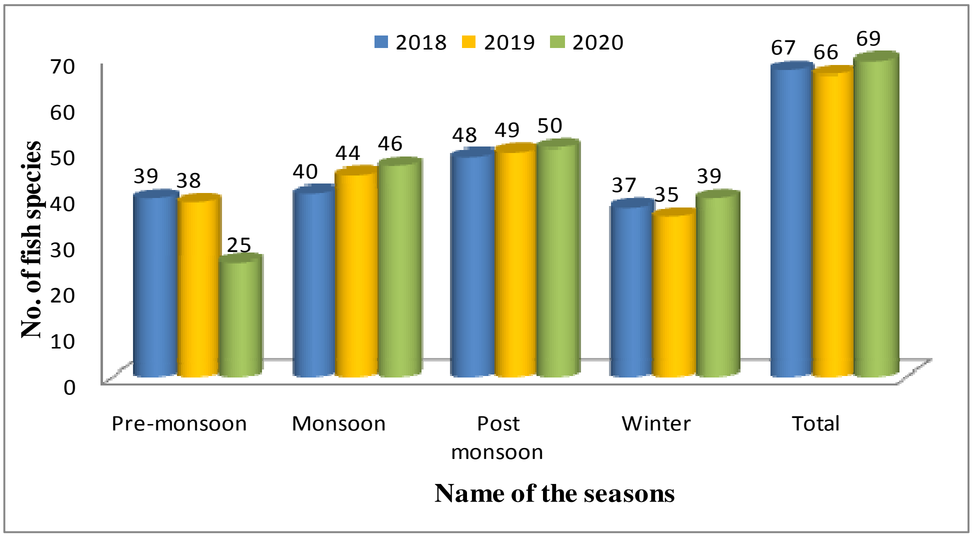


Fig 6: Seasonal variation of indigenous fish diversity in the Shari-Goyain River.

11.1.3. Status of fish biodiversity in the Kura River

During sub-project period 71 species of native fish species belonging to 22 families and 10 orders were assessed in the Kura River. List of available fish species with their taxonomic position (order and family name), scientific name, English name, local name, present status, conservation status, and population trends in Bangladesh and global aspects are presented in Table 7.

Table 7. List of recorded fish species in the Kura River

Sl. no.	Taxonomic position	English name	Local name	Present status	Conservation status		Population trend	
					BD	Global	BD	Global
	Beloniformes							
	Belonidae							
1	*Xenentodon cancila*	Freshwater garfish	Kakila	AA	LC	LC	UN	UN
	Clupeiformes							
	Clupeidae							
2	*Corica soborna*	The Ganges river sprat	Kachki	AA	LC	LC	UN	UN
3	*Gudusia chapra*	Indian river shad	Chapila	AA	VU	LC	DE	DE
	Cypriniformes							
	Cyprinidae							
4	*Amblypharyngodon mola*	Mola carplet	Mola	RA	LC	LC	DE	ST
5	*Amblypharyngodon microlepis*	Indian carplet	Mola	CA	LC	LC	DE	UN
6	*Chela cachius*	Silver hatchlet barb	Chela	AA	VU	LC	DE	UN

Sl. no.	Taxonomic position	English name	Local name	Present status	Conservation status		Population trend	
					BD	Global	BD	Global
7	*Esomus danricus*	Flying barb	Darkina	MA	LC	LC	DE	ST
8	*Osteobrama cotio*	Cotio	Dhela	RA	NT	LC	DE	UN
9	*Rasbora daniconius*	Slender barb	Darkina	MA	LC	LC	DE	UN
10	*Salmophasia acinaces*	Silver razorbelly minnow	Chela	MA	LC	LC	UN	UN
11	*Salmophasia bacaila*	Razorbelly minnow	Katari chela	MA	LC	LC	DE	ST
12	*Gibelion catla*	Catla	Catla	MA	LC	LC	DE	UN
13	*Cirrhinus cirrhosis*	Mrigal carp	Mrigal	CA	NT	VU	DE	DE
14	*Cirrhinus reba*	Reba carp	Lasso	MA	NT	LC	DE	ST
15	*Devario devario*	Sind danio	Chapchela	MA	LC	LC	DE	UN
16	*Labeo angra*	Angra labeo	Raiya	MA	LC	LC	UN	ST
17	*Labeo calbasu*	Black rohu	Kalibaosh	CA	LC	LC	IN	UN
18	*Labeo gonius*	Kuria labeo	Gonia	CA	NT	LC	DE	UN
19	*Labeo rohita*	Rohu	Rui	MA	LC	LC	DE	UN
20	*Puntius chola*	Chola barb	Chola punti	RA	LC	LC	UN	UN
21	*Pethia conchonius*	Rosy barb	Kanchan punti	RA	LC	LC	UN	UN
22	*Systomus sarana*	Olive barb	Sarpunti	CA	NT	LC	DE	UN
23	*Puntius sophore*	Spotfin swamp barb	Jat punti	AA	LC	LC	UN	UN
24	*Pethia ticto*	Ticto barb	Tit punti	RA	VU	LC	DE	UN
	Cobitidae							
25	*Botia Dario*	Queen loach	Rani mach	MA	EN	LC	UN	UN
26	*Botia rostrata*	Gangetic loach	Rani mach	MA	DD	VU	UN	DE
27	*Botia lohachata*	Reticulate loach	Rani mach	RA	EN	NE	DE	UN
28	*Lepidocephalichthys annandalei*	Annaldale loach	Gutum	RA	VU	LC	DE	UN
29	*Lepidocephalichthys guntea*	Guntea loach	Gutum	CA	LC	LC	DE	ST
30	*Canthophrys gongota*	Gongota loach	Ghora gutum	RA	NT	LC	DE	UN
	Cyprinodontiformes							
	Aplocheilidae							
31	*Aplocheilus panchax*	Blue panchax	Kanpona	MA	LC	LC	UN	UN

Sl. no.	Taxonomic position	English name	Local name	Present status	Conservation status		Population trend	
					BD	Global	BD	Global
	Mugiliformes							
	Mugilidae							
32	*Rhinomugil corsula*	Corsula	Corsula	RA	LC	LC	UN	UN
	Osteoglossiformes							
	Notopteridae							
33	*Chitala chitala*	Humped featherback	Chital	RA	EN	NT	DE	DE
34	*Notopterus notopterus*	Grey featherback	Kanla	CA	VU	LC	DE	ST
	Perciformes							
	Gobiidae							
35	*Glossogobius giuris*	Bareye goby	Baila	RA	LC	LC	UN	UN
	Channidae							
36	*Channa marulius*	Giant snakehead	Gazar	CA	EN	LC	DE	UN
37	*Channa punctate*	Spotted snakehead	Lati	AA	LC	LC	DE	ST
38	*Channa striata*	Murrel	Shol	CA	LC	LC	DE	ST
	Badidae							
39	*Badis badis*	Blue perch	Napit koi	MA	NT	LC	UN	UN
	Ambassidae							
40	*Chanda nama*	Elongate glass perchlet	Lomba chanda	MA	LC	LC	DE	DE
41	*Parambassis baculis*	Himalayan glassy perchlet	Kata chanda	RA	NT	LC	DE	DE
42	*Parambassis lala*	Highfin glassy perchlet	Ranga chanda	MA	LC	NE	UN	DE
43	*Pseudambassis ranga*	Indian glassy fish	Gol chanda	CA	LC	LC	UN	ST
	Sciaenidae							
44	*Johnius coitor*	Big-eyed jewfish	Poa	RA	LC	LC	UN	ST
	Nandidae							
45	*Nandus nandus*	Mud perch	Bheda	CA	NT	LC	DE	UN
	Anabantidae							
46	*Anabas testudineus*	Climbing perch	Koi	MA	LC	LC	UN	ST
	Osphronemidae							
47	*Trichogaster fasciata*	Banded gourami	Bara khailsha	RA	LC	LC	UN	UN
48	*Trichogaster labiosa*	Thick-lipped gourami	Khalisha	AA	LC	LC	UN	UN
49	*Trichogaster lalius*	Red gourami	Lal khailsha	MA	LC	LC	UN	UN

Sl. no.	Taxonomic position	English name	Local name	Present status	Conservation status		Population trend	
					BD	Global	BD	Global
	Siluriformes							
	Schilbeidae							
50	*Eutropiichthys vacha*	Batchwa vacha, bacha	Bacha	RA	LC	LC	DE	DE
51	*Neotropius atherinoides*	Indian potasi	Batasi, bashpata	MA	LC	LC	DE	UN
52	*Ailia punctate*	Jamuna ailia	Bashpata	CA	LC	DD	UN	UN
53	*Clupisoma garua*	Garua bacha	Ghaura	RA	EN	LC	DE	DE
	Bagridae							
54	*Hemibagrus menoda*	Menoda catfish	Ghagla	CA	NT	LC	DE	UN
55	*Mystus bleekeri*	Bleeker's mystus	Gulsha tengra	MA	LC	LC	UN	UN
56	*Mystus cavasius*	Gangetic mystus	Golsha	CA	NT	LC	DE	DE
57	*Mystus tengara*	Tengara mystus	Bujuri tengra	AA	LC	LC	UN	UN
58	*Mystus vittatus*	Asian striped catfish	Tengra	AA	LC	LC	UN	DE
59	*Sperata aor*	Long-whiskered catfish	Ayre	RA	VU	LC	DE	ST
60	*Sperata seenghala*	Giant river-catfish	Guijja ayre	CA	VU	LC	DE	UN
	Siluridae							
61	*Ompok bimaculatus*	Butter catfish	Kani pabda	CA	EN	NT	DE	UN
62	*Ompok pabda*	Two stripe gulper catfish	Madhu pabda	MA	EN	NT	DE	DE
63	*Ompok pabo*	Pabo catfish	Pabda	RA	CR	NT	DE	DE
64	*Wallago attu*	Freshwater shark	Boal	AA	VU	VU	DE	DE
	Sisoridae							
65	*Bagarius bagarius*	Gangetic goonch	Baghair	RA	CR	NT	DE	DE
	Synbranchiformes							
	Synbranchidae							
66	*Monopterus cuchia*	Gangetic mudeel	Kuchia	MA	VU	LC	DE	UN
	Mastacembelidae							
67	*Macrognathus aral*	One-stripe spiny eel	Tara baim	CA	DD	LC	UN	ST
68	*Macrognathus aculeatus*	One-stripe spiny eel	Tara baim	MA	NT	NE	UN	UN

Sl. no.	Taxonomic position	English name	Local name	Present status	Conservation status		Population trend	
					BD	Global	BD	Global
69	*Mastacembelus armatus*	Spiny eel	Sal baim	AA	EN	LC	DE	ST
70	*Macrognathus pancalus*	Stripped spiny eel	Chikra baim	MA	LC	LC	DE	UN
	Tetraodontiformes							
	Tetraodontidae							
71	*Tetraodon cutcutia*	Ocellated puffer fish	Potka	CA	LC	LC	UN	UN

*NE = Not Evaluated, NT = Near Threatened, LC = Least Concerned, VU = Vulnerable, EN = Endangered, DD = Data Deficient, CR = Critically Endangered, IN = Increasing, ST = Stable, DE = Decreasing, UN = Unknown

11.2.1. Baseline survey findings of *SUST component*

The baseline survey was conducted in the year 2020. It was found that 98% of respondents had no skill, training, or education other than fishing to involve higher earning activates. All the respondents mentioned that they are looked down upon by the non-fishers due to their occupation. Around 63% of the respondents told that there is no fishermen association in their village. But a section (28%) told that they are the members of fishermen association. It was found that the original fishers had poor idea to form fishers association where as a section of the fishers participated and became members of fishers association as they were hired by the non-fisher majority people who are mainly fish traders and locally influenced. These non-fishers motivate a group of fishers to form fishers' association to get lease from the government. This type of fake fishermen association is large number. In this process the identity of original fishers is being sold to non-fishers which ultimately uproot original fishers from their ancestral occupation.

According to FGD participants the poor genuine fishers did not take part in leasing process due to lack of money, complex process, and threat by non-fisher lease holders. As the total process runs with illegal procedures, powerless poor fishers had a tendency to hide the original scenario fearing discrimination and loss of income. As the lease holders deploy most of the poor fishers in their leased water bodies as day laborers (around 69% of fishers work as fish laborers) or share harvesters, it was perceived that they did not show their interest to share the hidden reality and explained themselves as lease holders.
According to FGD participants and KIIs powerful non-fishers take lease making fake fishermen association where fishers work there as laborers and get some money as their names are used in making association. More than 85% of the respondents are against leasing system arguing that this practice uproots them from water bodies and lease holders destroy fish through over fishing. More than 90% opined those fishes are decreased due to overfishing and due to pollution. 70% have shown their desire to continue their profession but they want actions for regaining fish varieties in which they are willing to participate.

Economic and social vulnerability and lack of education was identified as major reason for their incapability to get access to water bodies and market system. Almost all the fishers noticed that they sale their caught fishes on the spot and that is why do not get proper prices. According to them, brokers control the whole market system where they have no direct access to that. Due to their poor income most of the fishers cannot afford better education, food and shelter and treatment for their children and other family members. However, almost all (92%) of the respondents were conscious about the importance of conservation of fish biodiversity in *haors* and other adjacent water bodies. They identified overfishing, pollution, and interruption on water bodies as major reasons for the decrease of fish varieties in their locality. They noticed how fish varieties are decreasing in their adjacent water bodies. Research team practically observed how polluted water cause sudden death of fishes and other aquatic lives. According to the respondents, usually during the months of March and April polluted water comes from India and suddenly kills the local fishes in some points mainly Ratargul swamp forest adjacent area of Shari-Goyain River and also the Shari point of the same river. The fishers had little idea about the source and nature of water that pollute water bodies located inside Bangladesh. They observed that this water usually comes in the month of March and April and kills fishes with eggs. They suggested for actions for stopping all those reasons with the collaborative actions of India and Bangladesh Government. Few (22%) also told about siltation process and they perceived that siltation has become a problem for the existence of fish varieties. Some (19%) told that large size engine-run boats carry sands and stones through this river and that is why large fishes are dying regularly being injured by engine-run boats propellers. Most of the fishers identified the current practice of leasing system, which usually allows non fishers powerful people to get access in water bodies. These lease holders are always in the motive for maximizing benefits from the leased water bodies. Naturally they catch fish indiscriminately. Dewatering of water bodies for fishing is commonly seen in the study areas. Respondents opined that the leasing practice should be fishermen friendly and the concern government agencies should be caring about the necessity of protecting fish varieties in studied water bodies. They requested for intruding alternative income generation activities for the fishers so that they can survive with less involvement of water bodies so that indiscriminate fishing is stopped. They suggested for a revised policy through which genuine fishers can get easy access to water bodies as lease holders. However, the following key findings are mentioned below:

- Around 44% of respondents were illiterate.
- Around 98% of the respondents were single bread earners of their families.
- 66% of the respondent's monthly family income was less than 10 thousand taka.
- Around 96% of the respondents mentioned their income as insufficient to fulfill their basic needs and survive taking loan from informal sectors-relatives.
- In addition to fishing around 95% of them have to depend upon day laboring and other earning activities.
- 98% had no skill, training, or education to involve higher earning activates.
- All the respondents mentioned that they are looked down upon by the non-fishers due to their occupation.
- 63% of the respondents told that there is no fishermen association in their village.
- 28% told that they are the members of fishermen association.
- Around 80% did not take part in leasing process due to lack of money, complex process, and threat by non-fisher lease holders.
- Interestingly, around 46% of the respondents told that the lease holders are fishermen.

- According to FGD participants and KIIs powerful non-fishers take lease making fake fishermen association where fishers work there as laborers and get some money as their names are used in making association.
- Around 70% of fishers work as fish laborers.
- More than 85% of the respondents are against leasing system arguing that this practice uproots them from water bodies and lease holders destroy fish through overfishing.
- More than 90% opined that fishes are decreased due to overfishing and due to pollution.
- 70% have shown their desire to continue their profession but they want actions for regaining fish varieties in which they are willing to participate.
- Economic and social vulnerability and lack of education was identified as major reason for their incapability to get access to water bodies and market system.
- Almost all the fishes families are found with lack of essential commodities for survival.
- Skills additional income was not mentionable. One local government member (Female Word Member) in their community took initiative to train women in the community of a research site but she failed due to lack of interest of the people. A few rear duck and sale eggs at small scale to brokers.
- Sanitation facility and sources of drinking water was not satisfactory and most of respondents noticed that they have no hygienic sanitary latrine at their home, and they have to share one tube well for drinking water and some are drawn down during rainy season.

11.3.1. Baseline survey findings of *Chalan beel*

At the beginning of the present study, a baseline survey on 200 respondents (100 from site 1: Singra and 100 from site 2: Chatmohor) was conducted to find out the success and failure of the existing fish sanctuaries in the study areas and to know the causes of decreasing fish biodiversity in Chalan beel. Therefore, existing condition of the fish sanctuaries established earlier were evaluated. Data regarding 40 sanctuaries was found; whereas 16 were in well managed and 24 were in miss managed condition (Table 8).

Table 8. Present scenario of existing condition of fish sanctuaries in Chalan *beel*

Location	Upazila	Declared Sanctuary	Well Managed	Miss Managed
Naogaon	Atrai	1	1	-
Natore	Sadar	3	3	-
	Noldanga	6	3	3
	Singra	**8**	**2**	**6**
	Gurudaspur	4	2	2
	Boraigram	6	2	4
Sirajganj	Tarash	3	-	3
Pabna	**Chatmohar**	**4**	**1**	**3**
	Bhangura	5	2	3
Total		40	16	24

11.3.2. Success of previously established fish sanctuary in Chalan beel

The existing sanctuaries (previously made by DoF and other non-government organisations) impart a positive image on overall increment in fish productivity, biodiversity conservation and improvement in environmental and social status of local people (Fig 7) in Chalan Beel. 90% of the respondent from Site-1 and 88% of the respondent from Site-2 believe that existing sanctuaries increased fish productivity than before. They also believe (85% from Site-1 and 89% from Site-2) that existing sanctuaries conserved the biodiversity of the fishes in Chalan beel. Although the respondents from the both study sites were not concerned about the environmental issues, 75% from Site-1 and 81% from Site-2 responded on behalf of the positive role the sanctuaries have on the environment of Chalan beel. Interviewed respondents also found existing sanctuaries as a major source for their socio-economic improvement. They had reported higher fish catch and higher daily income from the adjacent areas of the existing sanctuaries. As shown in Fig 7, 95% from Site-1 and 97% from Sit -2 talk about their socio-economic improvement.

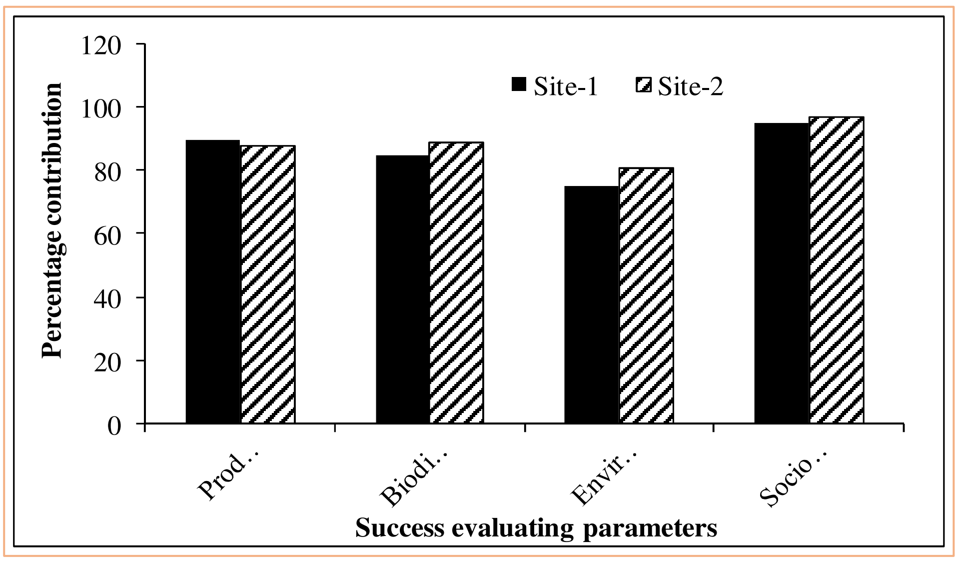
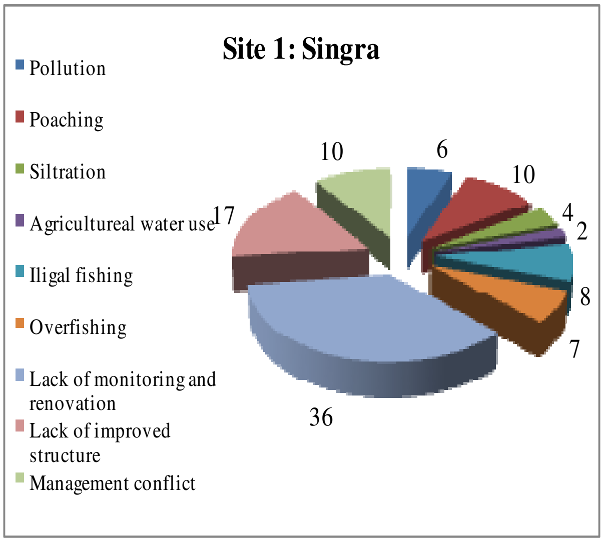


Fig 7. Success evaluating parameters of existing fish sanctuaries of Chalan beel**.**

11.3.3. Causes of failure of fish sanctuary

The respondents of the present study also asked for their opinion on the failure of the existing sanctuaries that was made by DoF and other non-government organisations. After the evaluation of respondent observation, the study identified lack of monitoring and renovation, and lack of improved structure as the main causes for the failure of existing fish sanctuary (Fig 7). The interviewed respondent of the two study sites also reported that complete dewatering were the most dangerous causes of biodiversity loss of the Chalan beel area and the second major issue for decreasing biodiversity of fish in Chalan beel was Khata fishing (Figs 8 & 9).



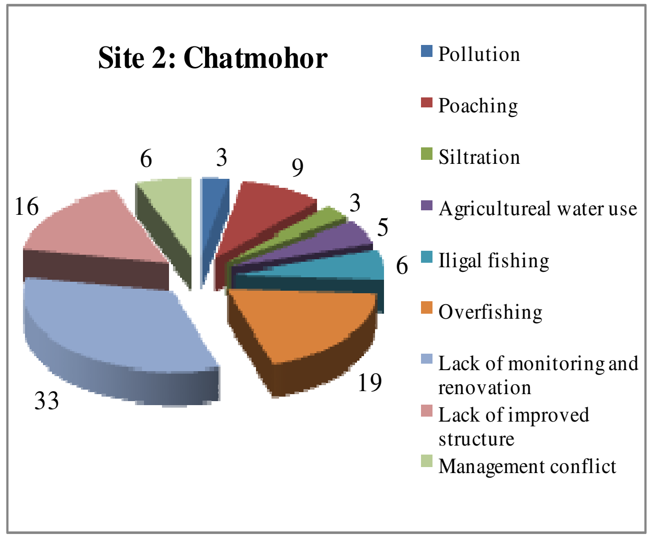
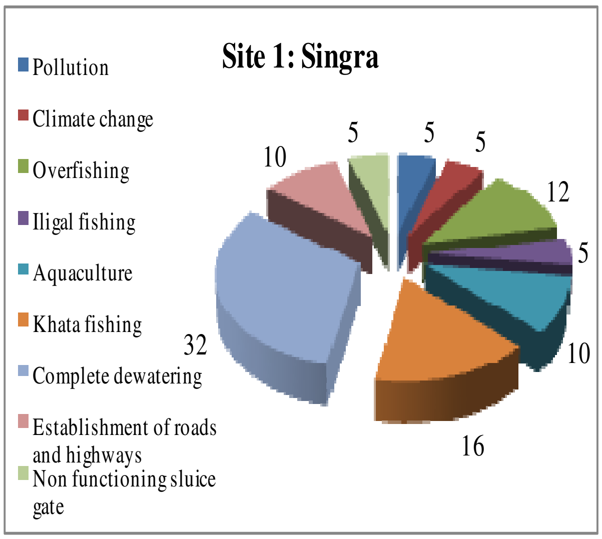


Fig 8. Perception on failure of fish sanctuary.



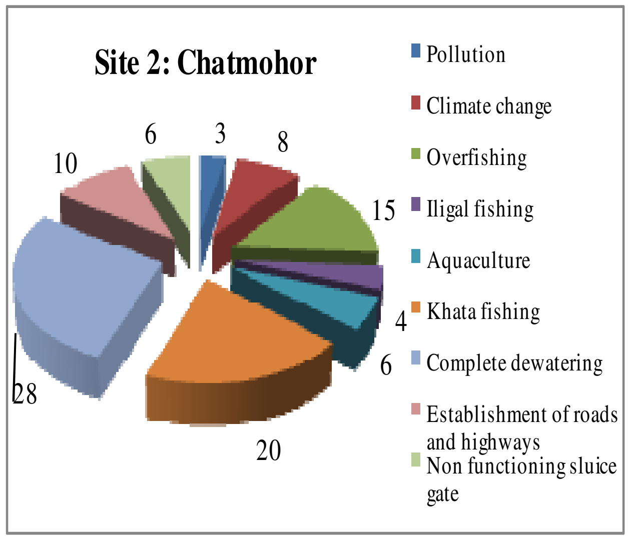


Fig. 9. Perception on loss of biodiversity from Chalan beel.

Again the perception of the respondents was also evaluated for their overall knowledge on fish sanctuaries (Table 9). 95% of the respondent from Site-1 and 96% from Site-2 believed that their fish catch has been decreased from the past. 65% and 60% respondent have knowledge on the impact of fish sanctuary at Site-1 and Site-2, respectively. However, majority of the respondent believe that establishment of well-structured sanctuary and stocking of fish species in that sanctuary might improve their livelihood condition.

Table 9. Base line survey on fish sanctuary

Survey items	Site 1		Site 2	
	Yes (%)	No (%)	Yes (%)	No (%)
Has your fish catch decreased using the same fishing effort as before?	95	5	96	4
Have any knowledge about the impacts of fish sanctuary?	65	35	60	40
Do you believe that fish sanctuary can increase the fisheries diversity?	86	14	89	11
Do you believe that fish sanctuary can increase the livelihood of the fishermen?	75	25	70	30
Is the exiting fish sanctuaries are sufficient?	7	93	6	94
What is your opinion about the use of ring pipes and hexapods in fish sanctuary?	76	24	70	30
Do you support a stocking program in fish sanctuary?	96	4	95	5
Do you think stocking can improve fish populations?	98	2	96	4

11.3.4. Fish catch and species diversity

During the baseline survey period, fish species abundance and their diversity was also evaluated from the two study sites. A total of 72 fish species were observed in both of the study sites. Catch per unit effort of 4 selected fishing gears is shown in Table 10, whereas the highest CPUF was recorded from lift net in both of the study sites. The study also showed species composition by weight in Table 11. Number of species catch with fishing gears was found to vary monthly with the fluctuation of water depth in Chalan beel area (Fig 10). Higher catch was recorded during the month of December and January and the lower during May to August in each year. Higher abundance of fishes during December and January was mostly due to complete dewatering and catching of fishes, whereas increased water mass during May to August reduced the efficacy of fishing gear for catching fish.

Table 10. Catch per unit effort (CPUE) of the fishing gears used in the two study sites

Gear used	Catch per unit effort (catch/hour)	
	Site 1	Site 2
Push net	0.10	0.12
Lift net	0.48	0.43
Cast net	0.19	0.21
Hooks	0.18	0.16

Table 11. List of abundance and % catch of fish species collected from two study sites.

Species name	Site-1		Site-2	
	Abundance	Catch (% weight)	Abundance	Catch (% weight)
Amblypharyngodon mola	VC	3.00	VC	3.00
Aristichthys nobilis	VC	1.50	VC	2.00
Catla catla	C	4.00	VC	3.00
Cirrhinus reba	R	-	R	-

Species name	Site-1		Site-2	
	Abundance	Catch (% weight)	Abundance	Catch (% weight)
Cirrhinus mrigala	VC	15.00	C	4.00
Ctenopharyngodon idella	C	6.00	C	8.00
Hypopthalmichthys molitrix	C	2.00	C	3.00
Oreochromis mossambicus	C	0.36	C	0.52
Cyprinus carpio var specularis	VC	1.20	VC	1.52
Cypricus carpio var communis	VC	1.00	VC	1.22
Oreochromis niloticus	C	6.00	C	6.00
Labeo calbasu	R	0.00	R	-
Labeo bata	C	2.00	C	1.00
Labeo rohita	VC	2.00	VC	2.36
Puntius chola	C	0.20	R	-
Puntius conchonius	R	-	R	-
Puntius phutunio	R	-	R	-
Puntius sophore	C	0.80	VC	2.00
Puntius sarana	R	-	R	-
Pantius gonionotus	C	0.20	C	0.52
Pangasius hypophthalmus	C	0.50	C	0.45
Pangasius pangasius	R	-	R	-
Rohtee cotio	R	-	R	-
Salmostoma bacaila	C	2.00	VC	8.00
Esomous danricus	VC	10.00	VC	7.00
Botia Dario	R	-	R	-
Danio devario	R	-	R	-
Botia lohachata	R	-	R	-
Lepidocephalus guntia	R	-	C	0.50
Aplocheilus panchax	C	0.20	VC	6.00
Somileptus gongota	R	-	R	-
Chanda nama	C	0.60	VC	5.00
Chanda ranga	C	1.00	VC	3.00
Chanda lala	C	0.45	C	0.89
Anabus testudineus	C	1.00	C	2.00
Glossogobius giuris	C	0.60	C	0.60
Colisa fasciata	VC	3.00	VC	1.00
Trichogaster chuna	C	0.10	C	0.50
Mastacembelus armatus	C	0.50	C	0.40
Macrognathus aculeatus	C	0.50	VC	3.00
Macrohnathus pancalus	C	0.12	C	0.56
Nandus nandus	R	-	R	-
Acanthocobities botia	R	-	R	-
Badis badis	R	-	R	-
Channa orientalis	C	0.60	C	1.00
Channa marulius	R	-	R	-
Channa punctate	C	0.30	C	0.50
Channa striata	R	-	R	-
Mystus aor	R	-	R	-
Mystus cavasius	R	-	R	-
Mystus seenghala	R	-	R	-
Mystus menoda	R	-	R	-
Mystus tengara	C	0.20	VC	4.00
Rita rita	R	-	R	-
Clarias batrachus	VC	5.00	VC	3.00

Species name	Site-1		Site-2	
	Abundance	Catch (% weight)	Abundance	Catch (% weight)
Pseudeutropius atherinoides	C	0.36	C	1.11
Heteropneustes fossilis	VC	1.23	VC	1.00
Ailia coila	C	0.52	C	0.52
Ailia punctate	C	0.50	C	0.50
Tetradon cutcutia	C	0.21	C	0.75
Gudusia chapra	VC	1.45	VC	1.23
Xenentodon cancila	VC	1.50	VC	1.50
Clupisoma garua	R	-	R	-
Chaca chaca	R	-	R	-
Eutropiichthys vacha	VC	8.00	VC	1.19
Ompok pabda	C	1.00	C	1.44
Ompok bimaculatus	R	-	C	0.60
Gagata cenia	R	-	R	-
Wallago attu	C	1.00	C	0.40
Monopterus cuchia	C	1.30	C	0.50
Notopterus chitala	C	6.00	C	0.20
Notopterus notopterus	R	-	C	0.52

*VC = Very Common, C = Common, R = Rare

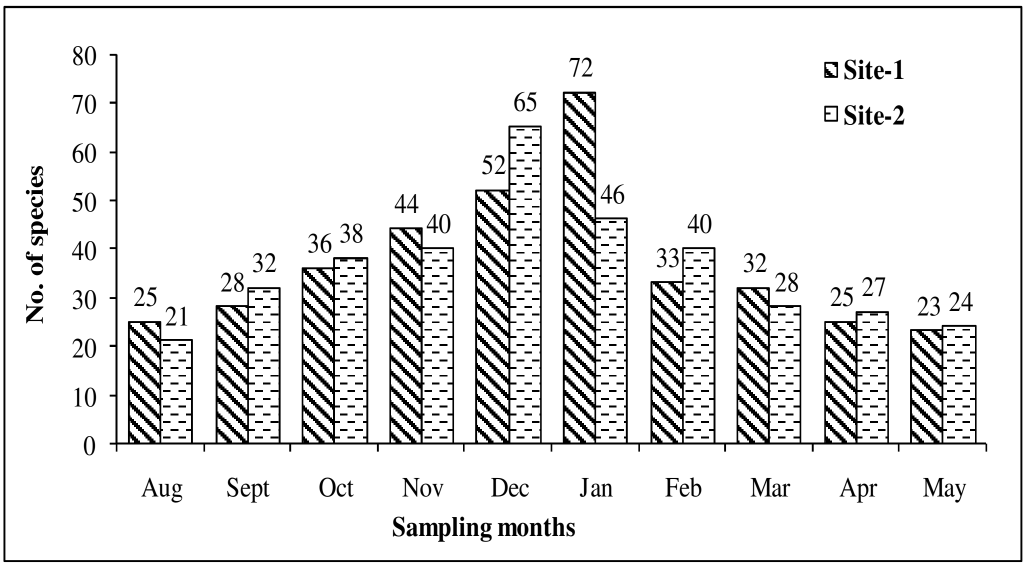


Fig 10. Number of fish species recorded during the study period.

Findings of the baseline survey clearly indicated the following recommendations to be considered to improve the productivity, diversity, environment and socio-economic improvement of fishermen:

- Establishment of sanctuary with improved structures.
- Stocking of less available fish species in the sanctuary.
- Ban on fishing during the peak breeding season of fish adjacent to the sanctuary area.
- Creating of alternative livelihood facilities through cage fish farming during fishing ban period.

11.3.5. Management of aquatic ecosystem through community participation

Awareness building activities were performed to motivate fishers about the conservation of the aquatic resources and to reduce causes of loss of fish biodiversity from natural waterbodies and the necessity of community participation for proper management of fish sanctuary as well as protection of fishes to avoid illegal fishing. The community people were also trained on how to build sanctuary by using roots and branches of trees, bamboo, etc. Target group from the fishers were kept directly involved in the project activities, such as taking care of sanctuaries and pens so that others cannot destroy those. Commercially formulated feed was supplied to the fishers' community; however, the feeding operations in cages were done by the beneficiaries. After intervention of the project they become more aware regarding the conservation of fishes. Fishers' also inspired by getting interactions with the Upazila Fisheries Officer (UFO), Upazila Nirbahi Officer (UNO), District Fisheries Officer and other project personnel.

Plate 23. Awareness raising meeting with local fishers at Gurukchi

11.3.5.1. Perceptions of fishers towards the effectiveness of the overall management

Table 12. Perceptions of fishers towards the effectiveness of management on ecosystem

Sl. no.	Perceptions	Perception of the respondents (N=170)	
		Numbers	Percentage (%)
1.	Sanctuary is helpful for protecting indigenous and threatened fish species.	154	90.58
2.	The abundance of small indigenous species (SIS) of fish is increasing.	146	85.88
3.	Sanctuary is creating habitats for fishes and other aquatic organisms round the year especially during dry season.	141	82.94
4.	Sanctuary is increasing fisher's daily catches and has influence on fisher's income.	132	77.64
5.	Sanctuary is better management approach for increasing ecosystem services.	126	74.12

Sl. no.	Perceptions	Perception of the respondents (N=170)	
		Numbers	Percentage (%)
6.	Cage culture activity reduces pressure on natural ecosystem and increases daily fish consumption.	117	68.82
7.	Present management is useful for conservation and restoration of aquatic ecosystem.	114	67.05
8.	Awareness of fishers has been increased by the project.	95	55.88
9.	Sanctuary is creating conflicts among fishers.	28	16.47
10.	Sanctuary is harmful for fishers catch and negatively impact on livelihoods of fishers.	7	4.12

One fisherman from Ratargul village said, "*This sanctuary has given shelter to many brood and juvenile fishes where some new species were also noticed. Fishes living in the sanctuary of the Ratargul swamp forest are not only the asset of government but also of common fishers, so it is our responsibility to manage the fish sanctuary forever.*" Another fisherman from Gurukchi village said, *"Fish sanctuary in the Gurukchi River has increased fish production and my income from fishing has also increased."*

Most of the fishers mentioned that the number fish species was decreasing day by day before establishing the fish sanctuary and catch assessment observation during baseline survey found 65, 67 and 57 indigenous fish species in the Ratargul swamp forest, the Shari-Goyain River and the Gurukchi River, respectively. During final survey 90% respondents indicated that these two sanctuaries were helpful for protecting indigenous and threatened fish species of respective waterbodies and enhance biodiversity as well as fish production (Table 12).

From the catch assessment data and fishers' perceptions, it is clear that the ecosystem based fish sanctuary management with community participation is fairly effective in terms of promoting fish availability, restoring biodiversity and increasing production and ecosystem services which ultimately enhance the livelihood status of the surrounding communities.

11.3.6. Establishment of sanctuary and its maintenance in Challan beel area

Based on the findings of base line survey on present status of fish biodiversity, two improved sanctuaries have been established in the two study sites. The sites of the sanctuaries were selected through the channel of Atrai River (Site 1, Singra upazila) and Gumni River (Site 2, Chatmohor upazila). A committee of 20 fishermen was also formed in each study site so they can observe and take part in the management of the sanctuary activity and can grow a positive thinking towards conserving fish diversity. To obtain the role of the sanctuaries established under this project on the socio-economic improvement of the selected committee members, a preliminary survey was conducted on their existing socio-economic status following Siddique *et al.* (2020). Majority of the committee members were belonging to Semi-paka house (60% and 65% at Site-1 and Site-2, respectively) in both of the study sites. Among the twenty committee members, 30% were within the income category of >3000 BDT, 45% within 3001-5000 BDT category and 25% within the income category of <5000 BDT per month at Site-1. At Site-2, majority of the committee members (40%) were within the income category of >3000 BDT and 3001-5000 BDT (Table 13).

11.3.6.1. Sanctuary materials : Sanctuary in both of the two study sites were manufactured from bamboo (bamboo with branches and without branches), tree branches (Indian oak Bn:Hizol), Babul (Bn:Babla), *Tamarind* (Bn:Tetul) and Indian Persimmon (Bn. Gub), sand bags (Plate 24), R.C.C. ring pipes (Plate 25) and R.C.C. hexapods (Plate 26 -28). Ring pipes and hexapods were made from rod, cement, bricks and sand. Placement of the ring pipes and hexapods was done from the small, mechanized boat. Established sanctuaries at the two study sites are shown in Plate 29 & 30)

Plate 24. Materials used for the establishment of fish sanctuary

Plate 25. R.C.C. ring pipe used in the sanctuary

Plate 26. R.C.C. hexapods used in the sanctuary.

Plate 27. Placement of R.C.C. ring pipes in the sanctuary.

Plate 28. Placement of R.C.C. hexapods in the sanctuary.

Plate 29. Sanctuary at Singra Upazila.

Plate 30. Sanctuary at Chatmohor upazila.

Monthly catch assessment conducted during baseline survey period was also evaluated to find out potential fish species to be stocked in the established sanctuary, based on their availability in the Chalan beel. A total of 72 fish species were observed during baseline survey in both of the study sites and observing their availability status, a total of 10 fish species were fond as less available species in Chalan beel and the present project stocked this less available species with different individual number in the experimental sanctuaries (Table 13). Total 14000 different fish species were stocked in each of the sanctuary in every successive year. The stocked fish species were mostly collected from wild sources such as river and beel of Rajshahi region. Only two fish species namely Pabda and Gulsa tengra were collected from hatchery source.

Table 13. Description of fish species stocked in the sanctuaries

S.l.	Bangla name	English Name	Scientific name	Source and size	Quantityy (Pcs)
01	বৌ/রানী/পুতুল	Bengal loach	*Botia dario*	Source: Wild/River Individual weight (g): 26g (± 6.00g)	500
02	বেট	Reticulate/Y-loach	*Botia lohachata*	Source : Wild/River Individual weight (g): 25g (± 4.00g)	500
03	পাবদা	Pabdah catfish	*Ompok pabo*	Source : Hatchery Individual weight (g): 50g (± 12.5g)	5,000
04	রিটা/রিঠা/ইটা	Rita	*Rita rita*	Source : Wild/River Individual weight (g): 450g (± 10.0g)	500
05	আইখর/রাইখর	Reba	*Cirrhinus reba*	Source : Wild/River Individual weight (g): 105g (± 6.50g)	500
06	ঘাউড়া	Garua bacha	*Clupisoma garua*	Source : Wild/River Individual weight (g): 150g (± 6.00g)	500
07	আইড়	Long whiskered catfish	*Sperata aor*	Source : Wild/River Individual weight (g): 800g (± 15.00g)	500
08	বাচা	Batchwa vacha	*Eutropiichthys vacha*	Source : Wild/River Individual weight (g): 45g (± 5.00g)	500
09	সরপুঁটি	Olive barb	*Puntius sarana*	Source : Wild/River Individual weight (g): 15g (± 2.00g)	500
10	গুলশা টেংরা	Gangetic mystus	*Mystus cavasius*	Source : Hatchery Individual weight (g): 35g (± 5.00g)	5,000
				Total	**14000**

Thereafter, monthly monitoring of water quality parameters, pollution parameters and fish abundance and diversity status were evaluated to find out the effectiveness of the established sanctuaries for improving ecological, biological and social aspects of both the environment of the Chalan beel and its dependent societies.

11.3.7. Enhancement of availability of SIS in the Shari-Goyain and Gurukchi Rivers

One of the activities of this sub-project was to enhance availability of the endangered nutrient rich SIS to ensure nutrient security and increased income for fishers' community. Mola and dhela are highly nutrient-rich SIS and now scarce in most of the natural waterbodies. For this reason, mola and dhela were stocked in the pens besides the sanctuaries. Before this sub-project work mola was scarce and dehla was almost unavailable in the study sites. According to catch monitoring data as well as fishers' statement, mola, dhela and other indigenous fish species have been increased in the Shari-Goyain and Gurukchi Rivers as well as in adjacent waterbodies.

11.3.7.1. Fish availability and diversity in the Ratargul swamp forest

During study period, total 72 species of indigenous fishes belonging to 24 families and 9 orders along with 4 species of prawn were observed in the Ratargul swamp forest and adjacent wetlands where numbers of fish species and their population trends were increasing (Table 14).

Table 14. Present status of fish biodiversity in the Ratargul swamp forest

Sl. no.	Taxonomic position	English name	Local name	IUCN status in BD	Availability status		Population trend
					Baseline	Final	
	Beloniformes						
	Belonidae						
1	*Xenentodon cancila*	Freshwater garfish	Kakila	LC	MA	CA	ST
	Clupeiformes						
	Clupeidae						
2	*Gudusia chapra*	Indian river shad	Chapila	VU	AA	AA	ST
3	*Corica soborna*	Ganges river-sprat	Kachki	LC	RA	RA	ST
	Cypriniformes						
	Cyprinidae						
4	*Amblypharyngodon mola*	Mola carplet	Mola	LC	RA	AA	IN
5	*Amblypharyngodon microlepis*	Indian carplet	Mola	LC	MA	AA	IN
6	*Esomus danricus*	Flying barb	Darkina	LC	MA	CA	IN
7	*Rasbora daniconius*	Slender barb	Darkina	LC	MA	CA	IN
8	*Osteobrama cotio*	Cotio	Dhela	NT	RA	MA	IN
9	*Devario devario*	Sind danio	Chepchela	LC	MA	MA	ST
10	*Salmophasia bacaila*	Large razorbelly minnow	Narkeli chela	LC	RA	MA	IN
11	*Salmophasia phulo*	Finescale razorbelly minnow	Fulchela	NT	MA	AA	IN
12	*Gibelion catla*	Catla	Catla	LC	MA	RA	DE
13	*Cirrhinus cirrhosus*	Mrigal carp	Mrigal	NT	MA	MA	ST
14	*Cirrhinus reba*	Reba	Laso	NT	RA	RA	ST
15	*Labeo calbasu*	Black rohu	Kalibaosh	LC	CA	AA	ST
16	*Labeo gonius*	Kuria labeo	Gonia	NT	CA	MA	DE
17	*Labeo rohita*	Rohu	Rui	LC	MA	MA	ST
18	*Labeo nandina*	Nandi labeo	Nanid	CR	NA	RA	IN

Sl. no.	Taxonomic position	English name	Local name	IUCN status in BD	Availability status		Population trend
					Baseline	Final	
19	*Labeo pangusia*	Pangusia labeo	Ghora maach	EN	NA	RA	IN
20	*Pethia guganio*	Glass barb	Mola punti	LC	RA	CA	IN
21	*Systomus sarana*	Olive barb	Sarpunti	NT	RA	RA	ST
22	*Puntius sophore*	Spotfin swamp barb	Jat punti	LC	AA	AA	ST
23	*Pethia ticto*	Ticto barb	Tit punti	VU	CA	CA	ST
	Balitoridae						
24	*Acanthocobitis botia*	Mottled loach	Balichata gutum	LC	RA	MA	IN
	Cobitidae						
25	*Botia dario*	Queen loach	Rani mach	EN	MA	MA	ST
26	*Lepidocephalichthys guntea*	Guntea loach	Gutum	LC	AA	AA	ST
27	*Lepidocephalichthys annandalei*	Annaldale loach	Gutum	VU	RA	MA	IN
28	*Canthophrys gongota*	Gongota loach	Bag gutum	NT	MA	CA	IN
	Cyprinodontiformes						
	Aplocheilidae						
29	*Aplocheilus panchax*	Blue panchax	Kanpona	LC	CA	CA	ST
	Osteoglossiformes						
	Notopteridae						
30	*Chitala chitala*	Humped featherback	Chital	EN	NA	RA	IN
31	*Notopterus notopterus*	Grey featherback	Kanla	VU	MA	MA	ST
	Perciformes						
	Badidae						
32	*Badis badis*	Blue perch	Napit koi	NT	RA	RA	ST
	Gobiidae						
33	*Glossogobius giuris*	Bareye goby	Baila	LC	AA	AA	ST
	Channidae						
34	*Channa orientalis*	Smooth-breasted snakehead	Raga	LC	CA	CA	ST
35	*Channa punctata*	Spotted snakehead	Lati	LC	AA	AA	ST
36	*Channa striata*	snakehead murrel	Shol	LC	CA	MA	DE
37	*Channa marulius*	Giant snakehead	Gazar	EN	NA	RA	IN
	Ambassidae						
38	*Chanda nama*	Elongate glass	Lomba	LC	CA	AA	IN

Sl. no.	Taxonomic position	English name	Local name	IUCN status in BD	Availability status		Population trend
					Baseline	Final	
		perchlet	chanda				
39	*Parambassis lala*	Highfin glass perchlet	Ranga chanda	LC	CA	CA	ST
40	*Pseudambassis ranga*	Indian glass fish	Gol chanda	LC	AA	AA	ST
	Nandidae						
41	*Nandus nandus*	Mud perch	Bheda, meni	NT	RA	CA	IN
	Anabantidae						
42	*Anabas testudineus*	Climbing perch	Koi	LC	AA	AA	ST
	Osphronemidae						
43	*Trichogaster fasciata*	Banded gourami	Bara khailsha	LC	RA	CA	IN
44	*Trichogaster chuna*	Dwarf gourami	Boicha	LC	MA	AA	IN
45	*Trichogaster labiosa*	Thick-lipped gourami	Khalisha	LC	MA	MA	ST
46	*Trichogaster lalius*	Red gourami	Lal khailsha	LC	RA	MA	IN
	Siluriformes						
	Schilbeidae						
47	*Eutropiichthys murius*	Indus garua	Garua	LC	MA	CA	IN
48	*Ailia punctata*	Jamuna ailia	Bashpata	LC	CA	CA	IN
49	*Clupisoma garua*	Garua bacha	Ghaura	EN	NA	RA	IN
	Bagridae						
50	*Rita rita*	Rita	Rita	EN	MA	MA	ST
51	*Sperata seenghala*	Giant river-catfish	Guijja air	VU	MA	CA	ST
52	*Sperata aor*	Long-whiskered catfish	Ayre	VU	RA	MA	IN
53	*Hemibagrus menoda*	Menoda catfish	Ghagla	NT	CA	CA	ST
54	*Mystus bleekeri*	Bleeker's mystus	Gulsha tengra	LC	MA	CA	IN
55	*Mystus cavasius*	Gangetic mystus	Gulsha	NT	CA	AA	IN
56	*Mystus tengara*	Tengara mystus	Bujuri tengra	LC	AA	AA	ST
57	*Mystus vittatus*	Asian striped catfish	Tengra	LC	MA	AA	IN
58	*Batasio tengana*	Dwarf catfish	Jalu tengra	EN	MA	MA	ST

Sl. no.	Taxonomic position	English name	Local name	IUCN status in BD	Availability status		Population trend
					Baseline	Final	
	Siluridae						
59	*Ompok pabda*	Two stripe gulper catfish	Pabda	EN	CA	CA	ST
60	*Ompok bimaculatus*	Butter catfish	Kani pabda	EN	MA	MA	ST
61	*Ompok pabo*	Pabo catfish	Kalo pabda	CR	NA	RA	IN
62	*Wallago attu*	Freshwater shark	Boal	VU	CA	AA	ST
	Sisoridae						
63	*Bagarius bagarius*	Gangetic goonch	Baghair	CR	NA	RA	IN
	Chacidae						
64	*Chaca chaca*	Squarehead or angler catfish	Chaka	EN	MA	AA	IN
	Clariidae						
65	*Clarias batrachus*	Walking catfish	Magur	LC	MA	CA	IN
	Heteropneustidae						
66	*Heteropneustes fossilis*	Stinging catfish	Shing	LC	MA	MA	ST
	Synbranchiformes						
	Synbranchidae						
67	*Monopterus cuchia*	Gangetic mudeel	Kuchia	VU	RA	RA	ST
	Mastacembelidae						
68	*Macrognathus aral*	One-stripe spiny eel	Pata baim	DD	RA	MA	ST
69	*Macrognathus aculeatus*	One-stripe spiny eel	Tara baim	NT	MA	CA	IN
70	*Mastacembelus armatus*	Spiny eel	Sal baim	EN	AA	CA	DE
71	*Macrognathus pancalus*	Stripped spiny eel	Chikra baim	LC	AA	AA	ST
	Tetraodontiformes						
	Tetraodontidae						
72	*Tetraodon cutcutia*	Ocellated puffer fish	Potka	LC	MA	CA	IN
	Prawns						
	Decapoda						
	Palaemonidae						
73	*Macrobrachium villosimanus*	Dimua river prawn	Dimua Icha	LC	AA	AA	ST

Sl. no.	Taxonomic position	English name	Local name	IUCN status in BD	Availability status		Population trend
					Baseline	Final	
74	*Macrobrachium lamarrei*	Indian whisker shrimp	Kalo icha	LC	RA	RA	ST
75	*Macrobrachium malcolmsonii*	Monsoon river prawn	Chatka icha	LC	RA	MA	IN
76	*Macrobrachium rosenbergii*	Giant freshwater prawn	Golda	LC	RA	RA	ST

*NE = Not Evaluated, NT = Near Threatened, LC = Least Concerned, VU = Vulnerable, EN = Endangered, DD = Data Deficient, CR = Critically Endangered, IN = Increasing, ST = Stable, DE = Decreasing, UN = Unknown.

11.3.7.2. Fish availability and diversity in the Gurukchi River : During present study, 62 species of indigenous fishes belonging to 22 family and 9 orders along with 4 species of prawn were observed in the Gurukchi River where both the numbers of fish species and population trends of many species were found increasing in the Gurukchi River and adjacent waters (Table 15).

Table 15. Present status of fish biodiversity in the Gurukchi River.

Sl. no.	Taxonomic position	English name	Local name	IUCN status in BD	Availability status		Population trend
					Baseline	Final	
	Beloniformes						
	Belonidae						
1	*Xenentodon cancila*	Freshwater garfish	Kakila	LC	CA	CA	ST
	Clupeiformes						
	Clupeidae						
2	*Gudusia chapra*	Indian river shad	Chapila	VU	CA	AA	IN
	Cypriniformes						
	Cyprinidae						
3	*Amblypharyngodon mola*	Mola carplet	Mola	LC	RA	AA	IN
4	*Esomus danricus*	Flying barb	Darkina	LC	AA	CA	DE
5	*Osteobrama cotio*	Cotio	Dhela	NT	RA	MA	IN
6	*Salmophasia bacaila*	Large razorbelly minnow	Katari chela	LC	RA	MA	IN
7	*Salmophasia phulo*	Finescale razorbelly minnow	Fulchela	NT	CA	AA	IN
8	*Salmophasia acinaces*	Silver razorbelly minnow	Chela	LC	MA	CA	IN
9	*Gibelion catla*	Catla	Catla	LC	RA	RA	ST
10	*Cirrhinus cirrhosis*	Mrigal carp	Mrigal	NT	RA	RA	ST
11	*Devario devario*	Sind danio	Chapchela	LC	CA	CA	ST

12	*Labeo calbasu*	Black rohu	Kalibaosh	LC	RA	MA	IN
13	*Labeo gonius*	Kuria labeo	Gonia	NT	RA	MA	IN
14	*Labeo rohita*	Rohu	Rui	LC	RA	MA	IN
15	*Oreichthys cosuatis*	Cosuatis barb	Titla	EN	RA	CA	IN
16	*Pethia conchonius*	Rosy barb	Kanchan punti	LC	MA	CA	IN
17	*Pethia guganio*	Glass barb	Mola punti	LC	RA	MA	IN
18	*Pethia phutunio*	Spottedsail barb	Phutani punti	LC	MA	MA	ST
19	*Systomus sarana*	Olive barb	Sarpunti	NT	CA	CA	ST
20	*Puntius sophore*	Spotfin swamp barb	Jat punti	LC	AA	AA	ST
21	*Pethia ticto*	Ticto barb	Tit punti	VU	MA	MA	ST
	Balitoridae						
22	*Acanthocobitis botia*	Mottled loach	Balichata gutum	LC	CA	AA	IN
23	*Acanthocobitis zonalternans*	River loach	Bali gutum	LC	MA	MA	ST
	Cobitidae						
24	*Botia Dario*	Queen loach	Rani mach	EN	CA	CA	ST
25	*Lepidocephalichthys guntea*	Guntea loach	Gutum	LC	AA	AA	ST
26	*Canthophrys gongota*	Gongota loach	Bag gutum	NT	MA	CA	IN
	Cyprinodontiformes						
	Aplocheilidae						
27	*Aplocheilus panchax*	Blue panchax	Kanpona	LC	CA	CA	ST
	Osteoglossiformes						
	Notopteridae						
28	*Chitala chitala*	Humped featherback	Chital	EN	NA	RA	IN
29	*Notopterus notopterus*	Grey featherback	Kanla	VU	CA	CA	ST
	Perciformes						
	Gobiidae						
30	*Glossogobius giuris*	Bareye goby	Baila	LC	AA	AA	ST
	Channidae						
31	*Channa orientalis*	Smooth-breasted snakehead	Raga	LC	MA	MA	ST
32	*Channa punctate*	Spotted snakehead	Lati	LC	AA	AA	ST
33	*Channa striata*	Snakehead murrel	Shol	LC	CA	CA	ST
34	*Channa marulius*	Giant snakehead	Gazar	EN	NA	RA	IN
	Ambassidae						
35	*Chanda nama*	Elongate glass perchlet	Lomba chanda	LC	AA	CA	DE

36	*Parambassis lala*	Highfin glassy perchlet	Ranga chanda	LC	AA	AA	ST
37	*Pseudambassis ranga*	Indian glassy fish	Gol chanda	LC	AA	AA	ST
	Nandidae						
38	*Nandus nandus*	Mud perch	Bheda, meni	NT	RA	MA	IN
	Anabantidae						
39	*Anabas testudineus*	Climbing perch	Koi	LC	RA	MA	IN
	Osphronemidae						
40	*Trichogaster fasciata*	Banded gourami	Bara khailsha	LC	RA	MA	IN
41	*Trichogaster chuna*	Dwarf gourami	Boicha	LC	MA	RA	DE
	Siluriformes						
	Schilbeidae						
42	*Neotropius atherinoides*	Indian potasi	Batasi	LC	CA	AA	IN
43	*Clupisoma garua*	Garua bacha	Ghaura	EN	NA	RA	IN
	Bagridae						
44	*Batasio batasio*	Titsta batasio	Jalu tengra	NT	CA	AA	IN
45	*Hemibagrus menoda*	Menoda catfish	Ghagla	NT	MA	CA	IN
46	*Mystus bleekeri*	Bleeker's mystus	Gulsha tengra	LC	AA	CA	DE
47	*Mystus cavasius*	Gangetic mystus	Gulsha	NT	AA	AA	ST
48	*Mystus tengara*	Tengara mystus	Bujuri tengra	LC	AA	AA	IN
49	*Mystus vittatus*	Asian striped catfish	Tengra	LC	CA	AA	IN
	Siluridae						
50	*Ompok bimaculatus*	Butter catfish	Kani pabda	EN	MA	MA	ST
51	*Ompok pabda*	Two stripe gulper catfish	Pabda	EN	CA	AA	IN
52	*Ompok pabo*	Pabo catfish	Kalo pabda	CR	NA	RA	IN
53	*Wallago attu*	Freshwater shark	Boal	VU	CA	AA	IN
	Sisoridae						
54	*Bagarius bagarius*	Gangetic goonch	Baghair	CR	NA	RA	IN
	Clariidae						
55	*Clarias batrachus*	Walking catfish	Magur	LC	RA	RA	ST
	Heteropneustidae						
56	*Heteropneustes fossilis*	Stinging catfish	Shing	LC	RA	RA	ST
	Synbranchiformes						
	Synbranchidae						

57	*Monopterus cuchia*	Gangetic mudeel	Kuchia	VU	RA	RA	ST
	Mastacembelidae						
58	*Macrognathus aral*	One-stripe spiny eel	Tara baim	DD	MA	CA	IN
59	*Macrognathus aculeatus*	One-stripe spiny eel	Tara baim	NT	MA	CA	IN
60	*Mastacembelus armatus*	Spiny eel	Sal baim	EN	MA	CA	IN
61	*Macrognathus pancalus*	Stripped spiny eel	Chikra baim	LC	CA	AA	IN
	Tetraodontiformes						
	Tetraodontidae						
62	*Tetraodon cutcutia*	Ocellated puffer fish	Potka	LC	MA	AA	IN
	Decapoda						
	Palaemonidae						
63	*Macrobrachium villosimanus*	Dimua prawn	Dimua icha	LC	AA	AA	ST
64	*Macrobrachium lamarrei*	Indian whisker shrimp	Kalo icha	LC	RA	MA	IN
65	*Macrobrachium malcolmsonii*	Monsoon river prawn	Chatka icha	LC	RA	MA	IN
66	*Macrobrachium rosenbergii*	Giant freshwater prawn	Golda	LC	RA	RA	IN

*NE = Not Evaluated, NT = Near Threatened, LC = Least Concerned, VU = Vulnerable, EN = Endangered, DD = Data Deficient, CR = Critically Endangered, IN = Increasing, ST = Stable, DE = Decreasing, UN = Unknown

11.3.7.3. Changes in fish availability, diversity and production in Ratargul swamp forest : During the present study 72 species of indigenous fishes were observed in the Ratargul Swamp Forest whereas 65 species was documented in the baseline survey befor establishment of the sanctuary. Not only increasing the biodiversity, availability of many species was found to be increased in the Ratargul swamp forest and adjacent waters. The availability status of fishes significantly changed after two years of establishment of sanctuary. Abundantly available and commonly available species were increased in their numbers comparing baseline status 10 and 13 to 19 and 21, respectively. Besides, the moderately available and rarely available species were decreased in their numbers 26 and 16 to 19 and 13, respectively (Table 16).

Table 16. Present status of fish biodiversity in the Ratargul swamp forest

Sl. no.	Availabilty status	Number of fish species		Remarks
		Baseline	Final	
1	Abundantly available	10	19	Increased
2	Commonly available	13	21	Increased
3	Moderately available	26	19	Decreased
4	Rarely available	16	13	Decreased
	Total no. of fish species	**65**	**72**	**Increased**

Average fish catch (mean±SD) per fisher was gradually increased from base line survey to after 1st year intervention and 2nd year intervention 2.46±2.23, 2.74±2.46 and 3.68 ±2.97 kg/day, respectively in adjacent wetlands of the Ratargul swamp forest (Fig 11). This is a clear view that fish production is gradually increasing in the wetland after establishment of the sanctuary and enhancement program of SIS through pen culture activity. Effective community-based management played an important role in this process.

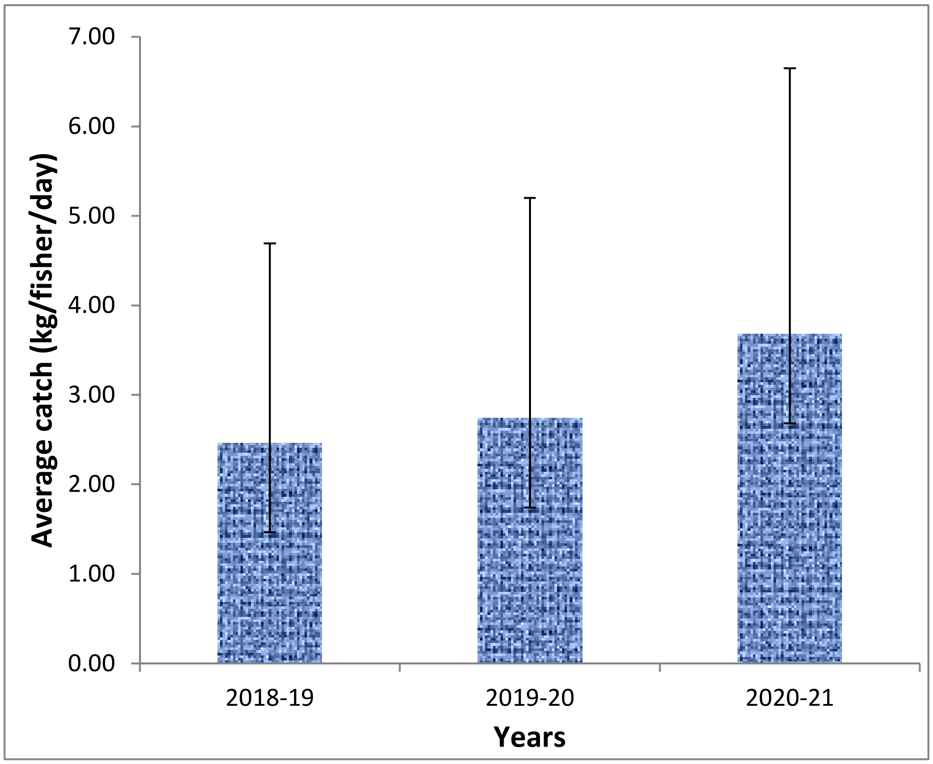


Fig 11. Changes in harvesting of fish (kg/fishers/day) in the Ratargul swamp forest.

Plate 31. SIS fish observed around the sanctuary site in the Ratargul swamp forest.

11.3.8. Impact of fish sanctuary on fish diversity indices at Ratargul swamp forest

To estimate species diversity and richness comparing baseline year to study period the diversity indices were calculated. Simpson dominance index (D) was 0.12 in the baseline year and after one year it was found 0.09. The Shannon index (H) increased from 2.77 to 2.98 and the Margalef richness index (d) decreased from 6.15 to 6.14. Pielou evenness index (J) also increased from 0.66 to 0.71. The result of the entire index supported the increased fish diversity in the sub-project area (Fig 12).

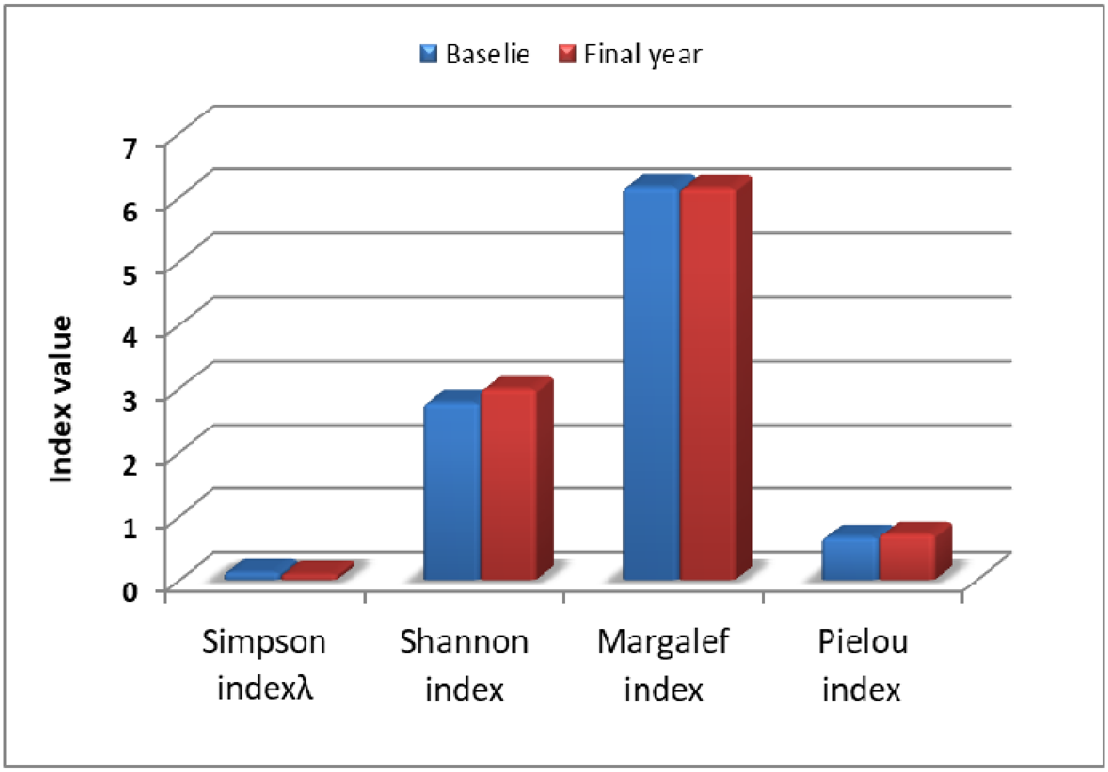


Fig 12. Values of fish diversity indices comparing baseline and final year in the Ratargul swamp forest.

11.3.9. Impact of sanctuary on fish diversity indices at adjacent Shari-Goyain River

In case of the Shari-Goyain River, Simpson dominance index (D) was 0.13 in the baseline year and after one year it was found 0.12. The Shannon-Weiner index (H) increased from 2.57 to 2.61 and the Margalef richness index (d) decreased from 5.72 to 5.48. Pielou evenness index (J) also increased from 0.63 to 0.64. The entire index showed that the diversity has been increased over the two years of intervention of the sub-project (Fig 13).

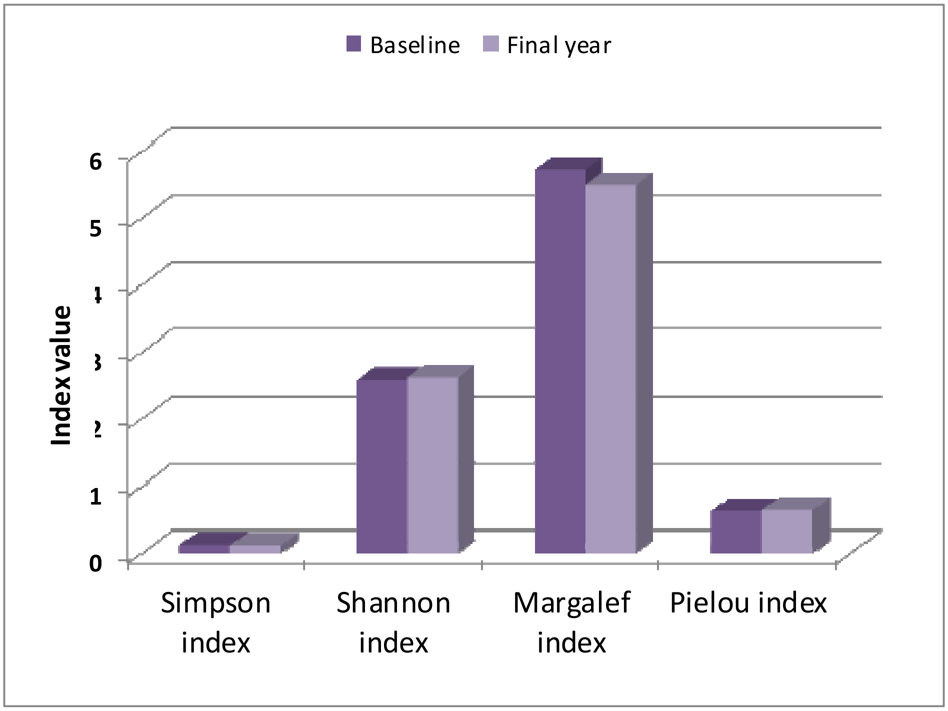


Fig 13. Values of fish diversity indices comparing between baseline and studied year at adjacent Shari-Goyain River.

The species richness and proportion of individual species is showed by Shannon-Wiener index, whereas the relative number of individual and the fraction of common species showed on the evenness and dominance indices (Hossain *et al*., 2014). Simpson dominance index (D) was lower in the studied year than baseline year. As lower value indicates enriched species diversity so the sanctuary is helpful to enhance species diversity. The Shannon-Wiener index (H) was 2.77 in the baseline year and increased to 2.98 after intervention of the project. Ali *et al.* (2020) found the H values 2.70 to 3.41 at the Andarmanik River sanctuary. Its value usually ranges from 1.5 to 3.5 and the values above 3.5 indicate more sustainable condition. Therefore, these results indicated the sanctuary is useful to create sustainable condition. Alam *et al*. (2013) reported H values from 3.29 to 3.49 in the Halda River. The lowest Pielou evenness index value was recorded baseline year while the highest value was recorded in fnal year which indicates that the species of fishes is more evenly distributed. Margalef species richness (d) index 6.15 recorded in the baseline year and 6.14 in the studied year.

In the Shari-Goyain River (just beside the swamp forest), Simpson dominance index (D) was 0.13 in the baseline year and 0.12 in the studied year which refers slightly enrichment of species diversity in the studied year. The Shannon-Wiener index (H) increased from 2.57 to 2.61 indicated the sanctuary is helpful to create favorable condition in the adjacent waters. The Margalef index decreased from 5.72 to 5.48. Pielou evenness index (J) also increased from 0.63 to 0.64. All those result proved that the sanctuary is supporting to enhance biodiversity and production in the Shari-Goyain River but not similar as Ratargul swamp forest. This might be associated with water pollution by coal mine drainage as well as katha fishing, sand mining, poison fishing, etc.

11.3.10. Changes in fish availability in the Gurukchi River

During present study, total 62 species of indigenous fishes were observed in the Ratargul swamp forest where numbers of fish species were increaed from 57 species in the baseline study and population trends of many species was found increasing in the Gurukchi River and adjacent waters. The availability status of fishes significantly changed after two year of establishment of sanctuary. Abundantly available and commonly available species were increased in their numbers comparing baseline status 11 and 16 to 19 and 18, respectively. Besides, the moderately available species were found stable and rarely available species were decreased in their numbers 16 to 11 in the baseline and final year, respectively (Table 17).

Table 17. Present status of fish biodiversity in the Gurukchi River

Sl. no.	Availability status	Number of species		Remarks
		Baseline	Present	
1	Abundantly available	11	19	Increased
2	Commonly available	16	18	Increased
3	Moderately available	14	14	Stable
4	Rarely available	16	11	Decreased
	Total no. of fish species	**57**	**62**	**Increased**

Income from fishing activities highly linked with the success of the sub-project, such as catch per fisher per day. Average fish catch (mean±SD) per fisherman was increased from baseline 1.78±2.11 to after 1st year and 2nd year intervention of the project 2.04±2.14, and 2.98±2.61 kg/day, respectively in the Gurukchi River (Fig 14) which indicated that fish production is gradually increasing in the wetland.

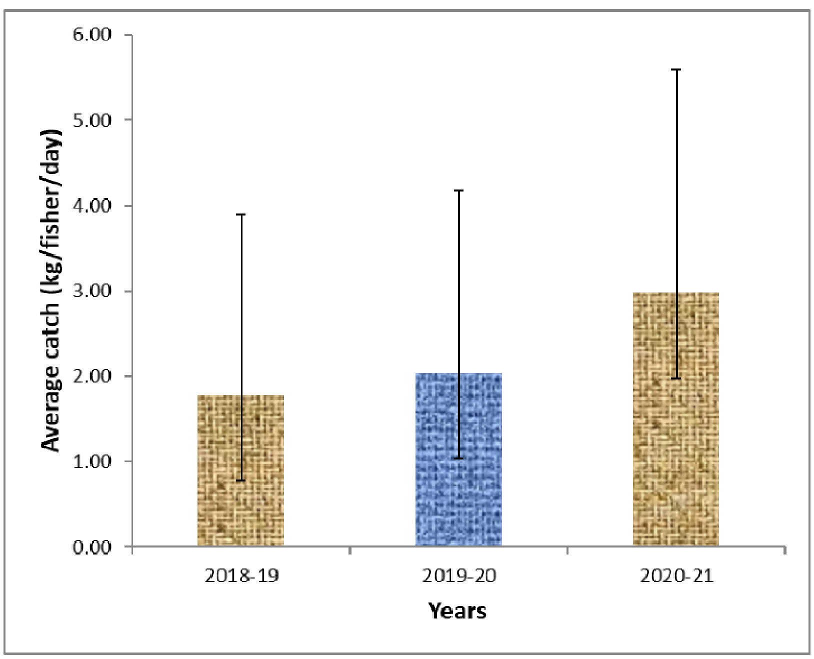


Fig. 14. Changes in the harvesting of fish (kg/fishers/day) in the Gurukchi River.

Plate 32. Harvested SIS by the fishers from Gurukchi River.

11.3.11. Changes in contribution of mola to fish production

Small indigenous species of fish played a vital role in rural areas of Bangladesh through providing regular dietary protein, vitamin A, calcium and iron (Jahan et al., 2014). Mola, an important SIS, was very abundant in rivers, canals, beels, streams and ponds before 1980. Through the continuous degradation of open water along with various manmade causes SIS, especially mola production was drastically reduced. Mola enhancement in the haor areas through this project was an experimental initiative to increase the SIS production. This study conducted to find out the impact of mola in annual fish production and fish biodiversity in the wetlands after execution of mola enhancement program. The results showed positive significance ($P < 0.05$) in case of fish production and mola production (Table 18).

Table 18. Contribution of mola to fish production

Name of the waterbody	Contribution rank		Contribution of mola (%)		Contribution of other fishes (%)	
	Baseline	Final	Baseline	Final	Baseline	Final
Ratargul swamp forest	11th	3rd	2.79	4.54	97.21	95.46
Shari-Goyain River	15th	20th	0.85	1.04	99.15	98.96
Gurukchi River	12th	5th	1.81	3.92	98.19	96.08
Kura River (Control)	10th	9th	2.94	2.88	97.06	97.22

11.3.12. Fish species revived after establishment of the fish sanctuaries

According to the catch monitoring data, nine native species (*Labeo nandina, Ompok pabo, Bagarius bagarius, Labeo pangusia, Megarasbora elanga, Chitala chitala, Channa marulius, Clupisoma garua, Labeo angra*) which were unavailable in the respective sites were found during this present study period (Table 19). Khan *et al.* (2018) recorded seven native species (*Nandus nandus, Ompok bimaculatus, Channa marulius, Puntius sarana, Mystus aor, Botia dario and Labeo calbasu*) were revived in the Kolavanga *beel* after fish sanctuary establishment. Haque (2013) reported 5 species (*Ompok bimaculatus, Puntius sarana, Nandus nandus, Labeo gonius, and Chitala chitala*) were revived due to establishment of Baikka *beel* sanctuary. According to MACH project (2003), the number of fish species found during the baseline year and final year was 71 and 85, respectively in Hail *haor* that indicated 14 revived species within 6 years. FFP (2005) reported that after establishment of sanctuaries, 23 fish and some prawn species including some endangered species have increased their population in the command area of the project. All these studies supported the present investigation that establishment of fish sanctuary at the deepest part of the *beel* and river positively impacted on the restoration of aquatic species through providing suitable and safe habitat for them. This study also exposed that community-based management approach of sanctuary management appeared to be effective for fish diversity enhancement which lead to increase in number and amount of various fish species.

Table 19. List of revived species and their present status

Sl. no.	Local name	Scientific name	IUCN status	Revived site
1	Nanin	*Labeo nandina* (Hamilton, 1822)	Critically endangered	Ratargul
2	Kalo pabda	*Ompok pabo* (Hamilton, 1822)	Critically endangered	Gurukchi/Ratargul
3	Baghair	*Bagarius bagarius* (Hamilton, 1822)	Critically endangered	Gurukchi/Ratargul
4	Ghora maach	*Labeo pangusia* (Hamilton, 1822)	Endangered	Ratargul
5	Elong	*Megarasbora elanga* (Hamilton, 1822)	Endangered	Shari-Goyain
6	Chital	*Chitala chitala* (Hamilton, 1822)	Endangered	Gurukchi/Ratargul
7	Gazar	*Channa marulius* (Hamilton, 1822)	Endangered	Gurukchi/Ratargul
8	Garua	*Clupisoma garua* (Hamilton, 1822)	Endangered	Gurukchi/Ratargul
9	Kharish	*Labeo angra* (Hamilton, 1822)	Least concern	Shari-Goyain

All of the above two experime2nts supported that establishment of fish sanctuary at the deepest part of the *beel* and river positively impacted on the aquatic species through providing suitable and safe habitat for them. This study exposed that community-based management approach of sanctuary establishment and management appeared to be effective tool for fish diversity enhancement which led to increase in number and amount of various fish species. However, these studies should be continued for a long time to evaluate the ultimate impact and sustainability of this model.






Plate 33. Harvested fishes during catch assessment around the sanctuary sites.

11.4. Fish diversity analysis of *around the sanctuary sites of Component -3*

Monthly sampling of fish species adjacent to the area of established fish sanctuaries (SS), partially protected area (PP) and open site (OP) area were done. Total fish abundance and number of species (Fig 15 -18) was higher during the month of October in all the sampling locations. Howerver, total abundance in sanctuary site was much higher compared to partially protected and open site, respectively. In general establishment of fish sanctuaries and stocking of some less available fish species increased the overall abundance of fish species in the study locations. Total abundance of fish species was found higher during October indicated the recruitment and localization of newly hatched juveniles at the sanctuary area that was found to contribute to the harvestable population during this month. Moreover, abundance of fish specis was also increased in partially protected and open site compared to the pervious year might be due to the spillover of fish species from the sactuary area. Therefore, establishment of sanctuary imparts a positive impact on the fisheries resources of the study area. However, number of fish species was higher during January, 2019 at Site 1 and December 2019 at Site 2. This does not mean that these increased fish species were newly produced; rather establishment of sanctuary with improved structure like ring pipe and hexapods creates a place for their safe living and reproduction. Moreover, complex habitat created by hexapods and ring pipes secure the habitat of benthic fauna and provided enhanced surface area for the attachment of periphyton, which might attract fish species on to the sanctuary area. Therefore, establishment of sanctuary imparts a positive impact on the fisheries resources of the study area. Abundance of fish species in the natural environment is controlled by natural phenomena; in general establishment of fish sanctuaries and stocking of some less available fish species increased the overall abundance of fish species in study locations. Retrieval of fisheries species was also reported by Siddique *et al.* (2020) in Halti beel tank sactuary in Chalan beel, Joadder *et al.* (2016) in Kumari *Beel* sanctuary (16 species) and Hasan *et al.* (2012) in Matshyarani fish sanctuary (32 species).

11.4.1. Abundance status of stocked fish species : There was an increasing trend in the total abundance of stocked fish species in our established sanctuaries (SS) showin in Table 20 and Table 22. Increase in the total abundance in SS was higher compared to PP and OS sites.

Plate 34. Sampling of Fish in at sanctuary site.

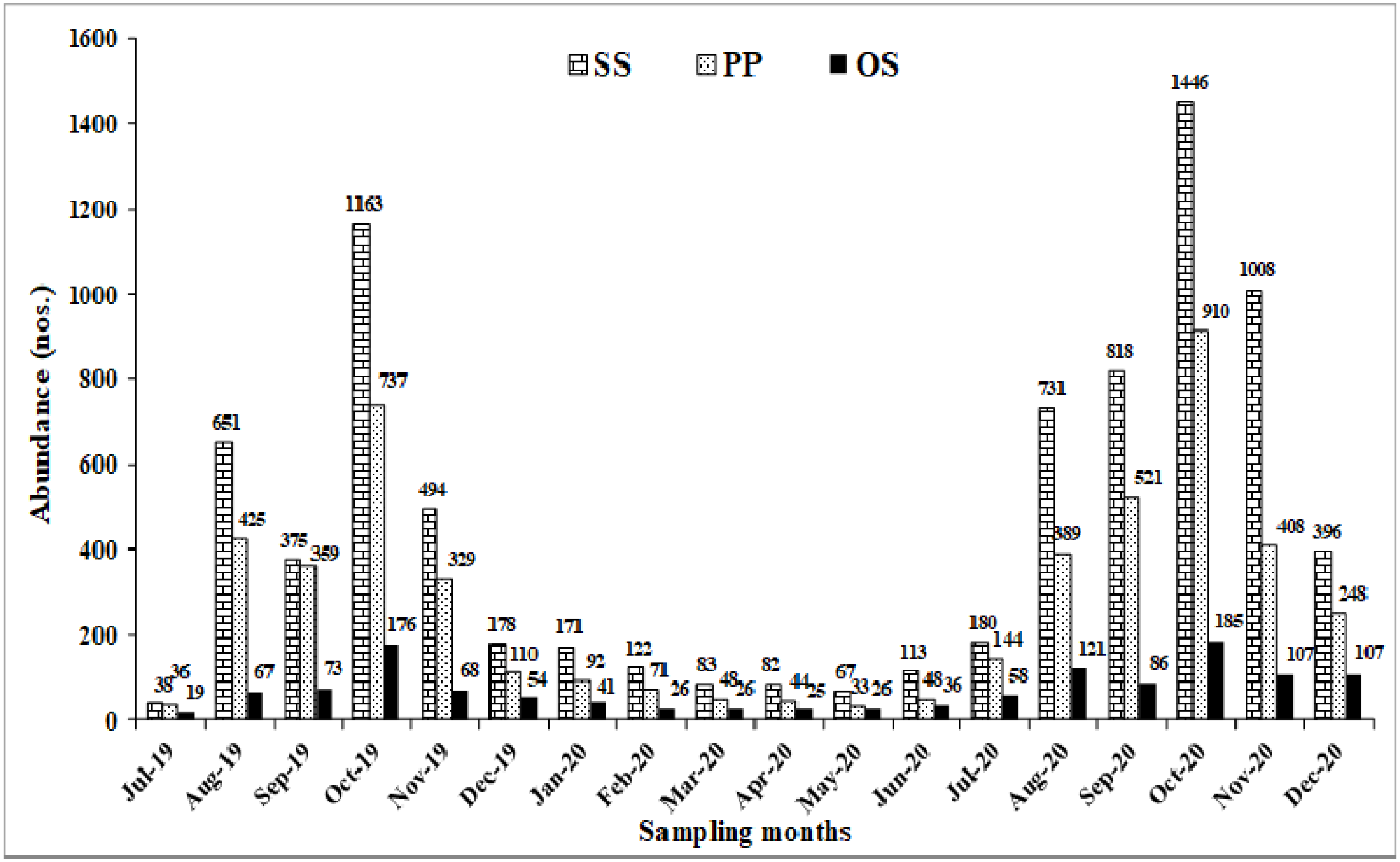


Fig. 15. Abundance of fish species at Natore, Singra site. SS=Sanctuary site, PP=Patrialy protected site, OS=Open site.

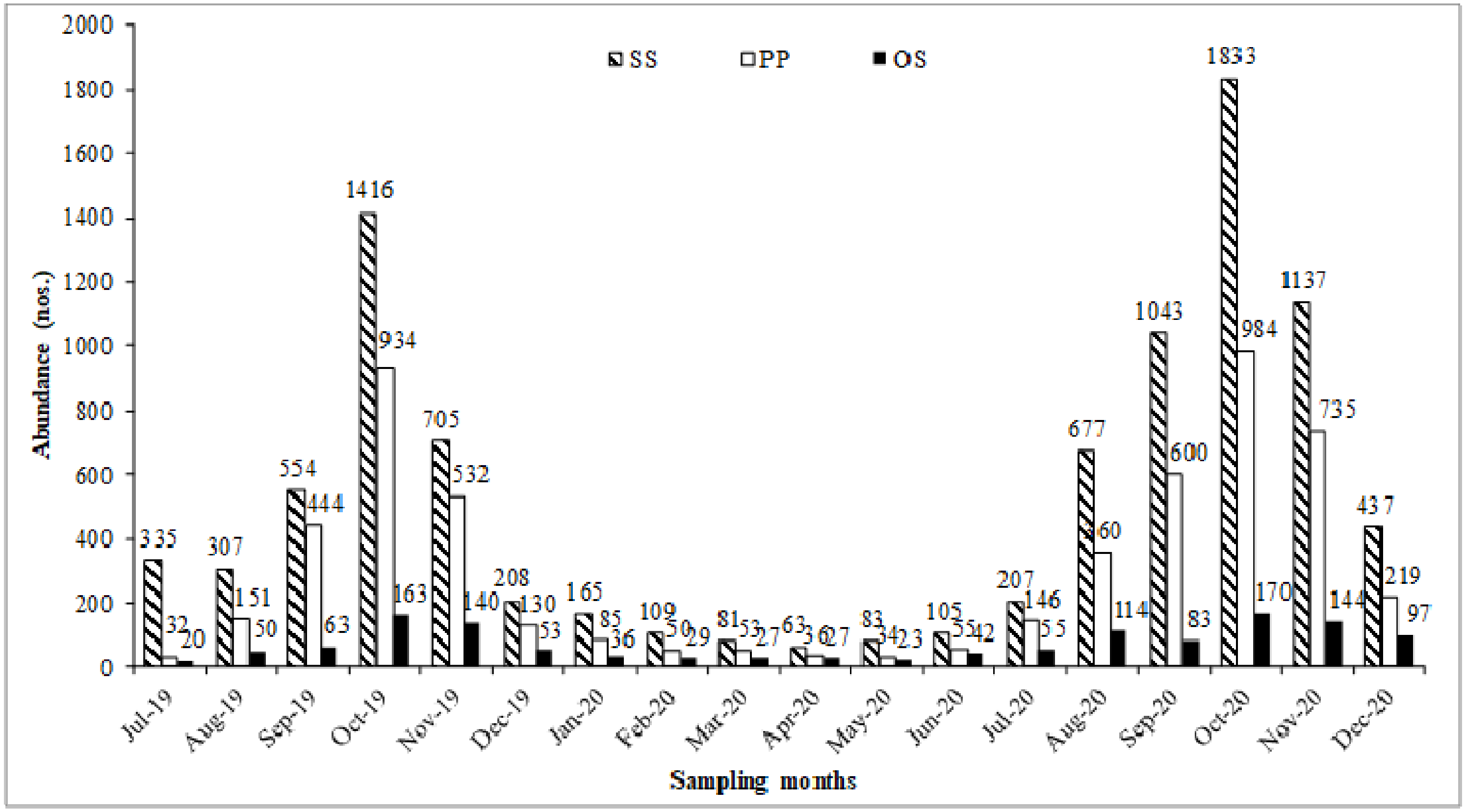


Fig. 16. Abundance of fish species at Chatmohor, Pabna site. SS=Sanctuary site, PP=Patrialy protected site, OS=Open site.

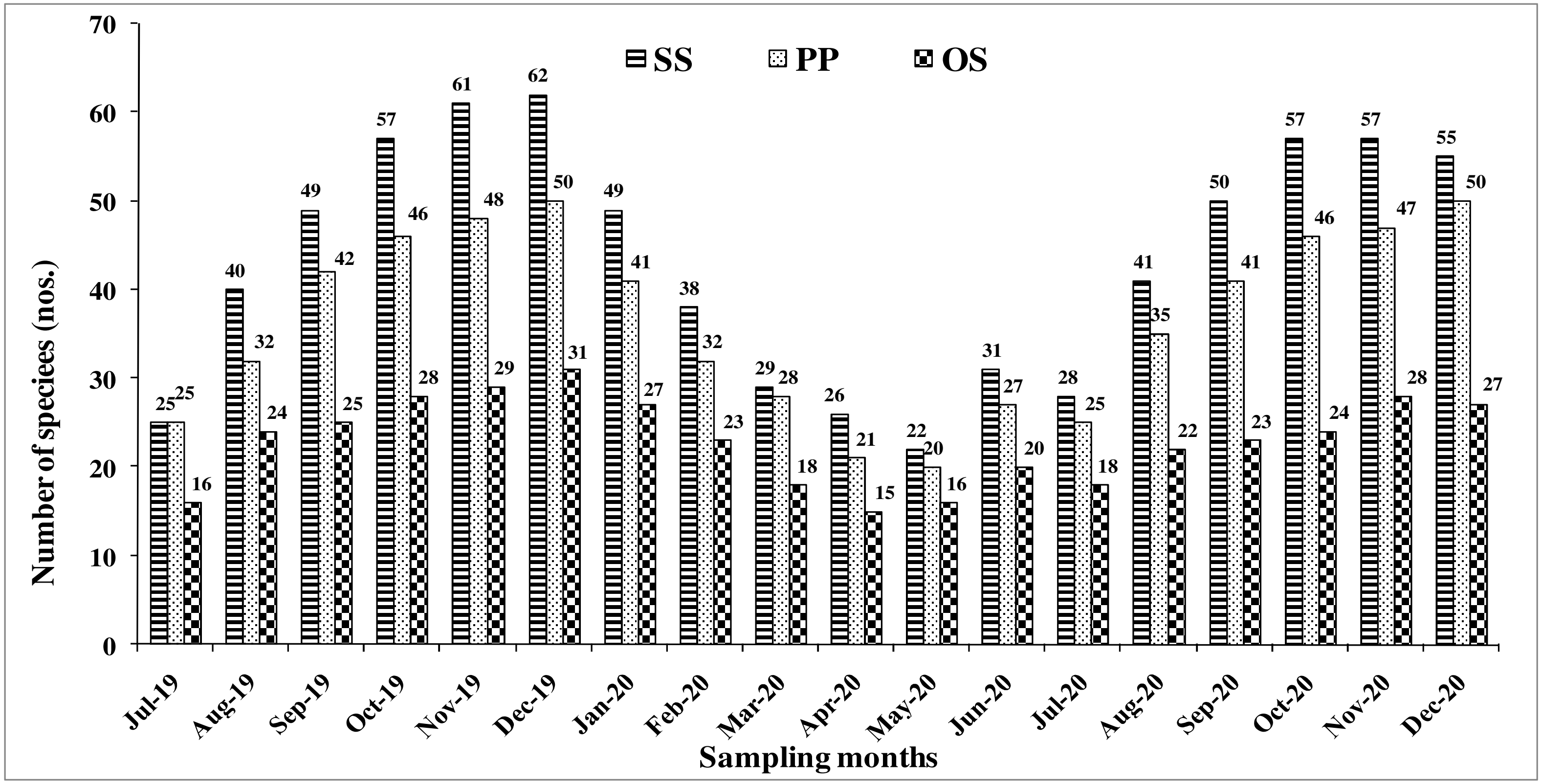


Fig. 17. Number of fish species at Natore, Singra site. SS=Sanctuary site, PP=Patrialy protected site, OS=Open site.

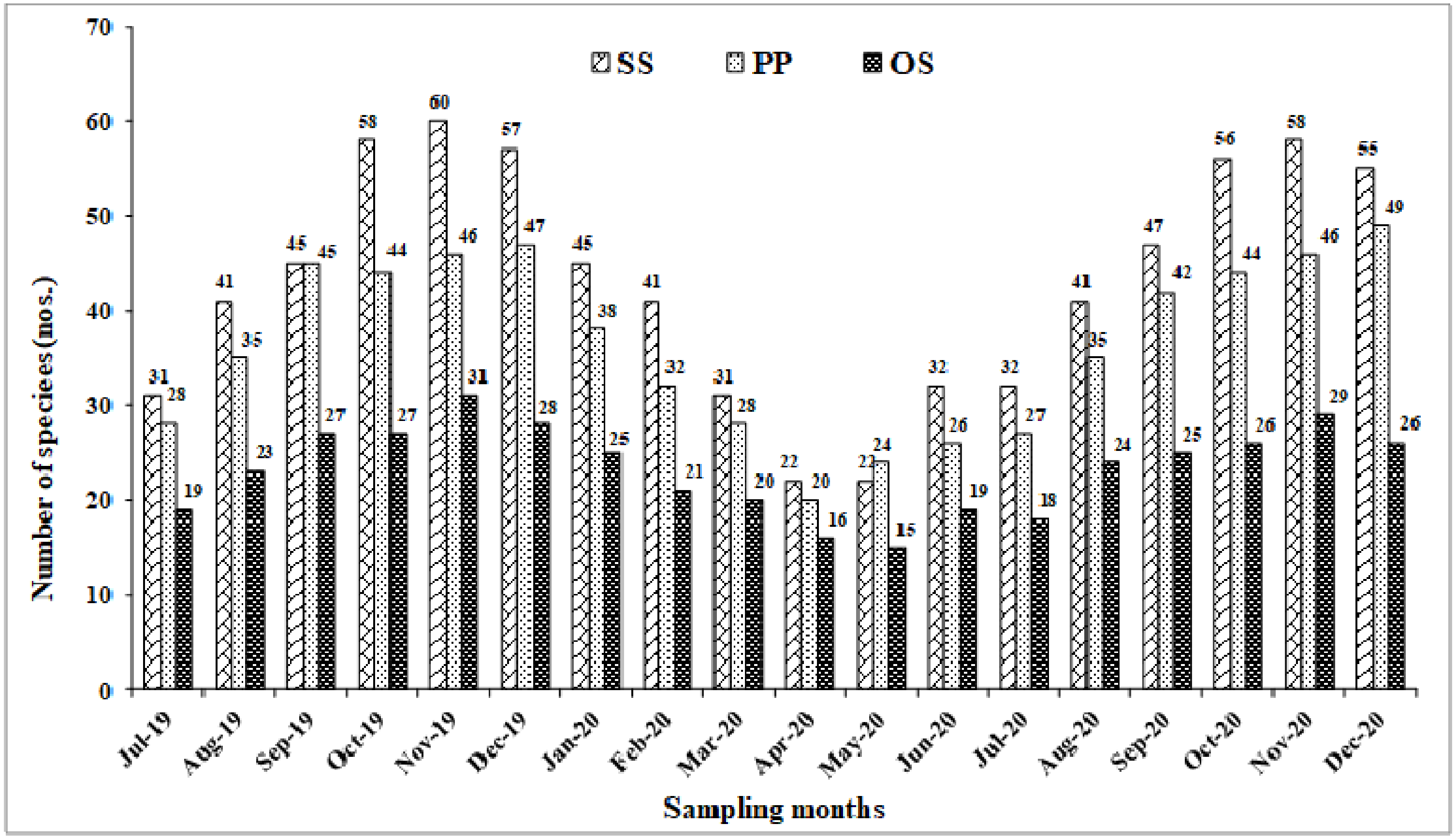


Fig. 18. Number of fish species at Chatmohor, Pabna site. SS=Sanctuary site, PP=Patrialy protected site, OS=Open site.

Table 20. Abundacne status of stocked fish species in sanctuary (SS), and its comparison with partially protected (PP) site and open site (OS) in Singra, Natore

Parameters	Site	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20	Mar-20	Apr-20	May-20	Jun-20	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20	Total
Botia dario	SS	0	0	1	4	14	11	15	22	36	25	22	16	11	12	20	19	18	7	253
	PP	0	0	0	0	5	0	0	0	3	0	9	0	0	3	0	0	1	0	21
	OS	0	0	0	2	0	0	0	0	0	0	3	0	0	0	0	0	0	0	5
Botia lohachata	SS	1	1	10	16	25	21	11	15	22	11	18	32	3	10	15	20	10	4	245
	PP	1	0	0	1	1	0	1	0	2	2	9	1	2	3	0	3	3	0	29
	OS	0	1	0	0	2	0	0	1	0	0	2	0	1	0	0	0	0	0	7
Ompok pabda	SS	0	6	15	26	33	21	12	23	13	25	12	33	6	0	12	16	19	14	286
	PP	3	0	1	1	1	10	6	1	3	4	1	3	9	0	8	7	1	1	60
	OS	0	3	0	1	0	0	0	1	0	0	0	2	0	0	0	0	0	0	7
Rita rita	SS	1	7	13	41	20	5	4	3	2	1	3	6	4	5	7	18	10	0	150
	PP	0	1	1	1	3	2	1	0	2	0	2	2	0	1	0	3	0	0	19
	OS	0	1	0	1	2	0	0	0	2	0	0	1	0	0	0	0	0	0	7
Cirrhinus reba	SS	0	1	5	12	11	9	10	13	4	26	27	33	9	11	13	12	15	12	223
	PP	0	1	0	0	3	0	0	0	2	0	1	2	5	4	0	0	0	0	18
	OS	3	0	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	6
Clupisoma garua	SS	0	3	5	15	4	3	2	2	2	1	2	2	0	6	0	12	8	3	70
	PP	0	1	0	1	1	0	1	2	1	0	0	3	0	1	0	1	0	0	12
	OS	2	0	0	2	2	0	0	1	0	0	1	0	0	0	0	0	0	0	8
Sperata aor	SS	0	3	6	25	9	2	2	2	2	1	1	2	0	3	12	0	5	3	78
	PP	0	1	1	4	2	0	1	0	1	0	0	3	0	2	2	0	0	0	17
	OS	0	0	1	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	4
Eutropiichthys vacha	SS	1	3	13	16	24	12	17	13	8	6	6	13	13	12	27	22	49	11	266
	PP	1	1	1	10	10	1	9	1	4	1	1	0	11	10	10	18	16	4	109
	OS	2	0	0	1	0	0	0	2	0	0	1	0	0	0	0	0	0	0	6
Systomus sarana	SS	0	6	11	31	12	10	22	21	8	6	21	11	0	8	12	27	16	11	233
	PP	0	1	0	2	1	4	0	2	0	6	0	1	0	9	0	17	14	5	62
	OS	0	1	1	1	3	0	0	1	2	0	0	1	0	5	2	4	2	0	23
Mystus cavasius	SS	0	6	13	15	22	18	21	16	14	17	11	15	7	9	22	19	21	16	262
	PP	0	0	2	5	5	5	7	0	4	1	3	0	0	0	7	15	9	0	63
	OS	2	0	0	0	1	0	2	0	0	0	2	0	0	0	0	0	0	0	7

Table 21. Abundacne status of stocked fish species in sanctuary (SS), and its comparison with partially protected (PP) site and open site (OS) in Chatmohor, Pabna

Parameters	Site	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20	Mar-20	Apr-20	May-20	Jun-20	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20	Total
Botia dario	SS	0	0	1	4	14	11	15	22	36	25	22	16	9	10	22	21	26	5	259
	PP	0	0	0	0	5	0	0	0	3	0	9	0	3	3	1	0	0	0	24
	OS	0	0	0	2	0	0	0	0	0	0	3	0	0	0	0	0	0	0	5
Botia lohachata	SS	1	1	10	16	25	21	11	15	22	11	18	32	9	4	14	13	8	4	235
	PP	1	0	0	1	1	0	1	0	2	2	9	1	2	1	2	0	0	2	25
	OS	0	1	0	0	2	0	0	1	0	0	2	0	0	1	0	0	0	0	7
Ompok pabda	SS	0	6	15	26	33	21	12	23	13	25	12	33	0	9	0	0	19	9	256
	PP	3	0	1	1	1	10	6	1	3	4	1	3	0	0	0	0	8	8	50
	OS	0	3	0	1	0	0	0	1	0	0	0	2	0	0	0	0	2	0	9
Rita rita	SS	1	7	13	41	20	5	4	3	2	1	3	6	4	9	0	14	12	0	145
	PP	0	1	1	1	3	2	1	0	2	0	2	2	2	0	0	0	0	0	17
	OS	0	1	0	1	2	0	0	0	2	0	0	1	0	0	0	0	0	0	7
Cirrhinus reba	SS	0	1	5	12	11	9	10	13	4	26	27	33	20	10	28	15	13	6	243
	PP	0	1	0	0	3	0	0	0	2	0	1	2	0	0	4	0	0	0	13
	OS	3	0	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	6
Clupisoma garua	SS	0	3	5	15	4	3	2	2	2	1	2	2	2	5	0	10	10	3	71
	PP	0	1	0	1	1	0	1	2	1	0	0	3	1	0	0	0	0	0	11
	OS	2	0	0	2	2	0	0	1	0	0	1	0	0	0	0	0	0	0	8
Sperata aor	SS	0	3	6	25	9	2	2	2	2	1	1	2	2	6	6	6	7	5	87
	PP	0	1	1	4	2	0	1	0	1	0	0	3	2	1	3	0	0	0	19
	OS	0	0	1	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	4
Eutropiichthys vacha	SS	1	3	13	16	24	12	17	13	8	6	6	13	0	13	21	32	31	11	240
	PP	1	1	1	10	10	1	9	1	4	1	1	0	0	9	8	20	15	6	98
	OS	2	0	0	1	0	0	0	2	0	0	1	0	0	0	0	0	0	0	6
Systomus sarana	SS	0	6	11	31	12	10	22	21	8	6	21	11	8	9	13	14	11	10	224
	PP	0	1	0	2	1	4	0	2	0	6	0	1	5	0	0	12	8	5	47
	OS	0	1	1	1	3	0	0	1	2	0	0	1	4	5	0	2	2	0	23
Mystus cavasius	SS	0	6	13	15	22	18	21	16	14	17	11	15	6	12	19	25	24	18	272
	PP	0	0	2	5	5	5	7	0	4	1	3	0	4	0	12	10	0	8	66
	OS	2	0	0	0	1	0	2	0	0	0	2	0	0	0	0	0	0	4	11

11.5. Plankton diversity in the Shari-Goyain River

During the study period, a total of 40 genera of phytoplankton and 18 genera of zooplankton were found from the selected sampling spots (Table 22).

Table 22. List of phytoplanktons and zooplanktons in the studied sites

	Phytoplankton (Genus)			Zooplankton (Genus)	
1	*Achnant hidium*	21	*Chlorella*	*1*	*Cyclops*
2	*Aulacos eira*	22	*Closterium*	*2*	*Diaptomus*
3	*Cyclotella*	23	*Colestrum*	*3*	*Asplanchna*
4	*Cryptomonas*	24	*Monoraphidium*	*4*	*Chydorus*
5	*Rhodomonas*	25	*Microspora*	*5*	*Brachionus*
6	*Cylindrospermopsis*	26	*Oocystis*	*6*	*Filinia*
7	*Diatoma*	27	*Pediastrum*	*7*	*Keratella*
8	*Fragillaria*	28	*Spirogyra*	*8*	*Lecane*
9	*Melosira*	29	*Staurastrum*	*9*	*Monostyla*
10	*Navicula*	30	*Treubaria*	*10*	*Cypris*
11	*Peridinium*	31	*Volvox*	*11*	*Daphnia*
12	*Synedra*	32	*Oedogonium*	*12*	*Diffugia*
13	*Lyngbya*	33	*Anabaena*	*13*	*Ceriodaphnia*
14	*Stigeoclonium*	34	*Merismopedia*	*14*	*Mytilina*
15	*Gyrosigma*	35	*Microcystis*	*15*	*Sida*
16	*Nitzchia*	36	*Oscillatoria*	*16*	*Moina*
17	*Spirulina*	37	*Euglena*	*17*	*Nauplius*
18	*Ankistrodesmus*	38	*Phacus*	*18*	*Crustacea*
19	*Ankyra*	39	*Trachelomonus*		
20	*Ceratium*	40	*Euglena*		

11.5.1. Phytoplankton composition : In the present study, a total of 40 phytoplankton genera were observed. During the study period these phytoplankton showed different abundance and diversity. The genera present in different groups were Bacillariophyceae (14), Cyanophyceae (9), Euglenophyceae (3), Dinophyceae (2), Chrysophyceae (2), Cryptophyceae (1), Coscinodiscophyceae (1), and Chlorophyceae (8). In the present study, phytoplankton diversity of this river was observed and found that Bacillariophyceae (30%) population was most abundant followed by Chlorophyceae (29%) and Cyanophyceae (28%) in the Shari-Goyain River (Fig 19). Hossain *et al.* (2016) observed plankton diversity in the Meghna River where there were 41 genera of phytoplankton belongs to Bacillariophyceae, Chlorophyceae, Cyanophyceae, Dinophyceae, Euglenophyceae, Myxophyceae and Xanthophyceae which is similar to the present study. In this river, phyplankton genera is comparatively lower than Meghna River because of the sandy river bed and the effect of coal mining effluent comes down from the upper stream from Meghalaya, India. Another cause was pH found always lower than the optimum level of plankton growth.

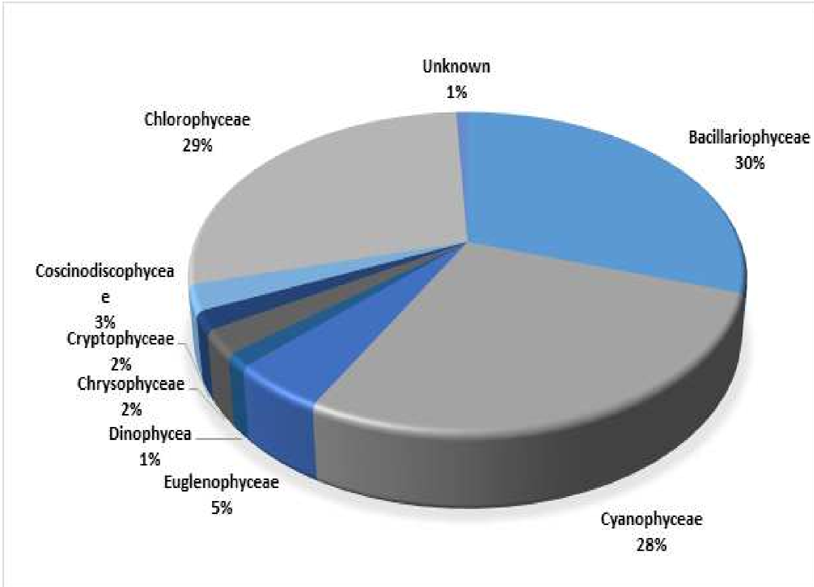


Fig 19. Percentage of phytoplankton diversity recorded in the Shari-Goyain River.

11.5.2. Zooplankton composition : During the study period, a total 18 genera of zooplankton was observed which was belonged to eight major classes such as Copepoda (2), Cladocera (5), Rotifera (5), Ostracoda (2), Branchiopoda (1), Tubulinea (1), Monogonta (1) and Euratatoria (1). Among the eight major classes of zooplankton, Cladocera was the most dominant group comprising 37% followed by Rotifera (28%) and Copepoda (12%) (Fig 20). Zooplankton diversity showed quite variations probably because of its mobility or environmental difference. Hossain *et al.* (2016) described total 9 genera of zooplanktons with four families namely Rotifera with 2 genera, Cladocera with 3 genera, Copepoda with 3 genera and Ostracoda with 1 genus were identified from the selected sampling spots of the Meghna River which were much lower than the present study.

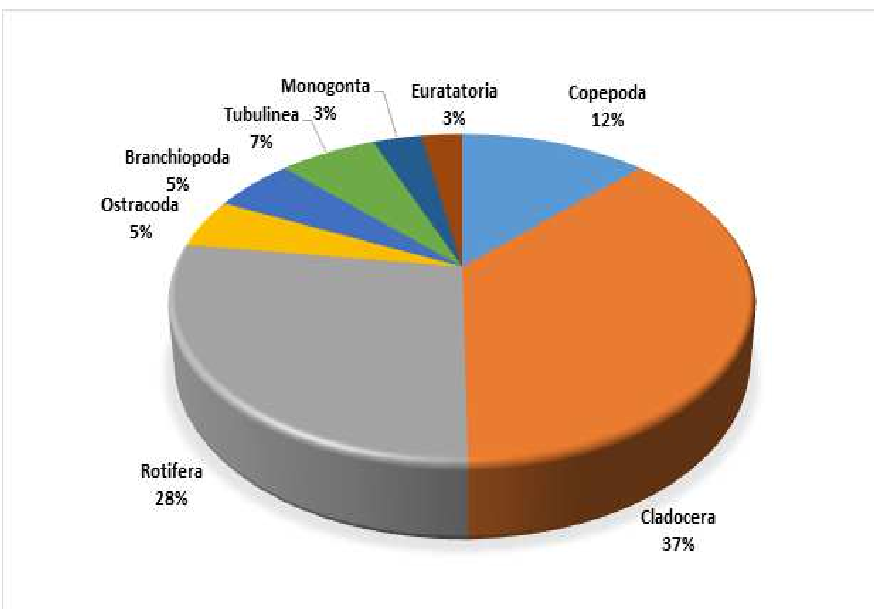


Fig. 20. Zooplankton diversity under different classes recorded in the Shari-Goyain River.

11.5.3. Spatio-temporal variation of plankton abundance in the Shari-Goyain River : Total abundance was highest in Jalurmukh site (1,53,333±6667 individuals/l) in the whole study year. Even the total plankton species diversity was higher in Jalurmukh site. Phytoplankton species diversity was higher in Lalakhal site and zooplankton species diversity was higher in Jalurmukh site. The cause of highest plankton abundance in the Jalurmukh as because of a river and many canals from adjacent wetlands connected to the Shari-Goyain River at this point and huge organic matter comes from the wetland that usually enriched the river water (Fig 21).

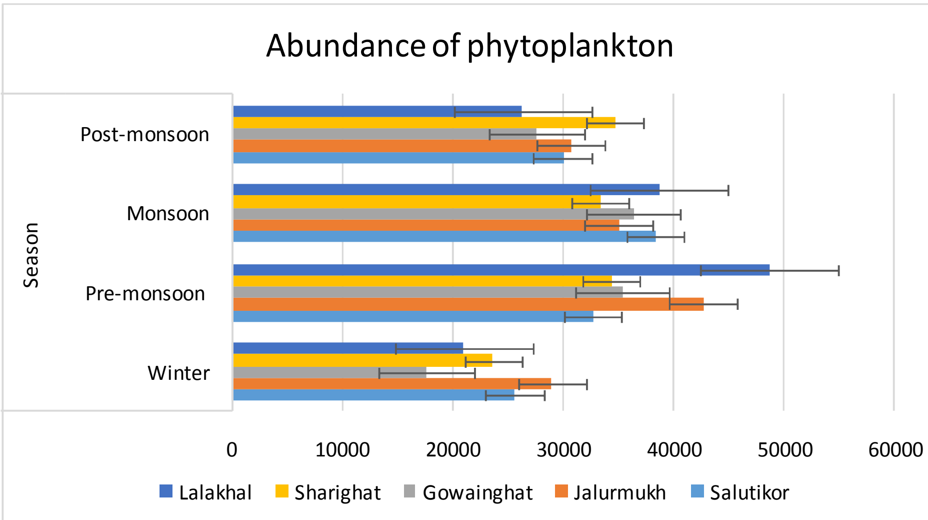


Fig. 21. Comparative abundance (mean±SD) of phytoplankton communities in different sampling sites and different seasons.

In the four seasons pre-monsoon and monsoon season showed higher abundance of phytoplankton. Abundance was highest in the Jalurmukh Site (1,37,333±6104 individuals/l) and lowest in Gowainghat Site (1,17,000±8638 individuals/l) of the river. But Lalakhal showed higher abundance in the pre-monsoon season (48,667±3024 individuals/l).

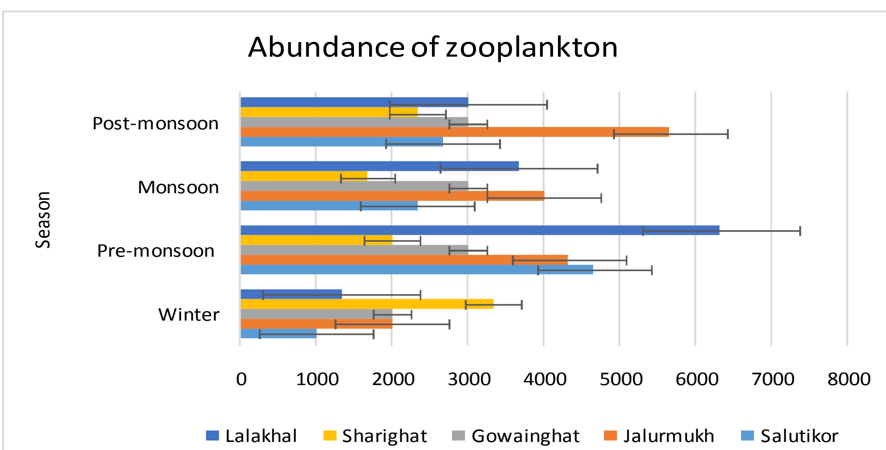


Fig. 22. Comparative abundance (mean±SD) of zooplankton communities in different sampling sites and different seasons.

Abundance of zooplankton was more or less different from the abundance of phytoplankton. Zooplankton was quite less in cell numbers comparing phytoplankton (Fig 22). Even the spatial and temporal abundance was different. Zooplankton was more abundant in pre-monsoon (20,333±2,309 individuals/l) and post-monsoon season (16,667±2,517 individuals/l). Site-wise abundance was highest in the Jalurmukh site (16,000±1,515 individuals/l) like phytoplankton but lowest in Sharighat site (9,333±720 individuals/l).

11.5.4. Seasonal variation of plankton diversity status in the study area : Diversity of phytoplankton and zooplankton varied depending on different sampling sites and seasons. The highest number of phytoplankton genera was found in post monsoon (31-34) followed by monsoon (29-33), winter (24-25), and the lowest in pre-monsoon (17-19) in the Shari-Goyain River (Fig 23).

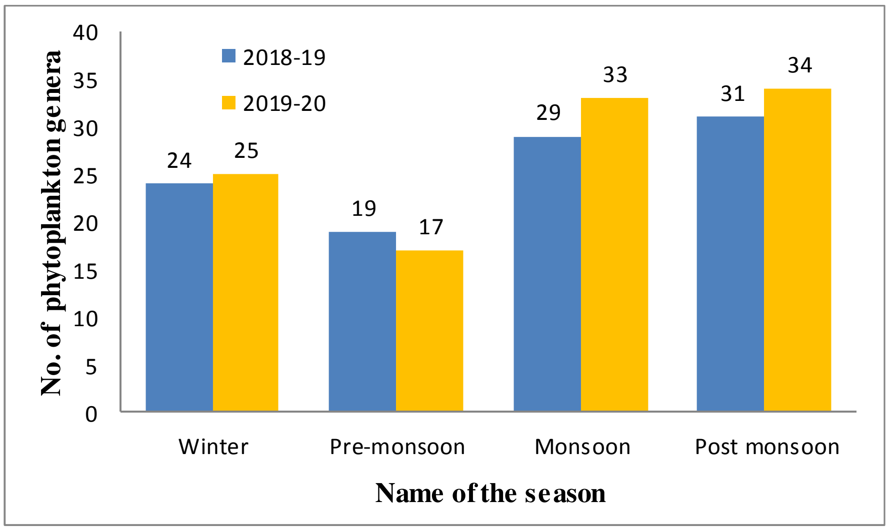


Fig. 23. Seasonal variation of phytoplankton diversity in the Shari-Goyain River**.**

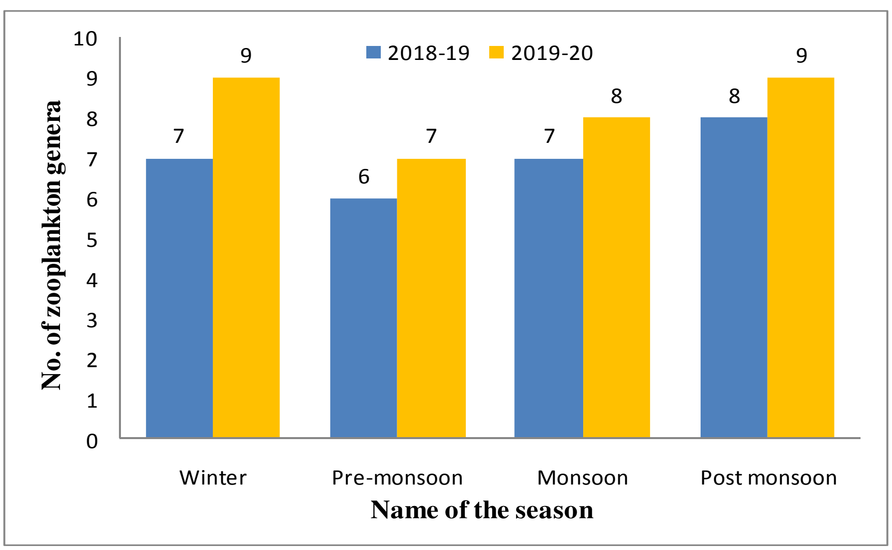


Fig. 24. Seasonal variation of zooplankton diversity in the Shari-Goyain River.

The highest number of zooplankton genera was found in post monsoon (8-9) followed by winter (7-9), monsoon (7-8), and the lowest in pre-monsoon (6-7) in the Shari-Goyain River (Fig 24). Findings of the present study can be used to improve the water management strategies of this river.

11.5.5. Abundance of plankton population in Chalan beel : A total of 4 classes, 53 genera and 63 species which belongs to Chlorophyceae (25 species), Bacillariophyceae (17 species), Cyanophyceae (16 species) and Euglenophyceae (5 species) were recorded during the study period from two study location of Chalan beel (Table 23). Monthly abundance of phytoplankton group is shown in Table 23. Chlorophyceae was the dominant among the four phytoplankton groups and its higher abundance was recorded during the month of November at both Site-1 and Site-2. However, other groups were arranged in order of Chlorophyceae> Bacillariophyceae>Cyanophyceae>Euglenophyceae. During the sampling period, lower abundance was recorded for Euglenophyceae. During July, abundance of Euglenophyceae was severally reduced and a scanty amount was recorded (Table 24).

Table 23. List of phytoplankton species in Chalan beel during August 2018 to December 2020

Chlorophyceae	Bacillariophyceae	Cyanophyceae	Euglenophyceae
Actinastrum sp.	*Amphora* sp.	*Anabaena circinalis*	*Euglena* sp.
Ankistrodesmus sp.	*Asterionella* sp.	*Aphanocapsa* sp.	*Euglena viridis*
Botryococcus sp.	*Bacillaria* sp.	*Chroococcus* sp.	*Lepocinclis* sp.
Chlamydomonas sp.	*Coscinodiscus* sp.	*Chroococcus* sp.	*Phacus* sp.
Chlorella sp.	*Cyclotella* sp.	*Cylindrospermopsis* sp.	*Trachelomonas* sp.
Chlorella vulgaris	*Cymbella* sp.	*Merismopedia punctate*	
Cladophora sp.	*Diatom* sp.	*Microcystis robusta*	
Closterium sp.	*Fragillaria* sp.	*Microcystis aeruginosa*	
Cosmarium sp.	*Gomphonema* sp.	*Merismopedium* sp.	
Cosmarium formosulum	*Grysosigma* sp.	*Merismopedia elegans*	
Crucigenia crucifera	*Melosira* sp.	*Nostoc* sp.	
Microspora sp.	*Navicula* sp.	*Oscillatoria subbrevis*	
Oedogonium borisianum	*Nitzschia* sp.	*Oscillatoria agardhii*	
Oedogonium sp.	*Rhizosolenia* sp.	*Polycistis* sp.	
Pandorina cylindricum	*Surirella* sp.	*Phormidium* sp.	
Pediastrum duplex	*Synedra* sp.	*Spirulina* sp.	
Pediastrum sp.	*Tabellaria* sp.		
Scenedesmus arcuatus			
Scnedesmus sp.			
Spirogyra hyaline			
Spirogyra sp.			
Ulothrix sp.			
Ulothrix zonata			
Volvox sp.			
Zygnema sp.			

Table 24. Descriptive statistics of monthly values of major groups of phytoplankton of the study sites during the study period

Sampling months	Chlorophyceae		Bacillariophyceae		Cyanophyceae		Euglenophyceae	
	Site-1	Site-2	Site-1	Site-2	Site-1	Site-2	Site-1	Site-2
Aug-18	154±21	259±121	142±45	150±28	23±13	28±10	0±0	0±0
Sep-18	421±100	557±287	546±200	460±105	73±27	80±42	10±3	22±10
Oct-18	8580±1063	8626±3014	10005±1673	8517±1976	927±190	923±302	244±87	269±151
Nov-18	11454±2109	11780±219	6947±5303	8598±1057	1819±349	1802±380	756±264	736±244
Dec-18	9421±2354	9404±1576	9859±2021	8752±2100	2634±586	2151±646	1051±180	805±302
Jan-19	10749±2566	10509±1989	8573±1678	10038±1668	8871±10947	2312±308	1860±246	1748±438
Feb-19	10906±1879	10575±746	11788±857	10144±1435	3060±510	2946±351	1482±202	1527±327
Mar-19	9724±2552	8926±1326	8182±2378	8815±2552	5011±565	5332±527	435±210	283±148
Apr-19	9996±1468	9924±1329	8001±1706	7826±1715	3404±2685	4343±1014	68±30	64±36
May-19	7136±825	8310±1350	9127±962	8239±605	3339±724	4450±795	21±5	20±8
Jun-19	6390±807	7549±2049	6567±862	5804±1538	1708±436	1742±422	4±2	4±2
Jul-19	2046±519	2157±531	1386±230	1187±250	411±212	315±170	0±0	0±0
Aug-19	173±73	266±89	127±28	183±60	53±11	38±18	0±0	0±0
Sep-19	423±283	562±305	294±64	208±103	97±63	82±45	9±4	8±7
Oct-19	7227±3490	8600±2619	4925±581	5484±2152	680±225	535±200	211±50	232±103
Nov-19	12056±1745	10519±1933	12971±3053	13264±2984	2341±1012	2069±2235	424±158	437±149
Dec-19	8437±2120	9193±525	8759±2983	9476±833	3578±971	3266±2038	983±135	734±259
Jan-20	11673±2389	11640±1515	9273±1715	10615±1353	8871±10947	2404±300	1733±510	1841±381
Feb-20	10571±599	11730±2153	12271±932	11080±1151	3060±510	2967±708	1342±272	1653±487
Mar-20	9289±2431	10331±831	8996±1349	9520±2589	5011±565	4690±1395	454±130	321±157
Apr-20	10319±1056	10412±844	8683±1385	8766±1356	4380±1026	4206±778	95±24	72±26
May-20	8750±1362	8680±1251	9826±1337	8057±1478	3339±724	2973±738	45±39	40±13
Jun-20	7520±1063	9130±2853	5789±2599	5476±2143	1834±458	1661±467	5±3	7±1
Jul-20	2571±628	3824±2502	1759±295	1265±368	441±274	357±101	1±2	1±1
Aug-20	398±330	440±308	484±282	233±125	66±5	46±37	2±1	5±6
Sep-20	575±322	601±246	444±115	436±327	137±119	112±107	16±8	17±7
Oct-20	8551±3976	8687±3657	7166±5065	5969±2219	697±253	755±385	152±123	163±158
Nov-20	15600±2515	15771±3944	15529±2656	13527±4346	4345±1928	3342±2598	448±296	463±375
Dec-20	8333±4668	8296±6013	9059±3238	10316±3717	4639±2600	3899±2104	1182±185	1052±720

11.6. Zooplankton in Chalan beel

A total of 4 groups, 20 species belonging to the group Rotifera (9 species), Cladocera (5 species), Copepoda (5 species) and Ostracoda (2 species) were recorded during the study period from August 2018 to May 2019 (Table 25). Monthly values of zooplankton are shown in Table 26. Among the zooplankton, Rotifera was the most dominant followed by Cladocera, Copepoda and Ostracoda. The abundance of Rotifera was the highest during the month of December at both Site-1 and Site-2. Ostarcoda was the least abundant zooplankton group during the study period (Table 26).

Table 25. List of zooplankton species in Chalan beel during August 2018 to December 2020 from two study sites

Rotifera	**Copepoda**	**Cladocera**	**Ostracoda**
Ascomorpha sp.	*Calanoid* sp.	*Bosmina* sp.	*Cypris* sp.
Asplanchna sp.	*Cyclops* sp.	*Daphnia* sp.	*Stenocypris* sp.
Brachionus angularis	*Diaptomus* sp.	*Diaphanosoma* sp.	
Filinia sp.	*Mesocyclops* sp.	*Moina* sp.	
Gastropus sp.	Nauplius larvae		
Hexarthra sp.			
Keratella sp.			
Lecane sp.			
Polyarthra sp.			

Table 26. Descriptive statistics of monthly values of major groups of zooplankton of the study sites during the study period

Sampling months	Rotifera		Cladocera		Copepoda		Ostracoda	
	Site-1	Site-2	Site-1	Site-2	Site-1	Site-2	Site-1	Site-2
Aug-18	16±5	10±2	12±3	13±8	20±5	24±11	0±0	0±0
Sep-18	14±4	15±4	12±8	13±9	20±8	20±10	0±0	0±0
Oct-18	46±8	45±17	21±10	23±11	21±8	28±7	0±0	0±0
Nov-18	755±102	768±80	288±36	305±159	263±56	228±100	2±2	3±4
Dec-18	790±153	813±112	294±208	263±71	398±65	358±252	5±4	4±5
Jan-19	1093±133	1013±144	529±106	503±226	471±144	438±83	9±3	12±2
Feb-19	862±105	824±125	426±100	521±308	371±117	378±330	3±2	3±3
Mar-19	812±337	754±266	344±99	260±150	168±81	192±160	13±3	13±8
Apr-19	745±116	746±110	197±63	217±53	249±106	240±123	17±6	20±13
May-19	535±85	527±246	174±61	156±40	202±47	213±76	3±2	2±2
Jun-19	172±55	168±75	125±18	134±13	115±9	119±31	0±0	0±0
Jul-19	85±40	128±105	62±15	56±11	50±23	43±11	0±0	0±0
Aug-19	13±9	14±2	19±7	21±22	16±7	18±4	0±0	0±0
Sep-19	19±4	17±4	22±6	21±5	19±7	21±2	0±0	0±0
Oct-19	38±11	44±29	22±10	23±12	17±6	15±13	0±0	0±0
Nov-19	611±154	491±323	299±136	248±119	284±155	175±133	2±1	2±2
Dec-19	557±199	560±107	350±82	395±154	448±81	447±98	7±3	10±2
Jan-20	1170±439	1073±192	632±110	544±100	529±100	494±143	8±7	17±4
Feb-20	667±266	664±85	554±99	554±369	454±120	398±341	5±4	4±4
Mar-20	906±359	756±239	447±120	280±149	196±80	220±127	15±3	16±9
Apr-20	686±210	753±101	234±104	244±8	281±120	278±71	20±13	21±12
May-20	588±200	447±192	224±43	183±66	194±65	258±111	5±1	3±4
Jun-20	187±50	215±97	144±12	137±23	122±24	131±62	0±0	0±0
Jul-20	134±77	183±156	88±39	96±62	60±31	74±48	1±1	3±4
Aug-20	30±16	31±12	33±30	40±32	29±15	25±18	2±3	3±2
Sep-20	31±21	42±39	26±15	42±31	28±15	40±40	2±2	3±4
Oct-20	56±26	74±27	41±20	50±25	21±11	34±10	4±4	3±2
Nov-20	619±322	743±330	462±281	564±279	439±264	484±368	5±1	4±3
Dec-20	739±478	796±377	336±104	388±159	497±272	649±276	11±8	18±8

11.7. Water quality parameters in the Shari-Goyain River

Seasonal fluctuations of different water quality parameters in the Shari-Goyain are presented in Table 27. Average water temperature was found 20.06±0.83°C in dry season and increased to 28.32±1.58°C in monsoon (annual average 25.58±3.74°C). The value of DO was found to be fluctuated from the minimum value of 4.67±1.78 mg/l in monsoon to the maximum value of 7.91±1.25 mg/l in dry season with a mean value of 6.04±1.36 mg/l.

Water transparency ranged from 65.11±5.57 cm in post-monsoon to 99.65±3.63 cm in dry season with a mean value of 84.10±17.17 cm. Discolored, turbid or exceptionally clear water indicates coal mine drainage (CMD) pollution. Water can have a distinct yellow-red brown coloration, caused by an abundance of suspended iron hydroxide particles. The turbidity of the CMD water generally decreases downstream as the iron and aluminum flocculate and salts precipitate with increasing pH. As a result, acidic waters can also be exceptionally clear and may give the wrong impression of being of good quality (Dave and Tipre, 2012) but dangerous to the aquatic organisms. This phenomenon was observed in the Shari-Goyain River.

The conductivity of water ranged from 58.40±14.22 µS in monsoon season to 84.33±8.78 µS in dry season with a mean value of 73.64±12.45 µS. The value of TDS was found to fluctuate from the minimum value of 27.77±6.46 ppm in June to the maximum value of 48.71±13.88 ppm in pre-monsoon with a mean value of 39.30±10.35 ppm. Average water depth was highest in monsoon (12.19±4.59 m) and lowest in dry season (2.73±0.38 m) with a mean value of 6.13±4.18 m. In this way, the hydro-chemical parameters of the Shari-Goyain River water are found to be fluctuating and sometimes exceeding or falling below the suitable limits for survival of aquatic flora and fauna.

Generally, pH is the indicator of acidic or alkaline condition of water status. The standard value for any purpose in-terms of pH is 6.5–8.5. The average pH of water was acidic in nature (5.88±0.49) whereas it was found slightly acidic round the year but highly acidic in pre-monsoon season (5.25±0.12). The possible reason of high acidity in pre-monsoon season is the coal mine drainage came from the upstream of the Shari-Goyain River. Dave and Tipre (2012) described coal mine drainage waters with a pH of less than 5.5 and obtained acidity through the oxidation of sulphide minerals which supports present study.

In Meghalaya, several large mining projects are currently running, ranging from open-pit, hard rock mines to strip mines for extracting coal. These unscientific coal mining activities without environmental consideration has adversely affected the water resources of the Jaintia Hills district of Meghalaya, leading streams with a very low pH (about 3-5) (Pyrbot & LalooRC 2015). Another study shows that the waterbodies in the mining areas of Meghalaya have been adversely affected by the contamination of AMD originating from coal mining operations. Low pH (approximately 4.0), low dissolved oxygen, high electrical conductivity, and high metal content are some of the implications brought about by coal mining activities which has resulted in the decline or complete loss of fish fauna in the wetlands of coal mining areas (Myllіemngap and Ramanujam, 2011). However, polluted AMD finds their ways into the Myntdu River and flows downstream to the Shari-Goyain River. Thus upstream polluted water has direct impact to the fish and wildlife resources of vast areas of aquatic habitat in the Shari-Goyain River of Bangladesh.

Table 27. Temporal fluctuation of water quality parameters in the Shari-Goyain River

Parameters	Name of the seasons				
	Pre-monsoon (Mar-May)	Monsoon (Jun-Aug)	Post-monsoon (Sep-Nov)	Dry season (Dec-Feb)	Annual average
Temp. (˚C)	26.69±2.36	28.32±1.58	27.26±1.95	20.06±0.83	25.58±3.74
DO (mg/L)	5.89±1.87	4.67±1.78	5.67±1.62	7.91±1.25	6.04±1.36
Cond. (µS)	83.28±11.00	58.40±14.22	68.56±1.23	84.33±8.78	73.64±12.45
TDS (ppm)	48.71±13.88	27.77±6.46	33.37±0.60	47.34±4.32	39.30±10.35
pH	5.25±0.12	6.29±0.41	6.24±0.18	5.72±0.17	5.88±0.49
Trans. (cm)	97.58±22.10	74.06±12.25	65.11±5.57	99.65±3.63	84.10±17.17
Depth (m)	4.22±2.76	12.19±4.59	5.39±1.12	2.73±0.38	6.13±4.18

11.8. Water quality of SUST selected sites

Water samples were collected from different sites and tested in the laboratory. Total 24 parameters are tested: DO (mg/L), BOD5 (mg/L), Temperature (0C), Electric Conductivity (EC), pH, Turbidity (NTU), Total Dissolved Solids (TDS, mg/L), Total Suspended Solids (TSS, mg/L), Nitrate (mg/L), Hardness (mg/L), Total Coliform (T.C), Faecal Coliform (F.C), Chloride (mg/L), Arsenic (mg/L), Iron (mg/L), Manganese (mg/L), Aluminium (mg/L), Sulfate (mg/L), Potassium (mg/L), Calcium (mg/L), Copper (mg/L), Chromium (mg/L), Zinc (mg/L), Nickel (mg/L). Data from test results were processed and analyzed manually and through MS Excel of Office 2007 version. Some of the test results are presented in tabular form in (SUST: Appendix-1 Tab A1 & A2).

Temperature of water may not be as important in pure water because of the wide range of temperature tolerance in aquatic life, but in polluted water, temperature can have profound effects on dissolved oxygen (DO) and biological oxygen demand (BOD). The fluctuation in river water temperature usually depends on the season, geographic location, sampling time and temperature of effluents entering the stream. Temperature of Shari- Goyain river water is usually a little bit lower than standard for fisheries, varies from 18 to 28^0C (standard for fisheries according to EQS 1997 is 25^0C). However, according to CCME standard the value is 15^0C. Oxygen is the single most important gas for most aquatic organisms; free oxygen or DO is needed for respiration. The DO levels below 1 mg/L will not support fish. DO of the river was found on and average good for fisheries (according to EQS 1997 standard value- 4 to 6 mg/L; according to CCME standard- 5.5 to 9 mg/L); however, it was found lowest (3.0 mg/L) in Ratargul (in October ’19) and Gowainghat (in November ’19). BOD directly affects the amount of dissolved oxygen in rivers and streams. The greater the BOD, the more rapidly oxygen is depleted in the stream. BOD5 of the river was found on and average within limit (standard value-maximum 2 mg/L, according to DoE).

EC value depends on the concentration and degree of dissociation of the ions as well as the temperature and migration velocity of the ion in the electric filed. The electrical conductivity measures the concentration of ions in water. The concentration of ions depends on the environment, movement and sources water. The soluble ions in the surface water originate primarily from solution of rock materials. Specific conductance of most natural water generally ranges from about 50 to 1500 µS/cm. Bangladesh standard for fisheries, this value is between 800-1000 µs/cm. According to Stone and Thomforde, acceptable value for fish species is between 30-5000 µs/cm. The Electric Conductivity in the study area ranged between 9- 214 µS/cm, which is sometimes less than the limit. Turbidity of river water was highest in May 2019 (106 NTU). TDS and TSS are often high in wet season, whereas normal in dry season. Coliform was found very few, within acceptable limit. Nitrogen (NO3-N) was well below the standard limit for fishes (CCME Standard value is 13 mg/L). Hardness was found 10-450 mg/L (according Bathnagar and Devi, 2013) this value should be between 20-300 mg/L). Chloride, Potassium, and Calcium are within limit. Arsenic is absent in the water.

Due to Acid Mine Drainage (AMD) parameters like Acidity, Iron, Manganese, Aluminum, Sulfate and some heavy metals are likely to be present. pH is found often less than 7, which means the water of Shari- Goyain is acidic. This indicates that there is an impact of upstream coal mining on water quality. pH of Zero point was only 3.8 in April 2019 (ECR 1997 standard value: 6.5- 8.5; CCME Standard value: 6.5-9). Sulfate concentrations in study area ranged between 0 to 56 mg/L, higher values were found in dry season. The standard value according to DoE 2001 is less than 22 mg/L for river water. BSTI standard for iron concentration in water is 0.3- 1.0 mg/L. Iron concentration in river water was found within limit. BSTI/ CCME standard for Manganese concentration in water is 0.1 mg/L. Value of Manganese concentration in river water was found even 0.36 mg/L. Aluminium and Zinc Concentrations have always been a concern in this river, even were found 5.23 mg/L at zero point in December '18 and 1.38 mg/L at Sharighat in February'19 respectively (CCME Standard Value: 0.005-0.01 mg/L and 0.007 mg/L respectively) which are way beyond the standard value. Highest values of Chromium, Copper, and Nickel were found more than standard; 0.068 mg/L, 1.18 mg/L and 1.43 mg/L respectively (standards 0.001, 0.002, 0.007 and 0.025-0.15 mg/L respectively). It is clear from above that the river water is polluted with heavy metals, which is a result of AMD. Heavy metal concentration results are shown in Table 28 in detail.

Some sediment samples were also collected from Zero point and Sharighat to detect heavy metals. Chromium, Nickel and Copper were found more than the standard values according to BSTI, especially at Zero point (Table 29). Concentration of heavy metals in soil samples are greater (except zinc) at Zero point than at Sharighat.

A statistical summary (season wise mean values and standard deviation) and standard values for all water quality parameters has been given in the (SUSU: Appendix-1 Tab A4a & A4b). Zero point is at the most upstream, concentration of almost every pollutant related to AMD was found higher than at Sharighat. But some of the pollutants in Sharighat are more, as anthropogenic activities are more here. Concentration at other sampling points was found much less than Zero point and Sharighat. The quality of water in control river Kura was found much better and almost within the standards (SUST: Appendix-1 Tab A1 & A2).

11.8.1. Water Quality Index (WQI) : Each year was divided into two seasons: wet season (May - October) and dry season (November - April). Season wise Water Quality Index (WQI) for the river Shari- Goyain was calculated. The CCME WQI values obtained from the study are illustrated in SUST: Appendix Table-A4 & A5). According to the CCME-WQI scores, the water quality of this river ranges from poor to marginal throughout the study and does not support the aquatic life. In addition, Zero-point (upstream) is ranked as poor in both seasons. However, Sharighat, Gowainghat, and Ratargul (downstream) are ranked as poor and occasionally rated as marginal. It is quite obvious from the CCME-WQI values that Zero-Point remains in critical condition in both seasons and this is may be due to the impact of coal mining and industrial effluent around this river in Meghalaya state, India (further upstream). SUST: Appendix Table-A5) provides information about the three factors such as F1 (scope), F2 (frequency), F3 (amplitude) used for CCME-WQI calculation during the dry season (November 2018 – April 2019) when lowest CCME-WQI value was found at Zero-Point. It is noticeable that F3 dominates over F1 and F2 at all the selected locations. That indicates the amplitude of deviation from the standard limit of the failed test value was very high at that time. In addition, CCME-WQI values show almost a decreasing trend from river downstream to upstream that implies the river water is deteriorating from lower to upper stretch.

Table 28. The Calculated Values of CCME WQI in Shari-Goyain River during deadly pollution

Dry Season (November 2018 - April 2019)				
Term of the Index	**Zero-Point**	**Sharighat**	**Gowainghat**	**Ratargul**
Scope, F1	41.66667	45.83333	50	50
Frequency, F2	31.25	29.16667	22.91667	25.6944444
Excursion	2375.203764	1019.701889	534.7749	588.548843
Nse	16.49447	7.081263	3.713715	4.08714474
Amplitude, F3	94.28391	87.6257	78.78531	80.3426077
CCMEWQI	37.80994	40.47332	44.52376	43.3852104
Category	Poor	Poor	Poor	Poor

Table 29. Summery of CCME-WQI Calculations for Aquatic Life Protection in selected locations during deadly pollution

Dry Season (November 2018- October 2019)				
Sampling point	**Number of failed variables**	**Number of failed tests**	**Variable with most failed tests**	**Variables with highest excursion**
Zero-Point	10	45	pH, Aluminium, Sulfate, Copper, Chromium, Zinc, Nickel.	Aluminium
Sharighat	11	42	BOD_5, pH, Aluminium, Sulfate, Copper, Chromium, Zinc	Aluminium
Gowainghat	12	33	Turbidity, Aluminium, Zinc	Aluminium
Ratargul	12	37	pH, Turbidity, TSS, Aluminium, Zinc	Aluminium

Table also reveals precise information of the water quality scenario during the deadly polluted season. It denotes that during this season pH value found unfavourable (acidic) for aquatic life. This can be attributed to acid mine drainage (AMD). Turbidity was a matter of concern for Gowainghat and Ratargul. In addition, the concentration of sulfate at Zero-Point and Sharighat found high owing to presence of iron sulphide in coal and rocks and its reaction with water and oxygen. Needless to say, Heavy metals such as Aluminium, Copper, Chromium and Zinc put a big impact in reducing the CCME-WQI value. These Heavy metals can be dissolved from mining site through the action of acid runoff or can be washed into the streams as sediments. Moreover, highest excursion was observed in Aluminium at all the selected locations. That implies serious pollution by this parameter.

Co-relations

From Pearson Correlation Analysis using SPSS version 25.0, correlations among the variables were established (Table 30). In this study, 24 water quality parameters were used for the analysis purpose. It was found that EC, pH, Aluminum, Sulfate, Copper, Chromium, Zinc, and Nickel were strongly correlated. As was mentioned, these are mostly responsible for water quality degradation and result of Acid Mine Drainage (AMD).

pH is a vital parameter for river water with AMD. AMD causes low level of pH. pH level of the river water in different seasons are shown in Fig 25 & 26. It is seen that most of the time in both seasons' pH is much less than 7, that means acidic. In the contrary, pH of River Kura is almost neutral (mean value is about 6.3) SUST: Appendix Table-A6a & A6b).

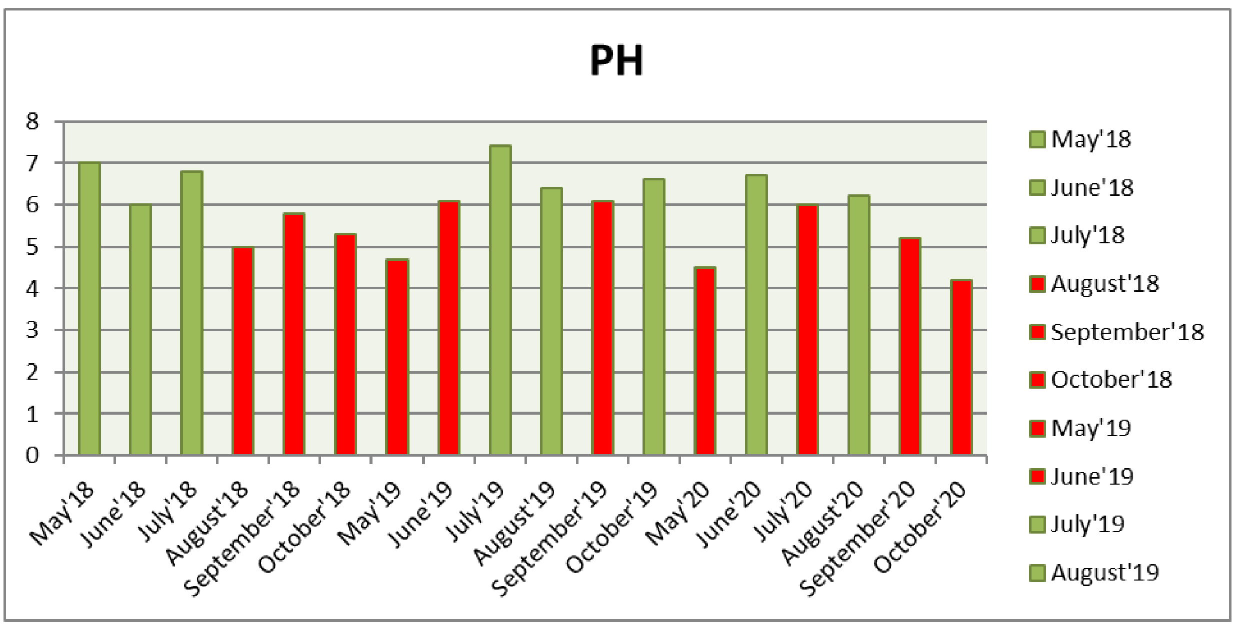


Fig. 25. pH in wet season.

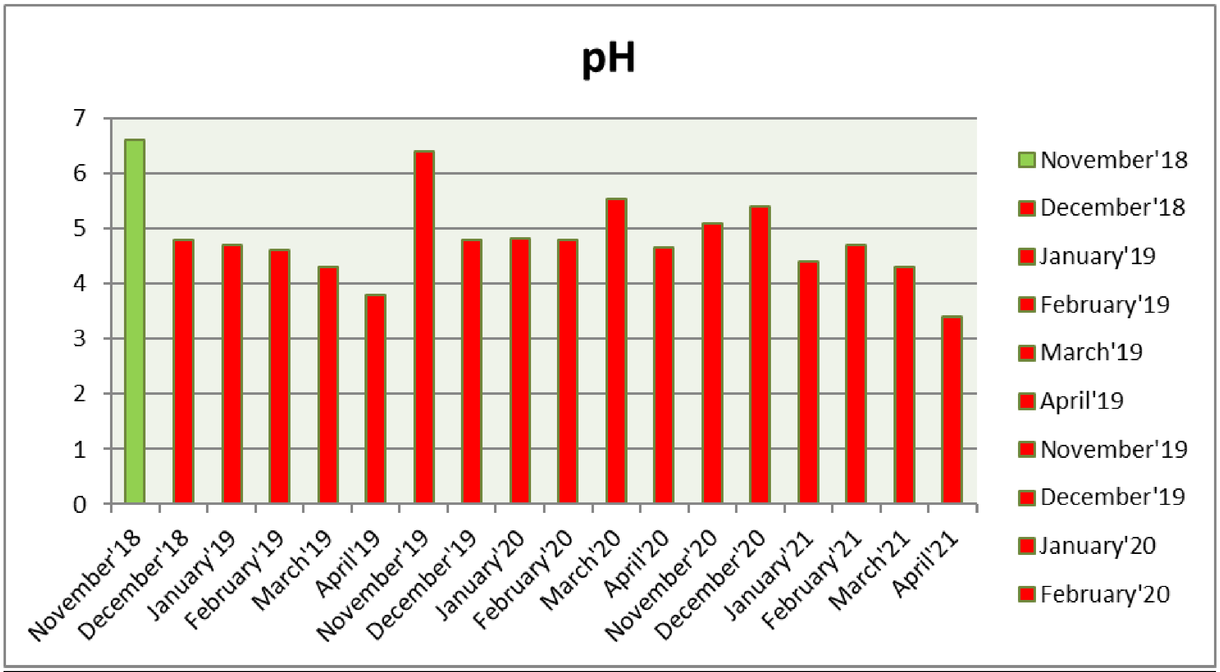


Fig. 26. pH in dry season.

There are strong relationships among pH and many other parameters; some of them are discussed below:

- pH with toxic metals: pH plays a vital role for river water with Acid Mine Drainage (AMD). AMD is responsible for lowering pH range, high conductivity, high concentration of heavy metals such as Aluminium, Copper, Chromium, Zinc, Nickel, Iron and so on.
- pH with Electric Conductivity (E.C): pH is a measure of the H^+ ion concentration of the solution. Conductivity depends on the concentration of ions, as they carry charges which are responsible for the conduction. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate and phosphate ions or sodium, magnesium, calcium, iron and aluminium.
- pH with Al^{3+}: At pH values below 4.5 solubility rapidly increases causing aluminium concentration to rise above 5 ppm. This may also occur at very high pH values. Dissolved Al^{3+} ions are toxic to plants. These affect roots and decrease phosphate intake.
- pH with sulphate: Sulphate reduction always increase alkalinity. The lower the pH the higher the level of sulphate.
- pH with Dissolved Oxygen (DO): If DO level in water drops below 5.0 mg/l, aquatic life goes under stress. The lower the concentration, the greater the stress. Oxygen level that remains below 1-2 mg/l for a few hours can result in large fish kills. DO level decreases due to decrease of pH level. If the pH is too low it decreases the ability of fish to absorb DO effectively. Low pH causes high BOD.

Table 30. Correlation among parameters

Parameter	Strongly co-related with	
	In dry season	In wet season
pH	EC, Sulfate, Calcium, TDS, TSS, Iron, Aluminium, Chromium	Iron, Aluminium, Sulfate, Potassium
Temperature	Sulfate, Copper, Zinc, Nickel	Nitrate, Manganese, Potassium, Chloride
DO	BOD5, Chromium, Nickel	BOD5, TC, Copper, Chromium
Turbidity	TSS	TSS, Hardness, Chloride, Iron, Potassium
Nitrate	BOD5, Chloride, Iron, Nickel	BOD5, Temperature, Nickel
BOD5	Nitrate, Iron, Nickel	DO, Nitrate
Iron	EC, TDS, TSS, Nitrate, Nickel	Turbidity, TSS, Manganese, Potassium
Aluminium	pH, Iron, Nitrate, Sulfate, Copper, Nickel	Sulfate, pH, E.C, TDS
Sulfate	pH, TDS, EC, Temperature, Aluminium, Calcium, Manganese	Aluminium, pH, EC, TDS
Copper	Aluminium, Temperature, Chloride	DO, Chromium, Nickel, Nitrate
Chromium	Nickel, Zinc, DO, BOD5	BOD5
Zinc	EC, TDS, Chromium	Temperature, Chloride, Nickel
Nickel	BOD5, Nitrate, Iron, Potassium	Nitrate, Copper, Chromium
Calcium	pH, Sulfate	-
TDS	EC, pH, TSS, Iron	-
TSS	EC, pH, Turbidity, TDS, Iron	Turbidity, Hardness, Chloride, Iron, Potassium
Manganese	Hardness	Temperature, Iron
EC	pH, TDS, TSS, Iron, Sulfate, Chromium, Zinc	Zinc, Aluminium, Sulfate
Chloride	Nitrate, FC, Potassium	Temperature, Turbidity, Potassium
Potassium	Nitrate, Chloride	Temperature, Turbidity, TSS, Chloride, Iron
TC	-	DO
FC	Chloride	Manganese

The relationship among the AMD parameters were also established (Fig 27 & 28) and Appendix 9.3 Tables A6a & A6b). The hierarchical clustering using SPSS showed how they linked up with pH. It was observed that in the wet season, Copper strongly correlated with Chromium which was just above 99%. Similarly, strong correlation was also found between Copper and Nickel which was above 76%. In addition, Substantial correlation was detected between Chromium and Nickel which was above 74%. Reasonable correlation was also found between Electric Conductivity and Zinc that was above 62%. In case of the correlation between Aluminum and Sulfate it was found above 50%. Although pH showed relatively low relationship with

Aluminum which was below 50%, the importance of pH was undeniable. As Zero point is upstream of the Shari-Goyain river and the nearest part of the coal mining area, it is very much expected to get highly concentrated heavy metals here than Sharighat and other selected points. On the other hand, in the dry season, Electric Conductivity was found significantly correlated with Sulfate and Zinc which was above 50% and correlation was also noticeable between pH and sulfate. Low pH of water causes the worst environment for aquatic life especially for fish survivals. Moreover, correlation of Aluminum with Copper and Nickel was found below 50%.

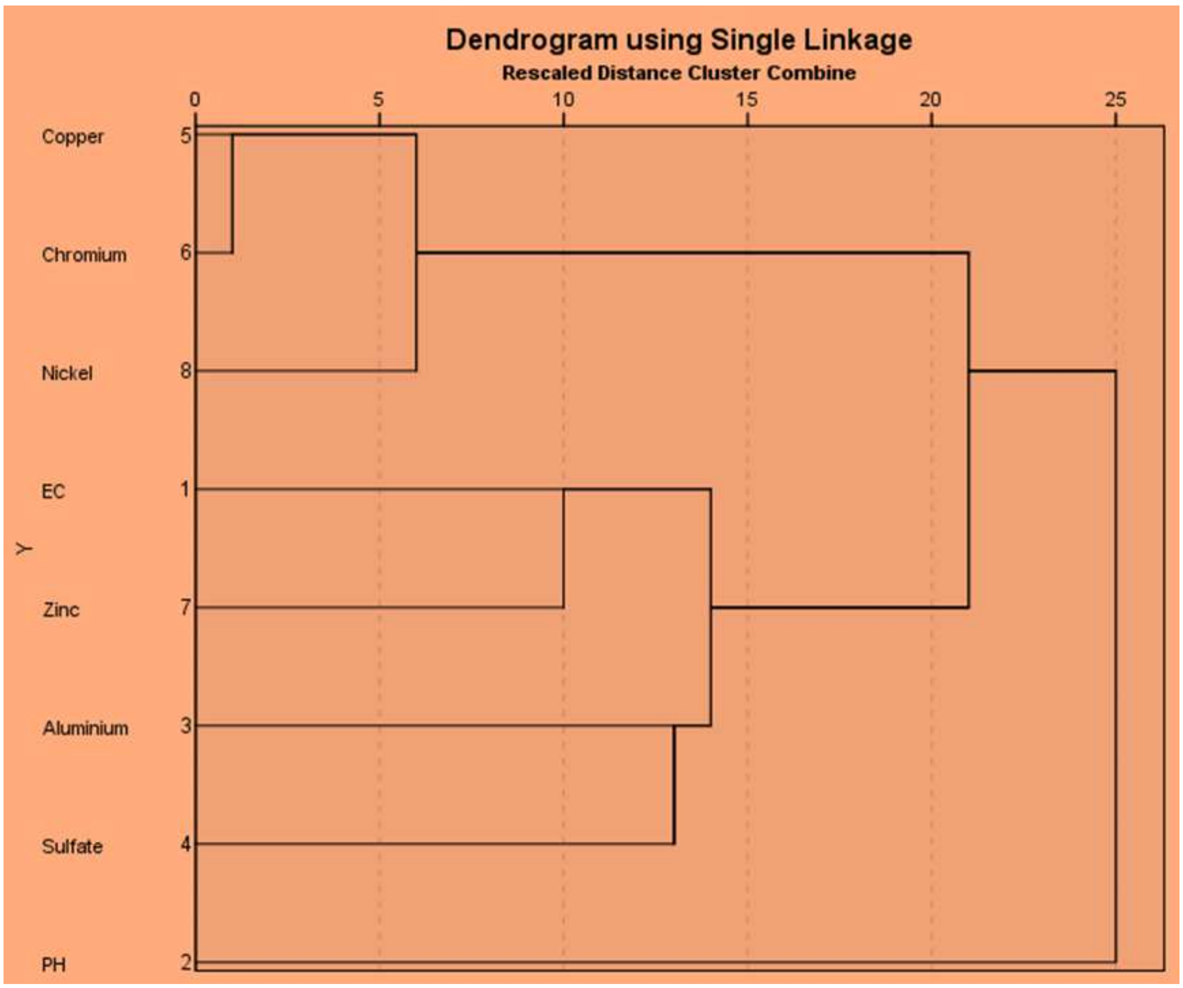


Fig. 27. Wet Season Hierarchical Clustering using SPSS.

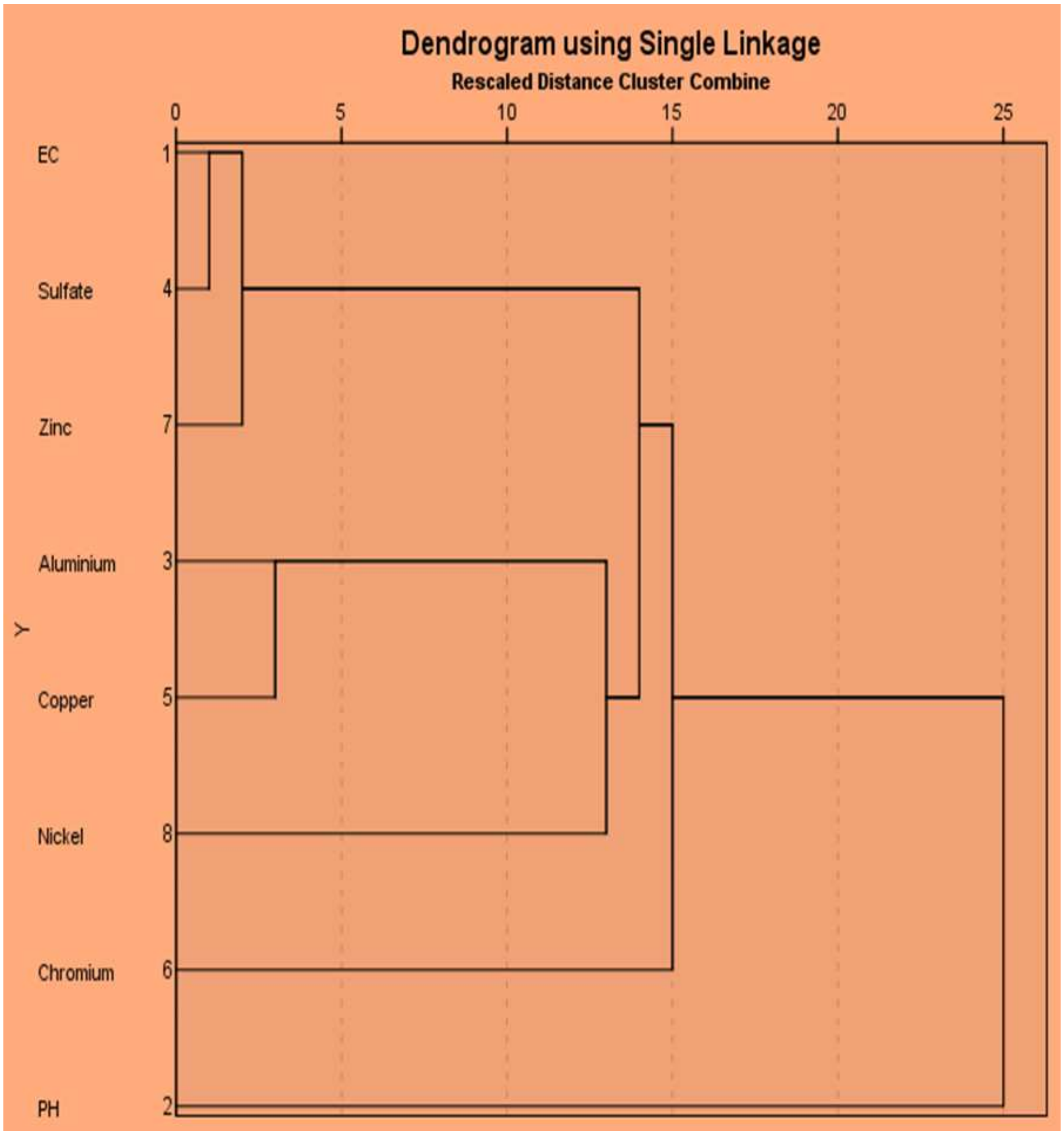


Fig. 28. Dry Season Hierarchical Clustering using SPSS.

11.8.2. Water quality parameters of *RU selected sites* : Monthly values of the water quality parameters of the selected study sites are shown in Table 31. Water quality parameters were more or less similar in both the study sites. However, monthly variation was observed in all the water quality parameters in both of the study sites. In both the study sites, the highest temperature was recorded during the month of August 2020 and the lowest in the month of January 2019. At site 1 water depth was high in the month of September 2018 and at site 2, the highest water depth was recorded during the month of August 2019. During the month of November 2018, the water transparency was highest at both of the sites. Highest value of DO was recorded in the month of January 2019. pH was highest during August 2020 at site 1 and during October 2019 at site 2. During the month of August, water of the both of the sites was found more alkaline and NH_3-N was found to vary among the months.

Table 31. Descriptive statistics of monthly values of water quality parameters of the study sites during the study period.

Sampling months	Temperature (ºC)		Water depth (cm)		Transparency (cm)		DO (mg/l)		pH		Alkalinity (mg/l)		NH_3-N (mg/l)	
	Site-1	Site-2	Site-1	Site-2	Site-1	Site-2	Site-1	Site-2	Site-1	Site-2	Site-1	Site-2	Site-1	Site-2
Aug-18	30.80±1.23	31.22±0.89	230.23±20.23	245.26±25.26	26.36±1.23	28.56±0.85	5.36±1.00	6.23±0.63	7.25±0.56	7.11±0.52	142.63±5.23	144.52±4.25	0.10±0.03	0.12±0.01
Sep-18	30.56±2.12	30.46±1.22	240.23±22.36	223.52±32.36	30.23±1.53	32.52±1.22	5.55±0.52	5.89±1.23	7.02±1.00	6.86±0.85	140.56±2.23	143.26±10.25	0.09±0.01	0.10±0.02
Oct-18	28.56±1.2	27.55±0.88	212.23±42.23	210.88±25.36	30.85±2.36	28.96±1.25	6.36±1.24	6.45±1.00	7.12±0.45	7.15±0.63	136.26±5.26	124.35±3.23	0.10±0.005	0.13±0.01
Nov-18	21.36±0.63	20.56±1.13	200.36±33.32	196.36±21.25	32.36±0.89	33.36±0.96	7.56±0.96	7.03±0.85	7.02±0.23	6.85±0.45	124.22±6.23	120.36±4.10	0.08±0.00	0.09±0.02
Dec-18	18.56±0.55	18.63±0.96	116.36±42.26	120.52±52.36	28.25±1.55	27.45±0.85	7.12±1.33	7.15±1.02	6.75±0.88	6.36±0.34	110.23±3.22	103.36±1.25	0.05±0.01	0.05±0.01
Jan-19	17.56±1.20	18.25±1.22	60.25±12.23	63.56±32.36	12.36±1.42	10.52±2.36	8.23±0.88	8.44±1.24	6.60±0.75	6.75±0.63	112.32±2.03	105.23±2.36	0.05±0.01	0.04±0.00
Feb-19	20.23±0.63	19.86±0.89	56.36±32.36	65.63±30.25	7.58±2.55	9.56±1.88	6.36±1.23	6.45±0.24	6.42±0.12	6.12±1.20	116.36±3.21	120.23±2.10	0.06±0.01	0.08±0.02
Mar-19	23.56±1.23	24.55±1.26	75.56±14.52	69.26±21.25	13.63±1.20	15.22±0.88	6.88±1.36	6.13±1.11	6.77±0.63	6.53±0.52	125.26±4.23	135.26±3.52	0.09±0.01	0.12±0.00
Apr-19	25.63±2.23	26.44±1.56	98.69±46.36	100.23±50.36	16.36±1.20	14.85±0.32	6.03±0.88	6.45±1.42	7.02±0.47	6.89±0.55	132.26±5.21	130.25±3.56	0.11±0.01	0.10±0.01
May-19	28.23±1.03	29.56±1.56	110.52±52.36	103.36±36.36	23.36±1.46	26.85±1.23	5.96±1.52	6.03±1.22	6.75±0.86	7.04±0.45	134.52±3.25	136.25±4.15	0.09±0.01	0.12±0.01
Jun-19	30.17±0.29	30.50±0.50	120.69±2.85	113.08±7.11	24.52±1.03	23.83±0.76	5.33±0.14	5.30±0.06	6.67±0.14	6.42±0.14	136.62±1.18	137.22±4.13	0.11±0.01	0.10±0.02
Jul-19	31.75±0.25	31.50±0.50	194.36±6.74	209.25±7.94	24.50±0.87	24.52±0.50	5.36±0.12	5.34±0.07	6.83±0.08	6.77±0.25	138.70±1.83	141.80±1.71	0.12±0.01	0.10±0.02
Aug-19	32.58±0.52	32.33±0.29	235.81±5.04	248.75±5.71	24.69±0.76	24.83±0.29	5.14±0.05	5.17±0.08	7.25±0.25	7.32±0.16	144.21±3.29	146.30±3.65	0.11±0.01	0.09±0.04
Sep-19	30.67±0.76	30.17±0.29	224.13±10.98	216.62±4.22	25.83±0.29	25.67±0.29	5.58±0.05	5.54±0.26	7.08±0.14	7.07±0.12	140.53±3.83	143.07±3.24	0.09±0.01	0.08±0.02
Oct-19	28.25±0.43	27.33±0.58	203.90±7.34	207.71±8.87	26.08±0.38	26.08±0.38	6.40±0.13	6.51±0.26	7.15±0.13	7.23±0.03	136.43±3.64	138.20±3.32	0.10±0.02	0.09±0.01
Nov-19	25.17±0.76	24.83±0.76	176.33±8.08	190.00±13.23	29.00±1.00	28.00±2.00	7.17±0.29	7.14±0.29	7.17±0.20	7.12±0.32	125.00±3.00	120.00±2.00	0.70±0.13	0.80±0.10
Dec-19	19.17±0.76	19.17±0.29	111.33±6.11	110.00±4.36	27.33±1.53	26.33±1.53	7.19±0.29	7.33±0.29	6.67±0.29	6.62±0.28	115.33±4.73	112.33±2.52	0.06±0.04	0.05±0.02
Jan-20	19.17±0.76	18.52±0.03	65.83±1.89	66.70±16.85	12.90±2.54	14.96±2.94	7.82±0.54	7.66±0.53	6.42±0.14	6.52±0.25	112.60±9.53	112.67±2.52	0.04±0.01	0.05±0.01
Feb-20	21.67±0.29	21.92±0.38	55.45±3.07	58.86±13.26	11.33±0.87	10.01±0.39	6.33±0.29	6.25±0.25	6.33±0.38	6.33±0.36	117.62±3.19	120.97±6.48	0.05±0.01	0.05±0.02
Mar-20	23.17±0.29	23.67±0.76	75.05±2.44	73.97±7.41	13.32±1.83	12.97±1.42	6.37±0.22	6.58±0.38	6.40±0.36	6.37±0.16	122.11±8.75	131.00±4.41	0.09±0.02	0.07±0.04
Apr-20	25.25±0.43	25.18±0.55	99.83±4.94	102.22±24.03	16.56±0.97	15.42±1.98	5.91±0.37	6.02±0.48	7.01±0.25	6.96±0.19	133.92±2.08	134.30±6.78	0.07±0.05	0.11±0.02
May-20	27.84±0.48	28.17±0.29	113.24±3.45	109.62±11.50	22.62±1.43	22.30±2.22	5.98±0.22	5.92±0.38	6.42±0.29	7.01±0.02	130.96±5.59	125.72±12.20	0.07±0.03	0.07±0.02
Jun-20	30.500.50	30.75±0.66	126.24±5.59	111.70±9.16	23.00±1.66	23.93±1.36	5.08±0.13	5.40±0.53	6.42±0.38	6.50±0.25	138.04±3.57	136.65±6.04	0.08±0.03	0.05±0.02
Jul-20	31.12±0.13	31.58±0.38	194.74±6.03	219.56±4.07	24.35±0.81	24.85±0.63	5.19±0.16	5.27±0.12	6.77±0.23	6.77±0.34	137.01±6.14	140.60±1.47	0.05±0.04	0.07±0.01
Aug-20	31.58±0.52	31.82±0.50	239.41±4.20	238.35±7.05	26.62±0.83	26.42±1.05	5.19±0.08	5.23±0.08	7.26±0.16	7.27±0.16	143.26±2.45	144.87±2.47	0.05±0.02	0.04±0.03
Sep-20	30.56±0.57	30.27±0.72	223.83±5.59	218.62±7.69	23.65±1.38	25.17±0.60	5.47±0.26	5.59±0.16	7.06±0.08	7.03±0.06	138.35±3.57	138.10±1.90	0.04±0.02	0.04±0.01
Oct-20	27.58±0.88	27.35±0.75	196.91±11.59	209.00±12.17	24.36±0.85	25.65±0.69	6.41±0.32	6.58±0.19	7.05±0.13	7.12±0.10	138.42±5.86	138.32±6.51	0.05±0.02	0.05±0.02
Nov-20	24.42±0.70	24.63±0.51	177.61±2.47	186.99±10.51	29.44±1.88	29.77±1.37	7.28±0.19	7.43±0.16	7.13±0.13	7.27±0.16	120.55±4.97	121.45±1.60	0.05±0.01	0.04±0.01
Dec-20	19.37±0.82	19.44±0.63	109.25±5.30	112.92±9.07	26.77±0.42	28.08±2.93	7.16±0.14	7.22±0.21	6.63±0.32	6.72±0.28	110.01±7.53	112.12±1.86	0.03±0.01	0.04±0.02

11.9. Sediment quality parameters of SAU selected sites

The present study assessed the pollution level and distribution of heavy metals in sediments of the Shari-Goyain River comparing with the Kura River. The pollutant accumulation of metals in the Shari-Goyain River ranked as follows: “Iron (Fe) > manganese (Mn) > nickel (Ni) > zinc (Zn) > chromium (Cr) > copper (Cu) > lead (Pb) > cadmium (Cd)” where average value of Fe, Mn and Ni crossed the maximum allowable concentration by USEPA (1999). On the other hand, sediments of Kura River contains lower amount of heavy metals than The Shari-Goyain River. Different sediment quality parameters in the Shari-Goyain and Kura Rivers are presented in Table 32. The parameters of the sediments are found to be fluctuating and maximum concentration of the heavy metals in the Shari-Goyain River exceeding the suitable limits for survival of aquatic flora and fauna.

Table 32. Sediment quality parameters in the Shari-Goyain and the Kura Rivers

Sl. no.	Parameters	Shari-Goyain River			Kura River (Control site)			Sangu River	MAC*
		Max.	Min.	Mean±SD	Max.	Min.	Mean±SD	Mean±SD	
1	pH	6.16	4.87	**5.23±0.47**	6.71	6.14	6.43±0.40	-	6.5-8.5
2	Cu (µg/g)	47.10	5.88	13.43± 11.27	10.90	10.00	10.45±0.64	29.2 ± 10.78	16
3	Zn (µg/g)	145.00	32.54	54.95± 30.79	76.00	59.00	67.50± 12.02	88.97 ± 58.97	110
4	Fe (µg/g)	2518.0	72.35	**9747.41± 5322.44**	1517.00	830.00	1173.50± 485.78	-	2
5	Mn (µg/g)	384.80	38.45	**122.03± 107.81**	102.30	101.50	101.90± 0.57	-	30
6	Cd (µg/g)	0.496	0.064	0.14±0.11	0.80	0.07	0.44±0.52	-	0.6
7	Pb (µg/g)	28.69	0.90	3.90±2.40	13.00	5.60	9.30±5.23	19.57 ± 7.01	31
8	Ni (µg/g)	212.50	13.57	**85.50± 47.39**	88.53	21.63	55.08± 47.31	32.75 ± 16.09	16
9	Cr (µg/g)	22.10	6.08	13.95± 5.21	36.00	23.80	29.90±8.63	25.14 ± 5.20	25
10	S (µg/g)	3154.20	131.6	**992.92± 736.49**	1753.00	1017.00	1385.00± 520.43	-	-

*MAC = Maximum Allowable Concentration by USEPA (1999)

11.9.1. Source identification of heavy metals : The norm of Principal Component Analysis (PCA) is to transform multiple evaluation indicators into a few representative comprehensive indicators by using the idea of dimensionality reduction (Kim and Kim, 2012; Jolliffe and Cadima, 2016). To identify the source of heavy metals in sediment of different sites of Shari-Goyain River, a principal component analysis (PCA) was conducted, which has been considered to be an effective tool for source identification (Bai *et al.* 2011; Anju and Banerjee 2012; Islam *et al.* 2018). PCA analysis incorporated the eight metal concentration and sulfur data of the studied river and explored the possible similar distribution pattern of metals. PCA was applied to obtain the validity of the source identification of metals through Kaiser-Meyer-Olkin, and is highly significant, according to the Bartlett’s test (Table 33). The finding of the PCA variation diagram, the total variance of “four principal components” (PC) is 92.364% with eigenvalues >1.

The resulting Principal component loadings for the selected metals are explicated in Table 34 and 35. PC1 explained the 42.276% of the total variance and exhibited high loading values for Cu, Zn, Fe, Mn and Pb. Li et al. (2018) analyzed the source of heavy metals in the soil around a coal mine in Henan Province and concluded that Pb, Cu and Zn came from gangue heap of coal. PC2 (21.942% of total variance) included Cr. Cr can enter the surrounding soil through sewage discharge, atmospheric settlement and during the operation of coal-fired power plants, causing certain accumulation. Therefore, PC2 can be interpreted as coal combustion activities (Zhang *et al.* 2021). PC3 grouped metals such as Cd and Ni explaining 16.317% of the total variance; and S was identified as high loading with 11.829% of total variance as PC4 which might be the deposition of components from acid mine drainage from coal mining area. The environmental issues related to coal mine water pollutants are attributable to the exposure of reduced iron, sulphides and coal materials to oxygen and water. In the generation of mine drainage pollution microorganisms play both beneficial and destructive roles. *Acidithiobacillus ferrooxidans* and *Leptospirillum ferrooxidans* accelerate the chemical rate of pyrite oxidation about 500,000–1,000,000 fold, which is responsible for high concentration of sulphate, acid and turbidity of waters (Dave and Tipre, 2012).

Table 33. KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.573
Bartlett's Test of Sphericity	Approx. Chi-Square	252.357
	Df	36
	Significance	0.000

Table 34. Total variance explained and component matrices for the heavy metals in sediment collected from the Shari-Goyain River

Component	**Initial Eigenvalues**			**Extraction Sums of Squared Loadings**			**Rotation Sums of Squared Loadings**		
	Total	% of Varianc	Cumulative %	Total	% of Varianc	Cumulative %	Total	% of Variance	Cumulative %
1	3.805	42.276	42.276	3.805	42.276	42.276	3.454	38.382	38.382
2	1.975	21.942	64.218	1.975	21.942	64.218	2.300	25.556	63.938
3	1.468	16.317	80.535	1.468	16.317	80.535	1.490	16.552	80.490
4	1.065	11.829	92.364	1.065	11.829	92.364	1.069	11.873	92.364
5	0.248	2.754	95.117						
6	0.215	2.391	97.508						
7	0.132	1.472	98.980						
8	0.047	0.526	99.505						
9	0.045	0.495	100.000						
Extraction Method: Principal Component Analysis.									

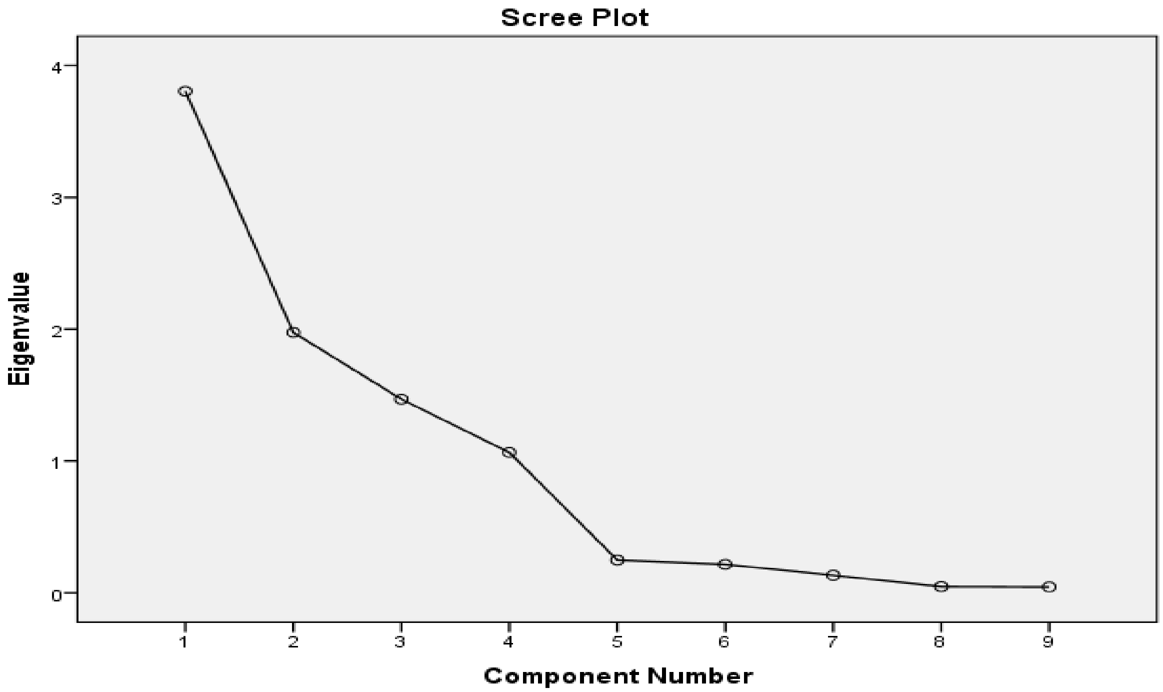


Fig. 29. Scree plot extracted by Principal Component Analysis.

Table 35. Principal component analysis of heavy metals in the sediments of the Shari-Goyain River

Parameters	Components			
	1	2	3	4
Cu(µg/g)	0.913			
Zn(µg/g)	0.727			
Fe(µg/g)	-0.767			
Mn(µg/g)	0.866			
S(µg/g)				0.982
Cd(µg/g)			-0.728	
Pb(µg/g)	0.899			
Ni(µg/g)			0.907	
Cr(µg/g)		.884		
Eigenvalue	3.805	1.975	1.468	1.065
% total variance	42.276	21.942	16.317	11.829
Cumulative % variance	42.276	64.218	80.535	92.364

Extraction Method: Principal Component Analysis.

11.10. Soil quality parameters of RU selected sites

The recorded soil quality parameters of Chalan beel collected form the two study sites are showed in Fig 30. Soil pH, organic matter (%) and total nitrogen (%) were highest during dry season. However, these values were not found to differ between the study sites.

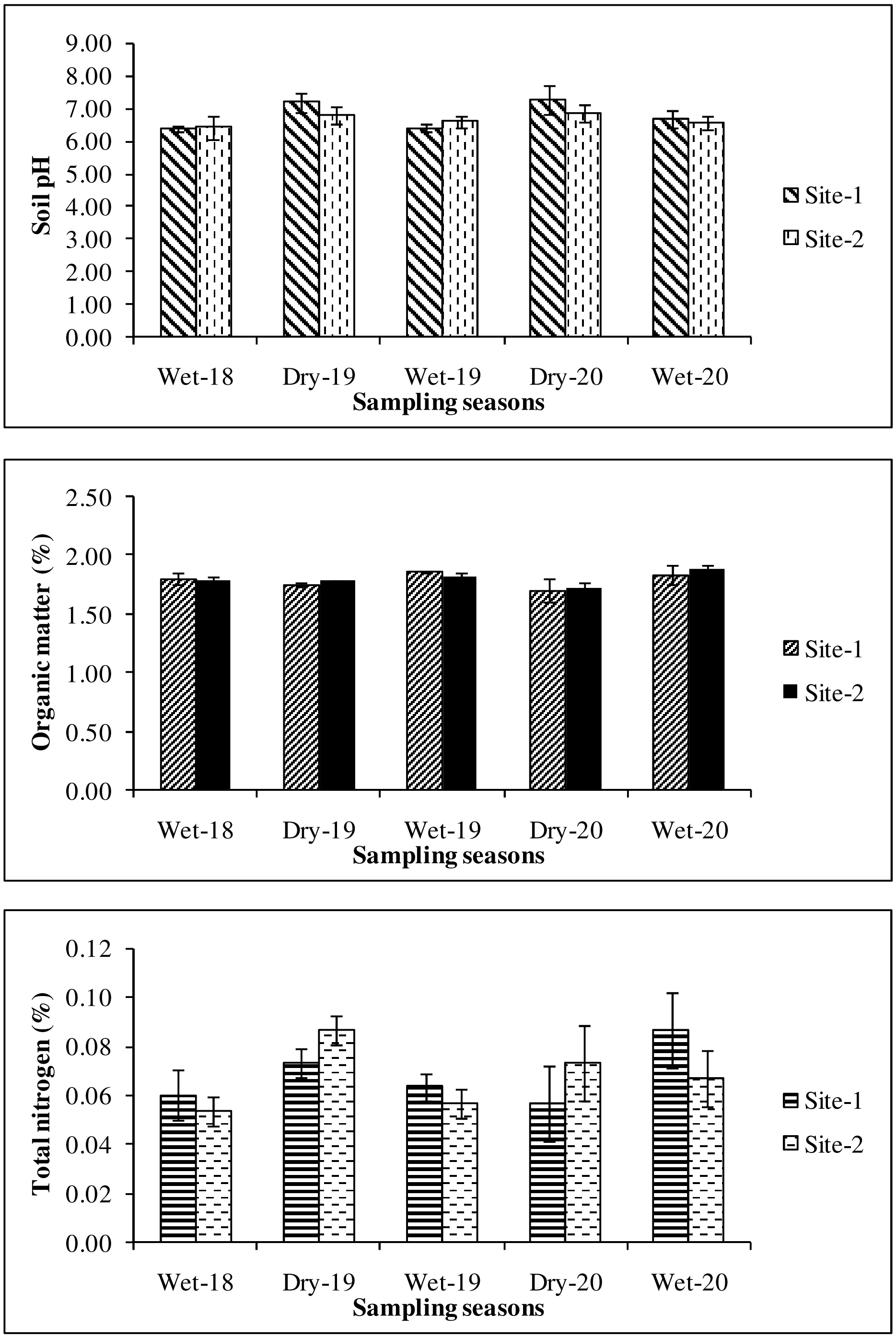


Fig. 30. Soil quality parameters of the study sites.

11.10.1. Heavy metal of water, sediment and fish samples : Heavy metal parameters (Cr, Pb, Cd, Cu and Zn) were analysed from the water, sediment and fish (Gudusia chapra) sample collected from the study sites and presented at Table 36. All the parameters were found to show their higher value during dry season. Dilution of water during wet season might be due to the causes of lower values of these parameters at that season. Sediment samples were found to have higher amount of heavy metals compared to water and fish samples. However, the heavy metals parameters were not found vary between the two study sites. During the study period, Pb was found relatively higher and Cd was lower in concentration in all the samples.

Table 36. Heavy metals of water, sediment and fish samples

Location	Samples	Parameters	Wet-18	Dry-19	Wet-19	Dry-20	Wet-20
Site-1	Water	Cr	0.152± 0.003	0.211±0.010	0.145± 0.007	0.161± 0.060	0.140± 0.002
Site-1	Water	Pb	0.551± 0.020	0.729±0.016	0.519± 0.050	0.719± 0.025	0.563± 0.115
Site-1	Water	Cd	0.021± 0.002	0.043±0.002	0.024± 0.004	0.043± 0.003	0.019± 0.002
Site-1	Water	Cu	0.136± 0.004	0.187±0.002	0.137± 0.006	0.180± 0.005	0.133± 0.006
Site-1	Water	Zn	0.123± 0.002	0.217±0.031	0.120± 0.002	0.196± 0.038	0.128± 0.022
Site-2	Water	Cr	0.140± 0.009	0.205±0.013	0.144± 0.006	0.207± 0.017	0.135± 0.005
Site-2	Water	Pb	0.519± 0.018	0.748±0.020	0.541± 0.013	0.710± 0.032	0.476± 0.035
Site-2	Water	Cd	0.015± 0.002	0.047±0.003	0.016± 0.005	0.040± 0.004	0.012± 0.005
Site-2	Water	Cu	0.141± 0.003	0.187±0.004	0.138± 0.003	0.190± 0.007	0.179± 0.005
Site-2	Water	Zn	0.127± 0.021	0.188±0.002	0.122± 0.035	0.166± 0.021	0.119± 0.014
Site-1	Sediment	Cr	0.185± 0.004	0.320±0.017	0.183± 0.009	0.252± 0.034	0.767± 0.031
Site-1	Sediment	Pb	0.667± 0.010	1.103±0.008	0.678± 0.009	1.043± 0.059	0.616± 0.121
Site-1	Sediment	Cd	0.035± 0.004	0.052±0.009	0.033± 0.006	0.045± 0.013	0.028± 0.007
Site-1	Sediment	Cu	0.187± 0.005	0.263±0.010	0.203± 0.025	0.254± 0.010	0.180± 0.013
Site-1	Sediment	Zn	0.223± 0.008	0.339±0.016	0.229± 0.008	0.322± 0.020	0.208± 0.007
Site-2	Sediment	Cr	0.197± 0.003	0.296±0.006	0.201± 0.004	0.266± 0.039	0.177± 0.010
Site-2	Sediment	Pb	0.861± 0.005	1.084±0.042	0.884± 0.007	1.055± 0.067	0.799± 0.013
Site-2	Sediment	Cd	0.031± 0.007	0.039±0.007	0.029± 0.011	0.037± 0.010	0.023± 0.009
Site-2	Sediment	Cu	0.185± 0.009	0.256±0.030	0.187± 0.012	0.244± 0.030	0.181± 0.014
Site-2	Sediment	Zn	0.214± 0.022	0.311±0.010	0.222± 0.019	0.293± 0.021	0.204± 0.016
Site-1	Fish	Cr	0.059±	0.057±0.010	0.039±	0.048±	0.019±

Location	Samples	Parameters	Wet-18	Dry-19	Wet-19	Dry-20	Wet-20
			0.005		0.029	0.012	0.015
		Pb	0.045±0.005	0.055±0.003	0.047±0.003	0.049±0.003	0.039±0.004
		Cd	0.010±0.001	0.000±0.000	0.000±0.000	0.000±0.000	0.001±0.002
		Cu	0.096±0.006	0.098±0.011	0.098±0.012	0.092±0.018	0.086±0.011
		Zn	0.091±0.005	0.101±0.017	0.091±0.006	0.100±0.029	0.092±0.005
Site-2		Cr	0.070±0.002	0.068±0.002	0.066±0.009	0.064±0.004	0.049±0.015
		Pb	0.044±0.002	0.234±0.299	0.044±0.002	0.059±0.002	0.037±0.003
		Cd	0.000±0.000	0.000±0.000	0.005±0.009	0.000±0.000	0.004±0.005
		Cu	0.094±0.007	0.094±0.008	0.086±0.006	0.095±0.017	0.085±0.010
		Zn	0.100±0.013	0.099±0.012	0.092±0.020	0.099±0.039	0.096±0.015

11.10.2. Bacterial parameters of water, sediment and fish samples : Result of the bacterial parameters evaluation of water, sediment and fish samples are shown in Table 37. Higher values of total heterotrophic bacterial (THB) count were recorded during dry season in both the study sites. E. coli and V. cholerae were also showed their higher value during dry season. Bacterial count was also found higher in sediment samples followed by water and fish samples.

Table 37. Bacterial parameters of water, sediment and fish samples

Location	Samples	Parameters	Wet-18	Dry-19	Wet-19	Dry-20	Wet-20
Site-1	Water	THB	1643±185	3219±154	1734±199	3130±110	1615±63
		E. coli	4±2	36±10	6±3	27±13	5±3
		V. cholerae	222±42	1088±336	183±63	1152±158	166±50
Site-2		THB	1380±298	3114±254	1355±205	3187±268	1300±169
		E. coli	7±4	34±8	7±4	30±14	5±4
		V. cholerae	338±81	1285±436	389±126	1254±226	375±78
Site-1	Sediment	THB	2484±257	4119±234	2343±297	3926±198	2066±386
		E. coli	18±3	36±10	27±7	39±8	19±7
		V. cholerae	262±87	1346±400	311±69	1396±295	272±75
Site-2		THB	2061±389	3904±368	2260±323	3731±359	2180±314
		E. coli	11±4	43±15	8±5	42±15	4±2
		V. cholerae	261±69	1296±456	269±135	1379±452	239±82
Site-1	Fish	THB	1111±212	2604±274	1118±534	2396±259	1034±231
		E. coli	0±0	8±5	0±0	6±6	0±0
		V. cholerae	145±66	432±207	186±144	414±121	110±13
Site-2		THB	957±198	2346±445	884±697	2065±308	759±608
		E. coli	0±0	9±7	0±0	8±7	0±1
		V. cholerae	97±56	469±189	113±52	517±235	94±94

11.11. Assessment of siltation level of SUST selected sites

During the heavy rainfall and flash flood, rate of sedimentation was found significantly very high and trap-1 (with deflector inside) encountered a problem of getting the deflector blocked with sediments and that led us to think about trap-2 (without deflector). Then trap-2 was installed and the rest of the samples were collected from this trap. However, during the dry season the rate of sedimentation was found comparatively low. On the other hand, similar trend was observed in the results obtained from Hossain's equation. In addition, Hossain's equation provides results almost close to measured value by sediment trap, especially in dry season. Due to the variation of water discharge and velocity during the exposure time of sediment trap, the results obtained from Hossains equation are not that close to the measured value in the wet season.

Tables 38 and 39 show some results of rate of sedimentation of Shari-Goyain River. Moreover, two relationships were developed between sediment load and observed water discharge, using the data for the year 2020-21 are as follows:

$Q_s = 193.81Q^{0.8449}$, R^2=0.2519 (Using data obtained from Sediment trap) and Q_s= $17.131Q^{1.2676}$, R^2 = 0.9509 (Using data obtained from Hossain's eqution). Where, Q_s is the sediment load in ton/day and Q is the water discharge and R is the coefficient of correlation.

Applying these relationships, the annual sediment load was calculated is shown in (SUST: Appendix-1 Tab 7). It is noticeable that the annual sediment load ranges from 2.24to 6.76 million tons and1.12 to 5.84 million tons according to the data of sediment trap and Hossain's equation respectively. The annual sediment load was found comparatively high in Shari-Goyain river than the river Surma, where, the annual sediment loadvaries from 1.563 to 3.966 million tons and from 1.67 to 3.924 million tons computed using the data of observed suspended sediment load and Hossain's equation respectively (Kamrunnessa, 1994).

Table 38. Rate of Sedimentation of Shari-Goyain River using Sediment Trap

Sediment Trap							
Study Series			**Cross-sectional Area of trap**	**Amount of dry sediments accumulated in trap**		**Exposure time**	**Sedimentation rate**
	From	**To**	**A (m²)**	**Solid Mass (SM) (g)**	**SM/A (g/ m²)**	**T (days)**	**Vs (g/d/m²)**
1	08.09.20	22.09.20	0.0069	648	93913.04	14	6708.075
2	23.09.20	30.09.20	0.0069	612	88695.65	7	12670.81
3	01.10.20	19.10.20	0.0069	374	54202.9	18	3011.272
4	21.10.20	03.11.20	0.0069	392	56811.59	13	4370.123
5	11.11.20	27.11.20	0.0069	17	2463.768	16	153.9855
6	30.11.20	11.12.20	0.0069	5	724.6377	11	65.87615
7	12.12.20	25.12.20	0.0069	6	869.5652	13	66.88963
8	26.12.20	15.01.21	0.0069	10	1449.275	20	72.46377

9	16.01.21	29.01.21	0.0069	6	869.5652	13	66.88963
10	30.01.21	12.02.21	0.0069	5	724.6377	12	60.38647
11	13.02.21	29.02.21	0.0069	4	579.7101	16	36.23188
12	02.03.21	12.03.21	0.0069	4	579.7101	10	57.97101
13	13.03.21	12.04.21	0.0069	3800	550724.6	30	18357.49
14	13.04.21	30.04.21	0.0069	44	6376.812	17	375.1066
15	03.05.21	17.05.21	0.0069	35	5072.464	14	362.3188
16	18.05.21	31.05.21	0.0069	37	5362.319	13	412.4861

Table 39. Calculation of Sediment transport of Shari-Goyain River using Hossain's equation

SL. No	Sampling date	Observed Discharge (cumec)	Average Velocity (m/s)	Observed Sediment Load by trap (ton/day)	According to Hossain's Equation, total sediment load (ton/day)
1	17.09.20	901.7072	0.815089	47122.16	141568.9
2	30.09.20	132.5784	0.154108	89008.53	3503.097
3	16.10.20	66.78449	0.145041	15493.95	2256.738
4	30.10.20	57.3488	0.140398	22485.67	1809.873
5	13.11.20	25.40194	0.130671	792.3042	991.9791
6	27.11.20	18.89258	0.12905	792.3042	936.3043
7	11.12.20	12.16172	0.102958	338.9537	485.3766
8	25.12.20	11.84836	0.094274	344.1684	452.8802
9	15.01.21	9.107171	0.084469	372.8491	274.2356
10	29.01.21	8.311391	0.076364	344.1684	223.6977
11	12.02.21	7.496158	0.077174	310.7075	207.7902
12	28.02.21	5.712816	0.059536	186.4245	118.167
13	12.03.21	7.389234	0.080379	298.2792	214.6252
14	27.03.21	4.825569	0.051237	94455.09	78.30677
15	12.04.21	8.921419	0.099447	94455.09	376.4911
16	30.04.21	7.666681	0.103247	1930.042	360.5176
17	17.05.21	25.82701	0.170878	1864.245	1723.477
18	31.05.21	79.86633	0.269276	2122.372	7523.447

11.12. Cage fish farming as alternate livelihood options of fishers (SAU)

The sub-project introduced cage fish farming as an alternate livelihood option for the fishers to reduce the fishing pressure during fishing ban period. The fishers received training on cage fish farming and involved in the maintenance of cages. The results of the cage fish farming are described below:

11.12.1. Expt. 1. Determination of suitable species for cage farming

Trial 1: Determination of suitable species for cage culture in the Ratargul swamp forest Growth performance

Average individual stocking weight of magur, pabda and pangas were 25.345±0.55g, 15.453±0.301g and 18.158±0.551g, respectively. Final average individual weight was highest in pangas (363.75±12.085 g) followed by magur (141.93±9.856 g) and pabda (53.223±3.073 g) where significance difference was found among treatments. Significantly higher total production (kg/cage) were recorded form the cages with pangas (356.337±18.524 kg) followed by magur (100.03±3.722 kg) and pabda (77.286±7.24 kg) (Table 40). The SGR (% body weight per day) of pangas was significantly higher (3.223±0.034) followed by magur (1.851±0.088) and pabda (1.329±0.068) (Table 40). The FCR in pangas was 1.262±0.072 which is significantly lower than magur (2.069±0.118) and pabda (2.168±0.271). Survival rate was also significantly higher in case of pangas than pabda and magur. Monthly weight and length vatiation are shown in Fig 31 & 32, respectively.

Table 40. Growth and production performance of different species (mean±sd)

Parameter	Treatments (Species)		
	Magur	**Pabda**	**Pangas**
Initial weight (g)	25.345±0.55[a]	15.453±0.301[c]	18.158±0 .551[b]
Final weight (g)	141.93±9.856[b]	53.223±3.073[c]	363.75±12.085[a]
Total yield (kg/cage)	100.03±3.722[b]	77.286±7.24[b]	356.337±18.524[a]
Total yield (kg/m^3)	3.705±0.138[b]	2.862±0.268[b]	13.197±0.686[a]
SGR (%/day)	1.851±0.088[b]	1.329±0.068[c]	3.223±0.034[a]
Survival	65.463±4.985[b]	89.589±5.309[a]	90.71±3.82[a]
FCR	2.069±0.118[a]	2.168±0.271[a]	1.262±0.072[b]

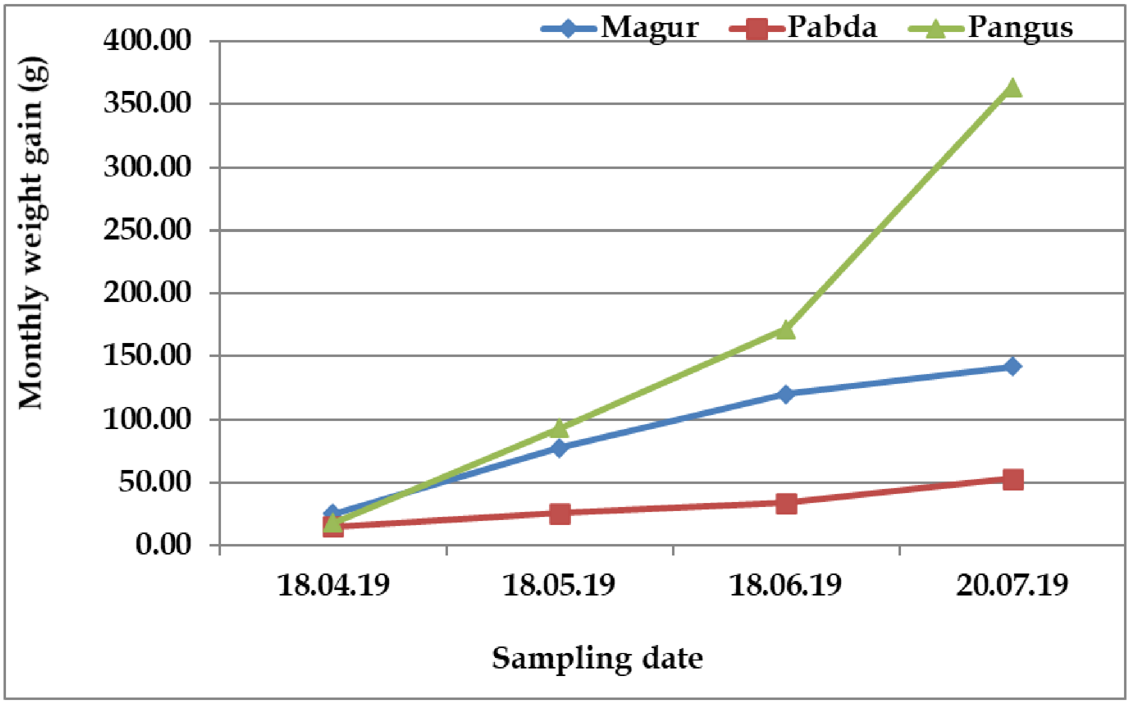


Fig. 31. Monthly variation of the average weight of fishes in different treatments

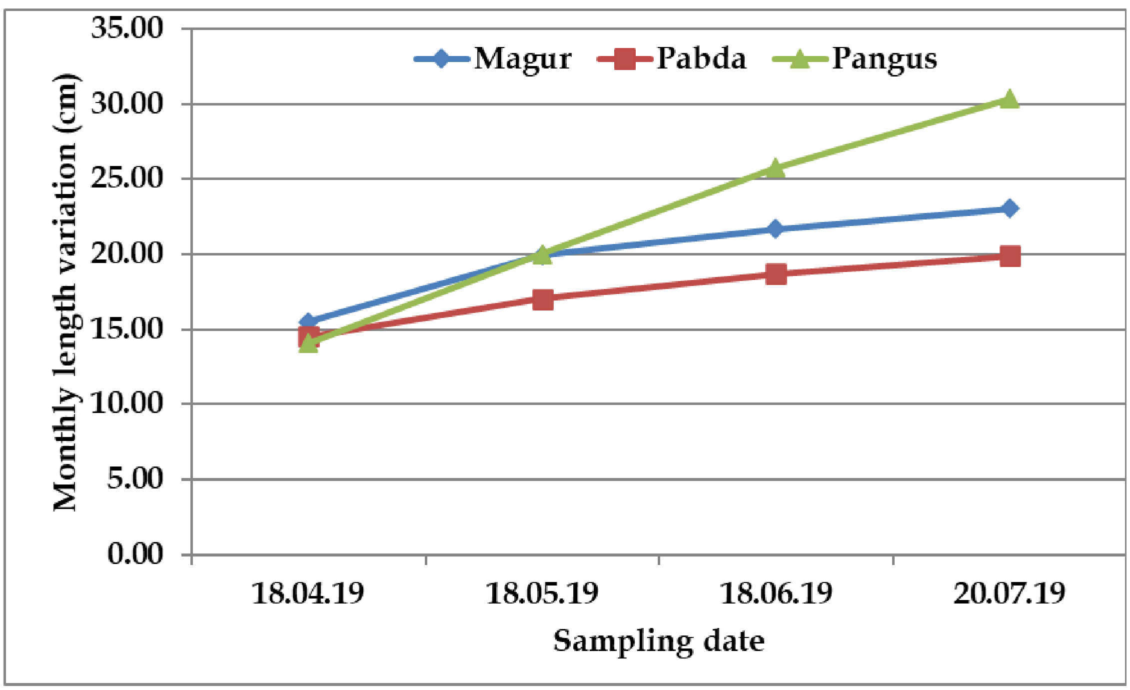


Fig. 32. Monthly variation of the average length of fishes in different treatments

Water quality parameters : The mean (±SD) values of the water quality parameters measured at fortnightly intervals in cages during the experimental period (Table 41). Water samples were collected from inside the cages. Mean values of water temperature, conductivity, TDS, and transparency were recorded within suitable limit without any significant variation during the experimental period. On the other hand, dissolved oxygen and pH were below the standard level for fish culture.

Table 41. Water quality parameters of cages during the culture period

Parameters	Value (mean±SD)
Water temperature (˚C)	28.69±1.19
Dissolved oxygen (mg/L)	2.92±1.17
Conductivity (µS)	51.61±13.91
TDS (ppm)	26.72±9.79
pH	6.05±0.53
Transparency (cm)	36.33± 8.20
Depth (m)	4.13±1.44

Economics

Benefit-cost ratio (BCR) was highest in pangas (1.246±0.084) followed by magur (1.224±0.046) and pabda (1.193±0.112) at the end of the study (Table 42). Therefore, findings of the present experiment suggested that pangas could be the most suitable species for cage farming in the study site as alternative livelihood option for fishermen. Moreover, pangas have a good market demand as the low income people preferred to by pangs.

Table 42. Benefit-cost ratio (BCR) of different species (mean±SD).

Parameter	Treatments (Species)		
	Magur	Pabda	Pangas
Total expenditure (BDT)	29010.00	23324.00	29840.00
Total revenue (BDT)	35511±1321^{b}	27823±2607^{c}	39402±374^{a}
Net revenue (BDT)	6501±1321^{ab}	4499±2607^{b}	9562±374^{a}
Benefit-cost ratio (BCR)	1.224±0.046	1.193±0.112	1.246±0.084

Trial 2: Determination of suitable species for cage culture in the Gurukchi River

Growth performance : Higher total production per cage were recorded form pangas (397.119±18.939 kg) followed by magur (118.984±4.876 kg) and pabda (78.888±7.89 kg). The SGR (% body weight per day) in pangas was significantly highest (3.393±0.020) followed by magur (1.903±0.055) and pabda (1.357±0.125) (Table 43). The FCR in pangas was 1.191±0.057 which is significantly lower than magur (1.633±0.098) and pabda (2.082±0.298). Mongthly weight and length variation are shown in Fig 33 & 34, respectively. In case of pangas a quick increment of weight gain than magur and pabda was noticed in the 3rd month. It may be due to the species specific differences in growth as because of pangas is a larger species than magur and pabda.

Table 43. Growth and production performance of different species (mean±sd).

Parameter	Treatments (Species)		
	Magur	Pabda	Pangas
Initial weight (g)	24.922±0.67[a]	14.998±0.945[c]	17.272±0.714[b]
Final weight (g)	146.348±8.747[b]	52.975±3.536[c]	405.647±24.019[a]
Total yield (kg/cage)	118.984±4.876[b]	78.888±7.89[c]	397.119±18.939[a]
Total yield (kg/m^3)	4.4067±0.181[b]	2.922±0.292[c]	14.708±0.701[a]
SGR	1.903±0.055[b]	1.357±0.125[c]	3.393±0.02[a]
Survival	75.432±4.901[b]	91.83±4.82[a]	86.012±8.926[a]
FCR	1.633±0.098[b]	2.082±0.298[a]	1.191±0.057[c]

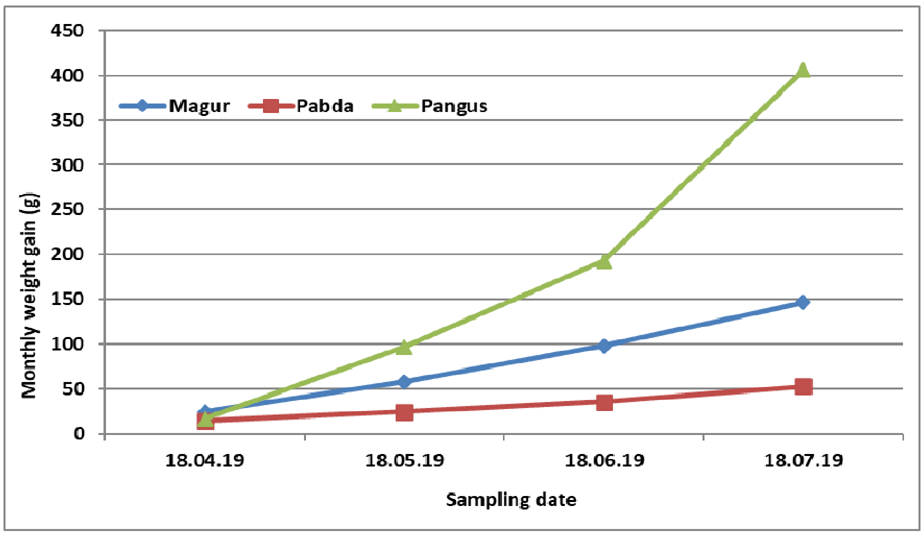


Fig. 33. Monthly weight variation of different species in the Gurukchi River.

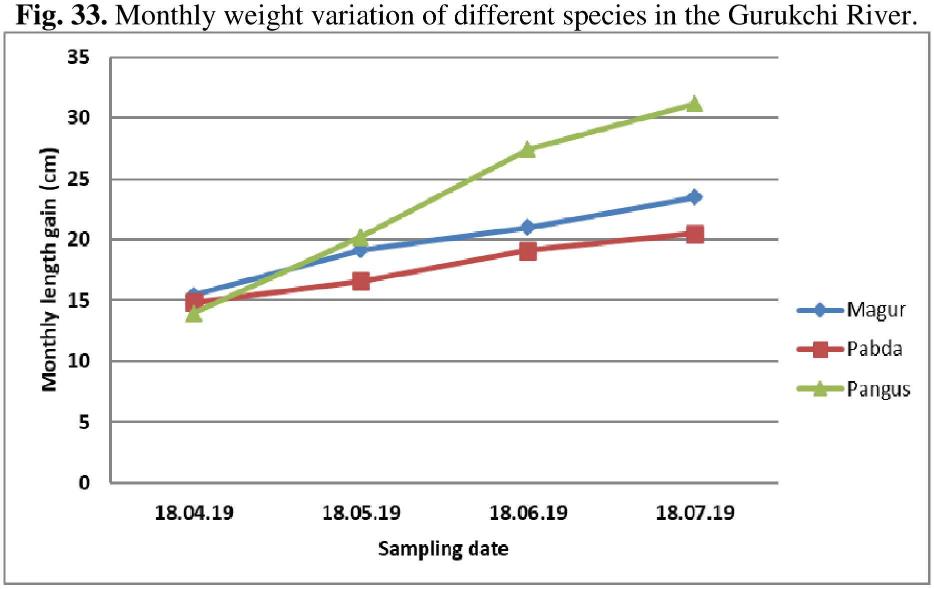


Fig. 34. Monthly length variation of different species in the Gurukchi River.

Water quality parameters : The mean (±SD) values of the water quality parameters measured in fortnightly intervals in cages during the experimental period are presented in Table 44. Mean values of water temperature, dissolved oxygen, conductivity, TDS, and transparency were recorded within suitable limit without any significant variation during the experimental period. On the other hand, pH was slightly below the standard level for fish culture.

Table 44. Water quality parameters of cages during the culture period

Parameters	Value (mean±SD)
Water temperature (˚C)	28.65±1.08
Dissolved oxygen (mg/L)	5.35±0.81
Conductivity (µS)	51.59±9.81
TDS (ppm)	27.93±11.48
pH	6.42±0.46
Transparency (cm)	24.17±5.78
Depth (m)	5.34±1.80

Economics : Benefit-cost ratio (BCR) calculated on the basis of cost incurred and the sale value of harvested fish. BCR of pangas (1.198±0.059) was significantly higher than magur (1.1161±.046) and pabda (0.985±0.098), respectively (Table 45). This comparative study of the benefit-cost ratios revealed that pangas and magur can be cultured profitably in the Gurukchi River where pangas culture provided significantly higher net profit than magur. On the other hand, culture of pabda in cages is not suitable in the Gurukchi River where total expenditure is higher than total revenue. Therefore, findings of the present experiment suggested that pangas could be the most suitable species for cage fish farming in the Gurukchi River as alternative livelihood option for fishers.

Table 45. Benefit-cost ratio (BCR) of different species (mean±SD).

Parameter	Treatments (species)		
	Magur	Pabda	Pangas
Total revenue (Tk.)	40454.6±1657.7[b]	28794.1±2879.9[c]	45415.9±2218.7[a]
Total expenditure (Tk.)	36246.00	29228.00	34466.67
Benefit-cost ratio (BCR)	1.1161±.046[b]	0.985±0.098[c]	1.198±0.059[a]

Plate 35. Experimental site visit picture of Project Coordinator.

11.12.2. Expt. 2. Optimization of stocking density for cage farming

Trial 1: Optimization of stocking density of pangas (Pangasianodon hypophthalmus) for cage culture in the Ratargul swamp forest

Stocking density influences the final production of cage aquaculture and it profitability. Present study was conducted to investigate the effect of stocking density on growth, production and economic return of striped catfish (*Pangasianodon hypophthalmus*). The fishes were reared in cages at three different stocking densities. Fishes were stocked at 30, 40 and 50 fish/m^3 densities indicated as treatments T_1, T_2 and T_3 respectively. After 94 days of the experimental period, growth and yield parameters were studied and economic analysis regarding profitability was carried out.

Growth performance : A significant effect (P<0.05) of stocking density on growth performance was found; the mean final weight at T_1 was significantly higher than that T_2 and T_3 (Table 46). Mean final weight observed 376.58±14.65 g, 311.86±14.04 g and 266.89±9.45 g, respectively at the densities of 30, 40 and 50 fish/m^3. Weight and length gain was decreased with increasing densities (Fig 35 & 36). The weight and length gain was found highest in T_1 followed by T_2 and T_3. The specific growth rate (%/day) ranged from 2.058±0.033 to 2.398±0.037 with a significant difference among the treatments. Lowest feed conversion ratio (FCR) was found in T_1 (1.632±0.119) followed by T_2 (1.748±0.132) and T_3 (1.845±0.195) that indicates stocking density affecting FCR. Stocking density did not significantly affect the survival rate (%) that ranged between 95.89±1.084 and 97.78±1.06.

Table 46. Growth and production performance of different treatments in 30 m^3 cages (mean±sd)

Parameter	Treatments		
	T_1	T_2	T_3
Initial weight (g)	40.48±1.39	39.88±2.01	39.37±1.30
Final weight (g)	376.58±14.65^a	311.86±14.04^b	266.89±9.45^c
Total yield (kg/cage)	331.48±16.42^b	361.87±20.44^{ab}	383.82±12.24^a

Total yield (kg/m^3)	11.05±0.55^b	12.06±0.68^{ab}	12.79±0.41^a
Net yield (kg/cage)	295.05±15.83	314.02±21.09	324.77±11.77
SGR	2.398±0.037^a	2.212±0.076^b	2.058±0.033^c
Survival	97.78±1.06	96.67±1.392	95.89±1.084
FCR	1.632±0.119	1.748±0.132	1.845±0.195

Treatments: T_1=30 fish/m^3; T_2= 40 fish/m^3; T_3=50 fish/m^3.

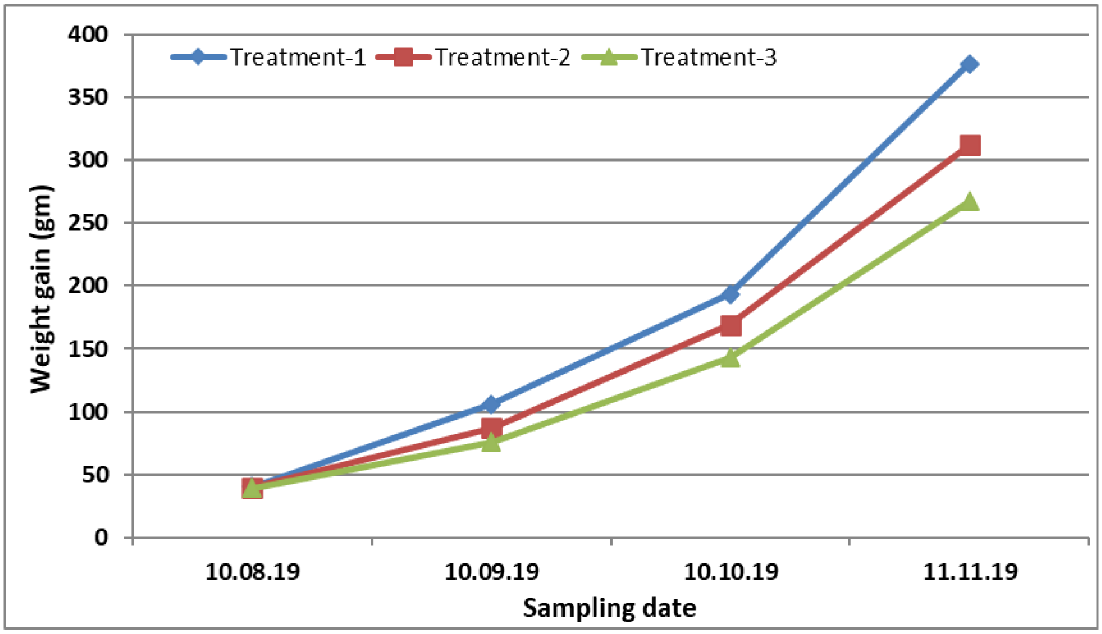


Fig. 35. Monthly growth variation of pangas among the treatments.

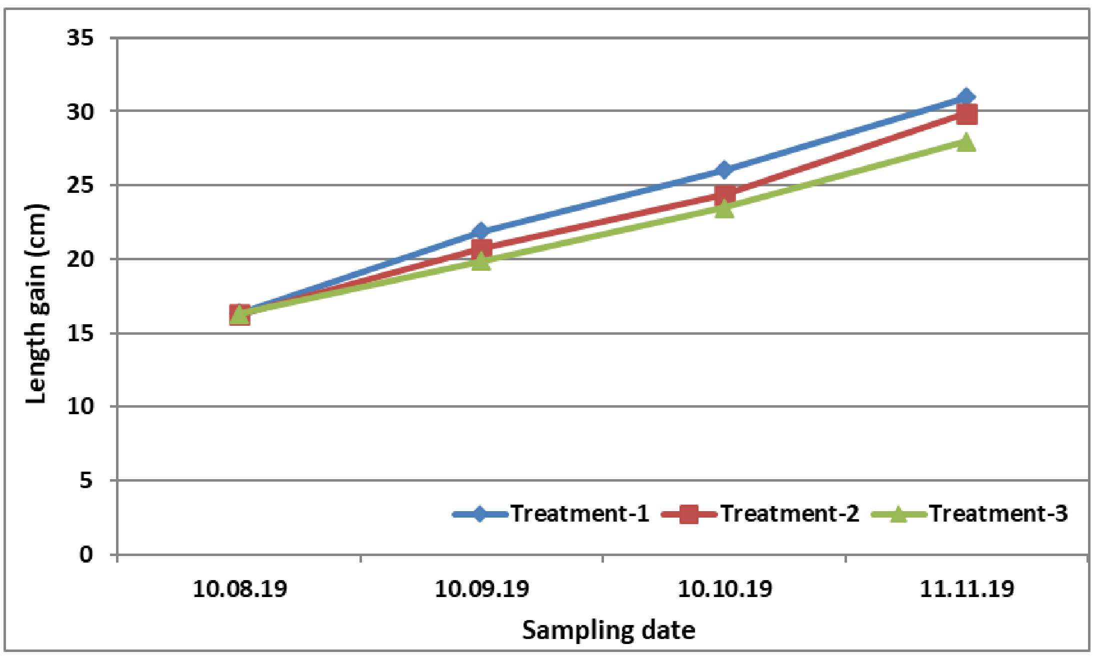


Fig. 36. Monthly length variation of pangas among the treatments.

Water quality parameters : Water quality parameters measured fortnightly intervals from each of the cages during the experimental period and results are presented in Table 47. Mean values of water temperature, conductivity, TDS, and transparency were recorded within suitable limit without any significant variation during the experimental period. On the other hand, pH and dissolved oxygen were slightly below the standard level for fish culture.

Table 47. Water quality parameters of cages during the culture period

Parameters	Value (mean±SD)
Water temperature (˚C)	26.73±3.93
Dissolved oxygen (mg/l)	4.47±.37
Conductivity (µS)	35.63±7.05
TDS (ppm)	18.58±5.69
pH	6.13±0.47
Transparency (cm)	18.98±6.73
Depth (m)	3.02± .74

Economics : Total expenditure was significantly different (P<0.05) among the treatments but total revenue of T_3 was significantly lower (P<0.05) than T_1 and T_2 (Table 48). The benefit-cost analysis indicated significantly higher (P<0.05) BCR in T_1 (1.617±0.035) than T_2 (1.383±0.047) and T_3 (1.039±0.023), respectively. Therefore, the overall economic analysis suggests that 30 fish/m^3 stocking density in floating cages in the Ratargul swamp forest would be profitable for local fish farmers within their economic efficiency as the investment is less with these densities.

Table 48. Benefit-cost ratio (BCR) of different treatments (mean±SD)

Parameter	Treatments		
	Treatment-1	Treatment-2	Treatment-3
Fry cost (BDT)	6300	8400	10500
Feed cost (BDT)	10147±595^b	11835±766^a	12509±831^a
Cage cost (BDT)	2000	2000	2000
Total expenditure (BDT)	18447±595^c	22235±766^b	25009±831^a
Total revenue (BDT)	29833±1477^a	30759±1737^a	25981±942^b
Benefit-cost ratio (BCR)	1.617±0.035^a	1.383±0.047^b	1.039±0.023^c

Overall result of the study indicates that 30 fish/m^3 stocking density of pangas is better among three treatments in respect of growth, survival rate, production and economic return. Therefore, the farmers could be suggested to rear pangas at lower stocking density (30 fish/m^3) in cages to get higher growth, survival and production in a short period of time.

Trial 2: Optimization of stocking density of tilapia for cage culture in the Gurukchi River

This study was conducted to investigate the effect of stocking density on growth, production performance and economic return of tilapia (*Oreochromis niloticus*) in cage aquaculture. The fishes were reared in cages at three different stocking densities viz. 40, 60 and 80 fish/m^3

densities indicated as treatment T_1, T_2 and T_3, respectively. After 93 days of the experimental period growth and yield parameters were studied and economic analyses regarding profitability was carried out and are discussed below:

Growth and production performances : The growth and production parameters of tilapia are shown in Table 49. The results of the present investigation showed a significant effect ($p<0.05$) of stocking density on growth and production performances. Mean final weights of tilapia were 337.39 ± 11.40 g, 312.06 ± 14.50 g and 265.69 ± 13.37 g, respectively in T_1, T_2 and T_3 indicating significantly higher mean final weight in T_1 and T_2 than T_3 (Table 49). However, no significant differences were observed in mean final weights between T_1 and T_2. Stocking density did not affect significantly on survival rate that ranged between 96.83 ± 1.22% and 98.17 ± 0.63%. Fish mortality was observed immediately after fish stocking in the cages which might be caused due to transportation stress.

The specific growth rate (%/ day) was significantly higher in T_1 (2.295 ± 0.06) and T_2 (2.219 ± 0.069) than T_3 (2.075 ± 0.052), but no significant difference was observed between T_1 and T_2. Significantly lower FCR was found in T_1 (1.046 ± 0.020) and T_2 (1.074 ± 0.055) than T_3 (1.248 ± 0.084) that indicated stocking densities of 40 fish/m^3 and 60 fish/m^3 have no significant effect on FCR, but showed significantly higher feed consumption with a density of 80 fish/m^3. Monthly weight and length increment in different densities are shown in Fig 37 & 38, respectively. So that it can be concluded that stocking densities of 40 fish/m^3 and 60 fish/m^3 both could be suggested for successful tilapia cage aquaculture.

Table 49. Growth and production performances of tilapia in different stocking densities (mean ± SD)

Parameters	Treatments		
	Treatment-1	Treatment-2	Treatment-3
Initial weight (g)	39.51 ± 0.91	39.61 ± 0.71	38.54 ± 0.57
Initial length (cm)	12.86 ± 0.25	12.86 ± 0.43	12.83 ± 0.18
Final weight (g)	337.39 ± 11.40^a	312.06 ± 14.50^a	265.69 ± 13.37^b
Final length (cm)	24.08 ± 0.35^a	23.62 ± 0.35^a	22.39 ± 0.14^b
Total yield (kg/cage)	397.47 ± 14.49^c	546.39 ± 21.11^b	617.65 ± 36.76^a
Net yield (kg/cage)	349.58 ± 15.57^a	475.10 ± 22.38^b	525.15 ± 36.55^b
Total yield (kg/m^3)	13.25 ± 0.48^c	18.21 ± 0.70^b	20.59 ± 1.23^a
Net yield (kg/m^3)	11.68 ± 0.51^a	15.90 ± 0.76^b	17.60 ± 1.19^b
SGR(%/ day)	2.295 ± 0.060^a	2.219 ± 0.069^a	2.075 ± 0.052^b
Survival	98.17 ± 0.63	97.30 ± 0.94	96.83 ± 1.22
FCR	1.046 ± 0.020^a	1.074 ± 0.055^a	1.248 ± 0.084^b

Treatments: T_1=40 fish/m^3; T_2= 60 fish/m^3; T_3=80 fish/m^3.

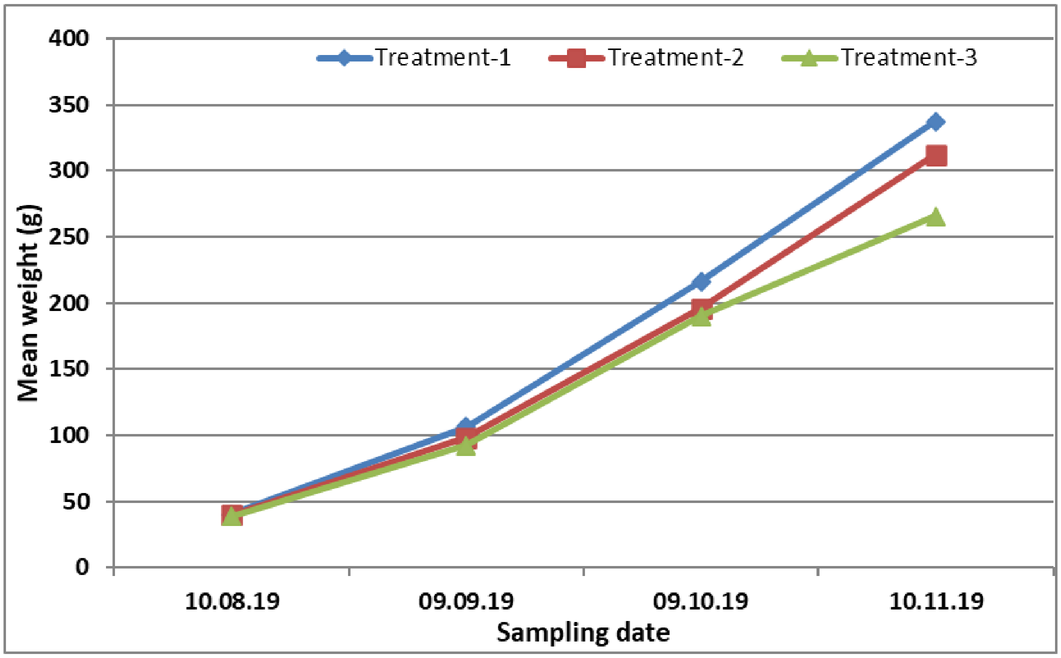


Fig. 37. Monthly weight variation of tilapia in different treatments

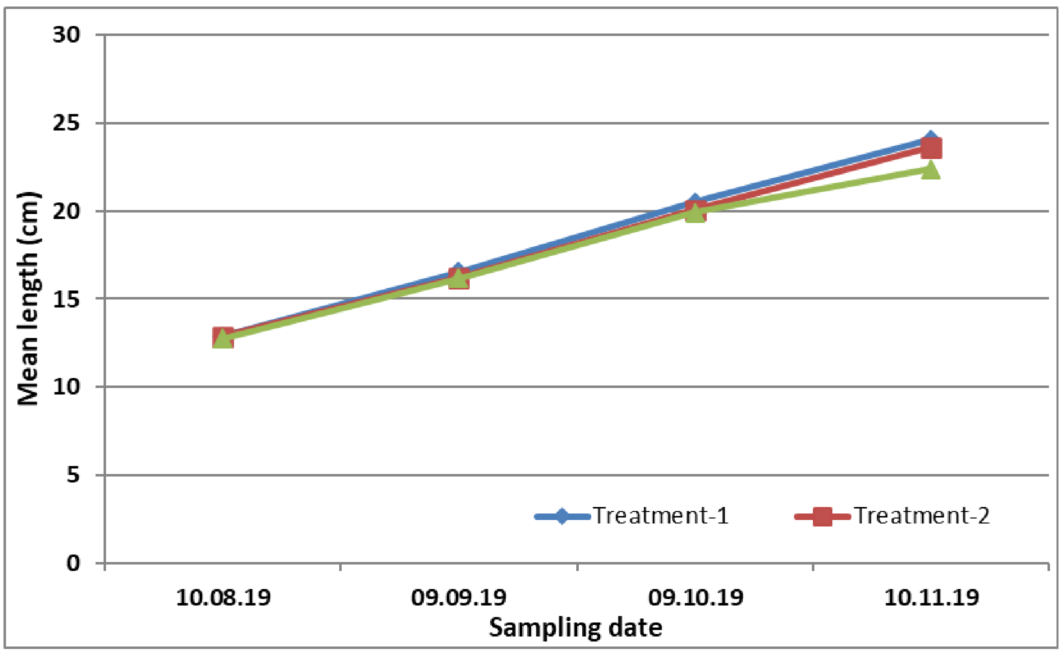


Fig. 38. Monthly length variation of tilapia in different treatments

Water quality parameters : The water quality parameters were measured from each of the cages at fortnightly intervals during the experimental period that are shown in Table 50. Mean values of water temperature, dissolved oxygen, conductivity, TDS, pH and transparency were found within the suitable limits for fish culture.

Table 50. Water quality parameters of cages during the culture period

Parameters	Values (mean ± SD)
Water temperature (°C)	27.40 ± 3.43
Dissolved oxygen (mg/l)	5.46 ± 1.48
Conductivity (µS)	43.65 ± 3.49
TDS (ppm)	21.30 ± 1.95
pH	6.58 ± 0.36
Transparency (cm)	30.88 ± 7.77
Depth (m)	4.17 ± 2.73

Economic return : Total expenditure was significantly different ($p < 0.05$) among the treatments but significantly higher ($p < 0.05$) total revenue showed in T_2 (BDT 54,639 ± 2,111) and T_3 (BDT 55,588 ± 3,309) than T_1 (BDT 39,747 ± 1,449) (Table 51). Significantly higher ($p < 0.05$) net revenue was observed in T_2 (BDT 18,168 ± 2,159) than T_1 (BDT 13,464 ± 730) and T_3 (BDT 8,926 ± 3,250). According to benefit-cost analysis significantly higher ($p < 0.05$) BCR was found in T_1 (1.512 ± 0.022) and T_2 (1.499 ± 0.063) than T_3 (1.191 ± 0.071), but there were no significant differences between T_1 and T_2. Therefore, considering the above facts, the economic analysis suggests that both 40 fish/m^3 and 60 fish/m^3 stocking density in floating cages in the Gurukchi River would be profitable, but considering the net revenue 60 fish/m^3 is the best among the three densities.

Table 51. Economic analysis of different treatments

Parameters	Treatments (mean ± SD)		
	Treatment-1	Treatment-2	Treatment-3
Fry cost (BDT)	6,000	9,000	12,000
Feed cost (BDT)	18,283 ± 893^c	25,471 ± 756^b	32,663 ± 994^a
Cage cost (BDT)	2,000	2,000	2,000
Total expenditure (BDT/cage)	26,283 ± 893^c	36,471 ± 756^b	46,663 ± 994^a
Total revenue (BDT/cage)	39,747 ± 1449^b	54,639 ± 2,111^a	55,588 ± 3,309^a
Net revenue (BDT/cage)	13,464 ± 730^b	18,168 ± 2,159^a	8,926 ± 3,250^b
BCR	1.512 ± 0.022^a	1.499 ± 0.063^a	1.191 ± 0.071^b

Treatments: T_1=40 fish/m^3; T_2= 60 fish/m^3; T_3=80 fish/m^3.

This study documented a higher yield in higher stocking density (80 fish/m^3) of tilapia where mean growth and economic return were lower. The stocking density of T_2 (60 fish/m^3) showed significantly higher yield, growth performance with a profitable economic return. Overall results of the present study indicate that 60 fish/m^3 stocking density of tilapia is better among three treatments in respect to growth, survival rate, production and economic return. Therefore, it could be suggested to rear tilapia with this stocking density (60 fish/m^3) in the cages to get sustainable production and higher economic return in a short period of time.

11.12.3. Expt. 3. Reducing supplementary feeds in cage aquaculture for better economics

Trial 1: Minizing supplementary feeds supply in cage aquaculture for better economics in the Ratargul swamp forest

Due to higher feed cost the economic benefit in aquaculture, especially in cage aquaculture is very minimum. This is why the study was conducted to investigate how to minimize the use of supplementary feeds and its impacts on growth, production and economic return of tilapia farming in cages. There were three treatments with three replicates each. In treatment-1 (T_1) fishes were reared in cages and fed daily, in treatment-2 (T_2) 1 day feeding gap per week, and in treatment-3 (T_3) feeding gap was maintained every three days interval. After 80 days of the experimental period, growth and yield parameters were studied and economic analysis was carried out.

Growth performance : A significant effect ($P < 0.05$) of feed supply on growth and production performance was observed. The mean final weight was significantly higher in T_1 and T_2 than T_3 (Table 52). Mean final weights of tilapia was observed in T_1 and T_2 than T_3 were 227.95±2.16 g, 225.42±6.69 g, and 164.69±10.70 g, respectively. Weight and length gain was increased with increasing feed supply (Fig 39 & 40). The weight and length gain was found the highest in T_1 followed by T_2 and T_3. The specific growth rate (SGR) (%/day) was highest in T_1 followed by T_2 and T_3 with a significant difference found in T_1 and T_2 with T_3. But no significant differences were shown in T_1 and T_2. Lowest feed conversion ratio (FCR) was found in T_2 followed by T_3 and T_1 but no significant difference was found between T_2 and T_3. Feed supply did not significantly affect the survival rate (%). Fish mortality was only observed immediately after stocking of fish in the cages which might be caused due to transportation stress. Tilapia can tolerate a wide range of environmental conditions allowing the culture of this species under high stocking density in cages without any adverse effect on mortality. Therefore, very little fish mortality was occurred in the treatments during the study period.

Table 52. Growth and production performance of tilapia in different feeding gap (mean±SD)

Parameter	Treatments		
	Treatment-1	Treatment-2	Treatment-3
Initial length (cm)	5.98±0.08	6.00±0.08	6.09±0.09
Final length (cm)	21.00±0.20[a]	20.69±0.12[a]	18.85±0.45[b]
Initial weight (g)	3.73±0.06	3.69±0.10	3.75±0.02
Final weight (g)	227.95±2.16[a]	225.42±6.69[a]	164.69±10.70[b]
Total yield (kg/cage)	346.86±6.88[c]	331.64±10.31[b]	238.12±17.73[a]
Net yield (kg/cage)	340.82±6.93[a]	325.67±10.15[a]	232.05±17.75[b]
Total yield (kg/m^3)	12.85±0.26[a]	12.28±0.38[a]	8.82±0.66[b]
Net yield (kg/m^3)	12.62±0.26[a]	12.06±0. 38[a]	8.60±0.66[b]
SGR	4.422±0.015[a]	4.422±0.013[a]	4.15±0. .103[b]
Survival	93.93±1.67[a]	90.82±1.48[b]	89.22±1.21[b]
FCR	0.749±0.043[a]	0.629±0.001[b]	0.661±0.052[b]

$T_{1=}$ Fishes reared in cages and fed daily; T_2= One day feeding gap per week and in T_3 = Feeding gap maintained every three days interval.

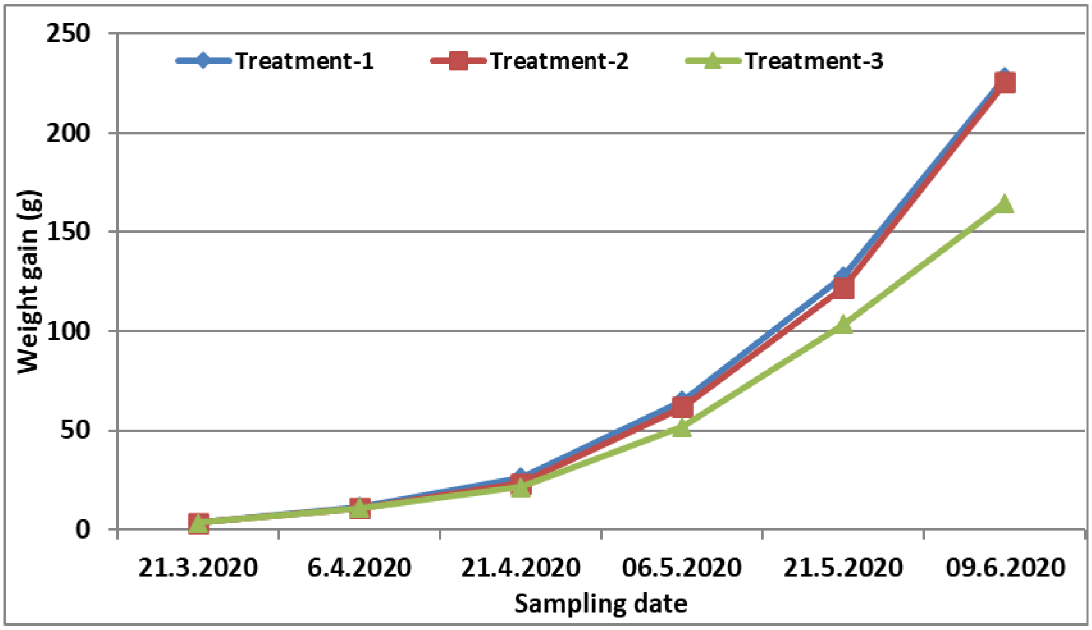


Fig. 39. Monthly weight gain of tilapia in different treatments.

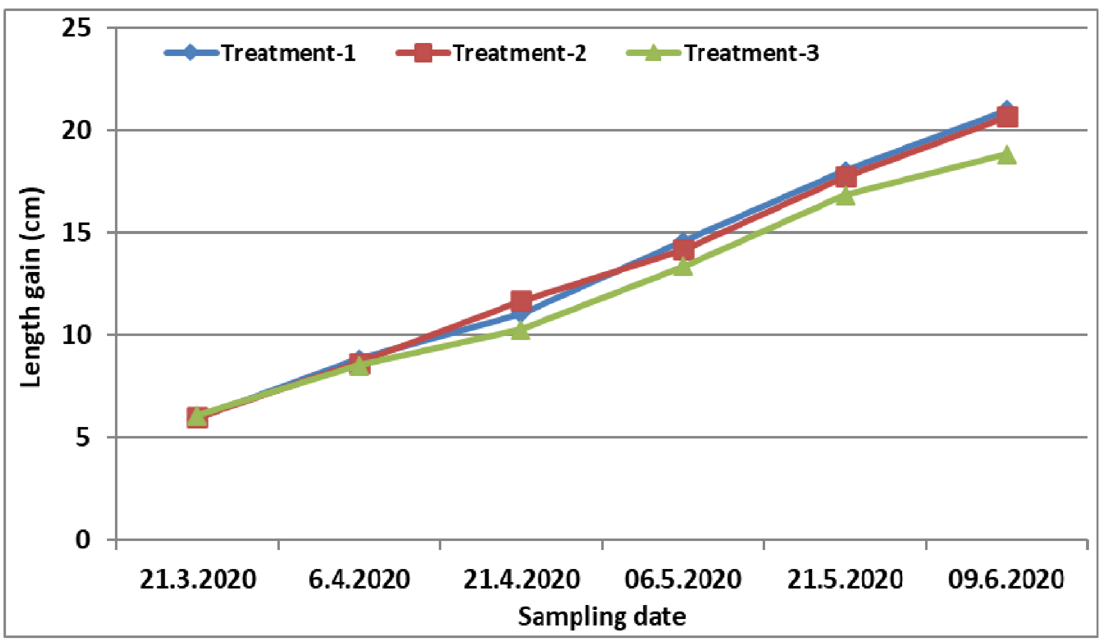


Fig. 40. Monthly length variation of tilapia in different treatments.

Economics : Total expenditure and total revenue were significantly different ($P<0.05$) among the treatments (Table 53). The benefit-cost analysis indicated highest BCR in T_2 followed by T_1 and T_3 where BCR of T_3 was significantly lower ($P<0.05$) than T_2 and no significant difference was found between T_1 and T_2. Therefore, considering the above facts, the economic analysis suggested that treatment 2 (One day feeding gap per week) would be the best option for tilapia cage culture saving operational cost by minimizing the use of supplementary feed.

Table 53. Benefit-cost ratio (BCR) of different treatments (mean±SD)

Parameter	Treatments		
	Treatment-1	Treatment-2	Treatment-3
Fry cost (BDT)	6480.00	6480.00	6480.00
Feed cost (BDT)	14299±741.99[a]	11470±369.75[b]	8561±31.29[c]
Cage cost (BDT)	2000.00	2000.00	2000.00
Total expenditure (BDT/cage)	22779±741.99[a]	19950±369[b]	17041±31.28[c]
Total expenditure (BDT/m^3)	843.66±27.48[a]	738.89±13.66[b]	631.14±1.16[c]
Total revenue (BDT/cage)	31218±619[a]	29848±928[a]	21431±1596[b]
Total revenue (BDT/m^3)	1156±22.93[a]	1106±34.36[a]	794±59.10[b]
Net revenue (BDT/cage)	8438±1037.76[a]	9898±560.11[a]	4390±1585.54[b]
Net revenue (BDT/m^3)	312.55±38.44[a]	366.59±20.75[a]	162.59±58.72[b]
Benefit-cost ratio (BCR)	1.372±0.057[ab]	1.496±0.019[a]	1.257± 0.093[b]

$T_{1=}$ Fishes reared in cages and fed daily; T_2= One day feeding gap per week and in T_3 = Feeding gap maintained every three days interval.

Trial 2: Reducing supplementary feeds supply in cage aquaculture for better economics in the Gurukchi River

This same study of Ratargul Swamp Forest was also conducted at Gurukchi River to investigate how to minimize the use of supplementary feeds and its impacts on growth, production and economic return of tilapia farming in cages. There were three treatments with three replicates each. In treatment-1 (T_1) fishes were reared in cages and fed daily, in treatment-2 (T_2) 1 day feeding gap per week, and in treatment-3 (T_3) feeding gap was maintained every three days interval. After 80 days of the experimental period, growth and yield parameters were studied and economic analysis was carried out.

Growth performance : A significant effect ($P < 0.05$) of feed supply on growth performance was found; the mean final weight was significantly higher in T_1 and T_2 than T_3 (Table 54). Mean final weights of tilapia stocked in T_1 and T_2 than T_3 were 291.14±8.93, 285.32±8.34 and 210.57±13.10 g, respectively. Weight and length gain was increased with the increasing feed supply (Fig 41 & 42). The weight and length gain was found highest in T_1 followed by T_2 and T_3. The specific growth rate (SGR) (%/day) was highest in T_1 followed by T_2 and T_3 with a significant difference found in T_1 T_2 with T_3. But SGR did not show significantly between T_1 and T_2. Lowest feed conversion ratio (FCR) was found in T_2 followed by T_3 and T_1 but no significant difference was found between T_2 and T_3. Feed supply did not significantly affect the survival rate (%), only few mortalities was observed immediately after stocking of fish in the cages which might be caused due to transportation stress. Very little fish mortality was occurred during the study period and there were no significant differences among the treatments.

Table 54. Growth and production performance of tilapia in different treatments in 30 m^3 cages

Parameter	Treatments		
	Treatment-1	Treatment-2	Treatment-3
Initial length (cm)	5.91±0.11	5.82±0.05	5.97±0.14
Final length (cm)	22.90±0.17[a]	22.64±0.04[a]	20.76±0.26[b]
Initial weight (g)	3.40±0.28	3.12±0.08	3.22±0.21
Final weight (g)	291.14±8.93[a]	285.32±8.34[a]	210.57±13.10[b]
Total yield (kg/cage)	444.51±2.62[a]	430.98±14.36[a]	312.27±2670[b]
Net yield (kg/cage)	439.01±2.23[a]	425.93±14.26[a]	307.06±26.77[b]
Total yield (kg/m^3)	16.46±0.10[a]	15.96±0.53[a]	11.57±0.99[b]
Net yield (kg/m^3)	16.26±0.08[a]	15.78±0.53[a]	11.37±0.99[b]
SGR	4.422±0.015[a]	4.422±0.013[a]	4.15±0. .103[b]
Survival	94.30±2.63	93.25±2.19	91.46±2.44
FCR	0.740±0.036[b]	0.578±0.033[a]	0.581±0.075[a]

$T_{1=}$ Fishes reared in cages and fed daily; T_2= One day feeding gap per week and in T_3 = Feeding gap maintained every three days interval.

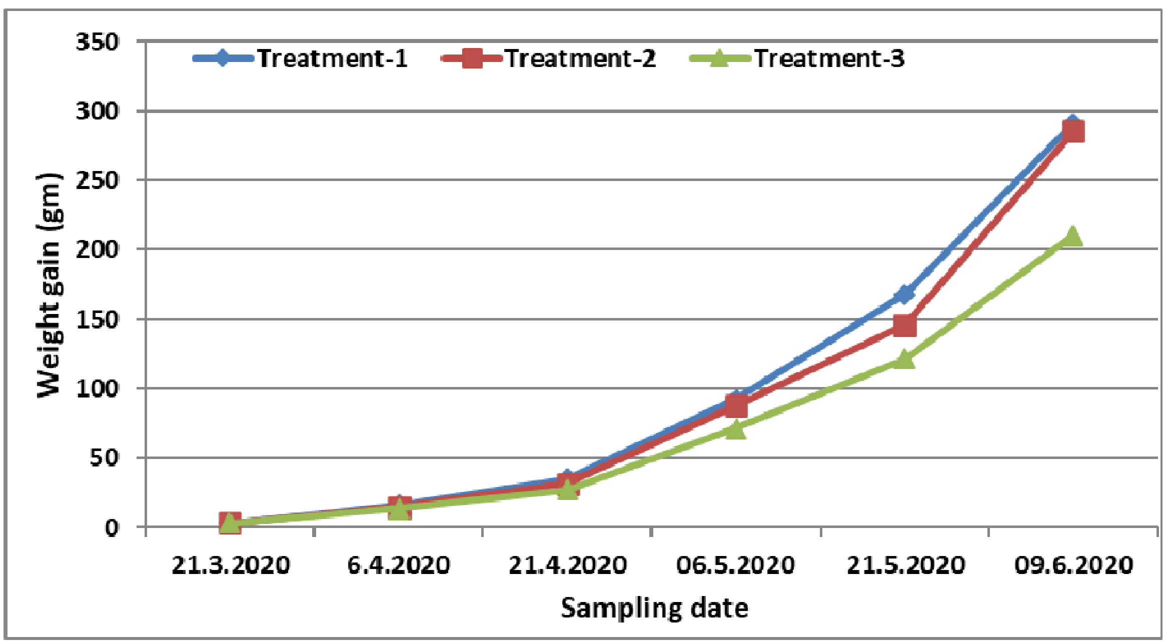


Fig. 41. Monthly weight gain of tilapia in different treatments.

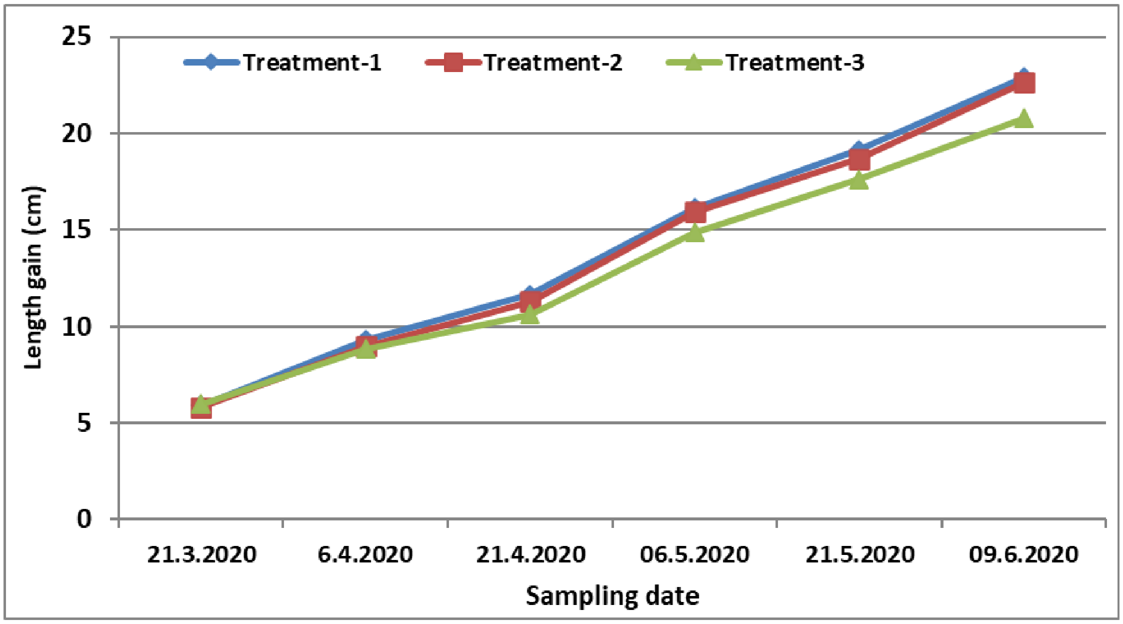


Fig. 42. Monthly length variation of tilapia in different treatments

Economics : Total expenditure and total revenue were significantly different ($P<0.05$) among the treatments (Table 55). The benefit-cost analysis indicated highest BCR in T_2 followed by T_1 and T_3 where BCR of T_3 was significantly lower ($P<0.05$) than T_1 and T_2, but there were no significant differences between treatment T_1 and T_2. Therefore, considering the above facts, the economic analysis suggested that treatment 2 (One day feeding gap per week) would be the best option for tilapia cage culture saving operational cost by minimizing the use of supplementary feed.

Table 55. Benefit-cost ratio (BCR) of different treatments (mean±SD)

Parameter	Treatments		
	Treatment-1	**Treatment-2**	**Treatment-3**
Fry cost (BDT)	6480	6480	6480
Feed cost (BDT)	18179±817^{a}	13769±435^{b}	9915±675^{c}
Cage cost (BDT)	2000	2000	2000
Total expenditure (BDT/cage)	26658±817^{a}	22249±435^{b}	18395±675^{c}
Total expenditure (BDT/m^3)	987±30.27^{a}	824±16.11^{b}	681±24.99^{c}
Total revenue (BDT/cage)	40006±236.1^{a}	35933±1652.9^{b}	23918±1327.8^{c}
Total revenue (BDT/m^3)	1481±8.74^{a}	1331±61.22^{b}	885±49.18^{c}
Net revenue (BDT/cage)	13347±1017^{a}	13684±1816^{a}	5524±1665^{b}
Net revenue (BDT/m^3)	494.33±37.68^{a}	506.80±67.25^{a}	401.90±156.09^{b}
Benefit-cost ratio (BCR)	1.501±0.054^{a}	1.616±0. .087^{a}	1.302±0.10^{b}

$T_{1=}$ Fishes reared in cages and fed daily; T_2= One day feeding gap per week and in T_3 = Feeding gap maintained every three days interval.

11.13. Overall discussion on cage culture activities

As an alternate livelihood option of the fishers a total of 9 cages were set up inside the Ratargul swamp forest and 9 cages in the Gurukchi River of Gowaingaht upazila, Sylhet. According to the result of the 1st experiment pangas performed comparatively better than magur and pabda. Depending of the findings pangas was selected for the research at Ratargul swamp forest and as the profit margin was very low another widely cultured species in cage aquaculture tilapia was introduced for Gurukchi River as an alternative livelihood option for the local fishers. In case of pangus a significant effect ($P < 0.05$) of stocking density on growth performance was found and overall result of the study indicated that 30 fish/m^3 stocking density of pangas is the best among three treatments in respect of growth, production and economic return. In case of tilapia, a significant effect ($P < 0.05$) of stocking density on growth performance was found and result of the study indicated that 60 fish/m^3 stocking density of tilapia is the best among three treatments in respect of growth, production and economic return.

Overall results of the present study indicated that tilapia would be the best option for cage culture with weekly one day gap in supplementary feeding. The growth of tilapia generally depends on some factors which include the stocking density, physiological status of fish, reproductive status of fish, food quality, energy content of the diet, and environmental drivers like pH, temperature, etc. (Lovell, 1989; Gibtan *et al.*, 2008). However, the present study was designed to find out a suitable species and appropriate stocking density in the local context and minizing the operational cost for more economic return and that would eventually improve the livelihoods of the rural fishers as an alternative income generating activity.

A decreasing trend of fish growth was observed with increasing stocking densities for tilapia. Significantly higher mean final weight, mean final length, and SGR (%/ day) were attained in the stocking density of 40 fish/m^3 and 60 fish/m^3 than 80 fish/m^3,respectively. Significantly lower FCR was also found at the density of 40 fish/m^3 and 60 fish/m^3 than that of 80 fish/m^3 densities. Fish got more space for easy movement in the lower stocking densities and feed efficiency is positively correlated with space in the cages (Slembrouck *et al.*, 2009; Refaey *et al.*, 2018). Besides, a lesser amount of stress in cultured fish was documented in lower stocking densities (Liu *et al.*, 2019; Zahedi *et al.*, 2019). Higher feed efficiency and lower level of stress in fish body ensured significantly higher final weight gain which was previously reported by several researches (Chowdhury *et al.*, 2002; Rahman *et al.*, 2006). Stocking densities have no significant effect on the survival rate of tilapia, which was similar with several other researches with different type of fish species under different culture conditions and environments (Jiwyam, 2011; Liu *et al.*, 2019; Refaey *et al.*, 2018). Tilapia can live in a wide range of aquatic environmental parameters which allows this species to culture with high stocking densities in cages without any significant effect on mortality. However, stocking density and production performance obtained in this study are found consistent with many other researches on this species with various environments (Gibtan *et al.*, 2008; Alam *et al.*, 2014; Moniruzzaman *et al.*, 2015; Marma *et al.*, 2017). In this study, all physico-chemical parameters of the river water were found within the acceptable limits for aquaculture in the tropical waters (Boyd and Tucker, 1998).

Marma *et al*. (2017) studied on Nile tilapia with 35, 40 and 45 fish/m^3 stocking densities in the Dekar *Haor* of Sunamganj district covering 120 days of culture period and found the highest mean final weight was 175.07 ± 17.52 g in the treatment with 35 fish/m^3 densities which is significantly ($p < 0.05$) higher final weight of tilapia than those of 40 stocking densities (169.3 ± 15.19 g) and 45 fish/m^3 densities (143.00 ± 14.92 g). The authors also documented daily weight gain of tilapia was reduced with increasing stocking density. In the present study, gross yield increased with increasing stocking density. However, the fingerling and feed costs were also increased with the increasing stocking density. Feed cost comprises about 69.56% to 70.00% of the total cost for the each treatment. Cage infrastructural cost remained same in all treatments and calculated based on depreciation cost. The higher fry cost and feed usage for higher stocking density found in a lower BCR with low economic return.

The design of the present research was prepared to support local fishers involving them as an alternate livelihood option to cope up the situation during fishing ban period as well as finding out the suitable stocking density of tilapia in cage aquaculture in the riverine condition and semi-closed wetlands. It is evidenced that higher stocking density might be increased gross production but the production cost increased with the increasing stocking density and more supplementary feeding that might not be affordable for the local farmers. On the other hand, very lower stocking density provides less net profit which could not be economically viable. Moreover, the *haor* region is prone to regular flash floods and the poor and middle-class fishers and fish farmers are susceptible to this hydro-meteorological hazards and threats (Kamal *et al.*, 2018). Therefore, efficient management of cages with higher stocking densities is difficult, and shifting the cages to a relatively safer zone almost impossible during such kind of sudden disasters, which may cause total loss to the cage aquaculture system (Chowdhury *et al*. 2020). However, as the tilapia desnity 60 fish/m^3 showed significantly higher production, growth performance and a commercial economic return could be suggested for cage aquaculture for thr haor region. Pangas could be the other good option with with a stocking density of 30 fish/m^3. Pabda and magur have also good prospect in cage culture, but need more tial in the haor region to find out the suitable culture technique in cages. Feed cost is the main cost for cage aquaculture and third trial was designed how to reduce feed use to make the cage culture more profitable. However, the present study suggested that weekly one day gap in feed supply in case of tilapia is better to reduce feed cost and better economic return.

11.14. Cage fish farming by RU component during fishing ban period

The sub-project has successfully implemented cage fish farming of Gulsa tengra as alternative livelihood option for the fishermen through a series of three potential experiments. In the first experiment, more preferable catfish species was selected among Gulsa tengra, Pabda, Magur and Pangas. After a successful selection of gulsa tengra among the four species, potential density was optimized through experiment two. Finally, at experiment three, a study on feeding restriction was conducted to make cage farming of gulsa tengra economically sustainable in riverine floodplain of Chalan beel.

11.14.1. Expt. 1: Determination of suitable species for cage fish farming in Chalan *beel*, Bangladesh : Water bodies in Bangladesh including rivers, irrigation canals, oxbow lakes and haors offer potential sites for cage culture (Golder *et al.*, 1996) as it affords a prospect for small-scale farmers to use their limited resources and to include high-valued species in their cage to generate more income and improve their livelihood. Fish species cultured in cage fish culture of

Bangladesh are mainly; Climbing Perch *Anabas testudineus* (Mondal *et al.*, 2010; Habib *et al.*, 2015; Uddin *et al.*, 2016), Tilapia *Oreochromis niloticus* (Mondal *et al.*, 2010; Begum *et al.*, 2017; Moniruzzaman *et al.*, 2015; Marma *et al.*, 2017; Hossain *et al.*, 2017) and Walking Catfish *Clarias batrachus* (Sangma *et al.*, 2017). However, in Bangladesh, among the various fish species catfishes are particularly important for their fast growth, lucrative size, good taste, and high market demand. Catfishes are also popular for most essential vitamins and minerals, including; vitamin A, vitamin C, calcium, iron manganese etc. Not only are those, catfishes are very popular air-breathing fish species can survive even at low oxygen levels in water. Therefore, catfish can be grown more successfully in cages and these are more desirable species for cage culture. Moreover, conservation of catfishes are now in danger due to the destruction of natural breeding and feeding grounds because of anthropogenic pressure on inland water habitats (Mazid and Kohinoor, 2003; Ali *et al.*, 2018) and cage culture can be a solution for extinction of these fish species from natural water habitat. Therefore, many commercially important indigenous catfishes such as Pabda (*Ompok pabda) and* Gulsha tengra (*Mystus cavasius)* are highly susceptible and on the limit of extinction (Akhteruzzaman *et al.*, 1991; 1993). Under the above circumstances, the present study was designed to evaluate the performance of cage fish farming in running water of Atrai River in *Chalan beel* area of Bangladesh through the selection of suitable catfish species for better economic performance.

Experimental design : The sub-project was to develop alternate livelihood option through appropriate cage fish farming to reduce the fishing pressure during ban on fishing for sanctuary operation, whereas in the first year experiment, 4 catfish species Pangus (*Pangasius hypophthalmus)*; Magur (*Clarias batrachus)*; Pabda (*Ompok pabda)* and Gulsha tengra (*Mystus cavasius*) were selected for trial of cage culture. The treatments T_1, T_2, T_3 and T_4 were assigned for Pangus, Magur, Pabda and Gulsha tengra, respectively. Fry of selected fishes were released in experimental cages at a stocking density of 100 fish/m^3 and growth monitoring was done. The fishes were fed with commercial feed containing 32% protein and feeding was done at the rate of 5% of body weight.

Results and discussion

Water quality parameters of cages

Water quality parameters of the studied cages at different treatments are shown in Table 56. There was no significant differences ($P>0.05$) were observed in all the water quality parameters among the treatments. However, higher values of pH were recorded at T_4 followed by T_3, T_1 and T_2. DO level was also higher at T_4 and lowest at T_3. NH_3 content of the water were more or less similar in all the treatments. The factors affecting the water quality of cage farming are wastes from uneaten feed and faecal materials of cultured fishes as previously reported by Shahidul (2005). Being the running water, these factors were eliminated successfully by the water current in the present experiment, therefore, maintained the uniformity of the water quality parameters among the treatments. pH and DO were within the suitable range for fish culture in cage environment and coincide with the findings of Uddin et al. (2016), Moniruzzaman et al. (2015) and Rahman & Marimuthu (2010) where they reported a pH ranged between 6.3 to 7.4 and DO 5.8 to 7.8 mg/l. Selection of study site in running water decreased environment degradation during the present study. In cage culture system, higher stocking density of fish, uneaten feed materials and feces of fishes are common phenomena which cause deterioration of water quality in terms of lower dissolved oxygen, higher ammonia and excessive algal blooms due to nutrient build up (Nabirye et al., 2016; Temporetti et al., 2001). Sangma et al. (2017), Begum et al. (2017) and Habib et al. (2015) reported pH and DO range between 7.2-7.4 and 4.91-4.92 mg/l, 7.18-7.38 and 5.37-5.42, 7.50-7.90 and 4.90-6.70 mg/l, respectively in pond cage culture system, which were lower than the findings of the present study. NH_3-N ranged between 0.010-0.07 mg/l was also reported by Sangma et al. (2017) and Begum et al. (2017) in water of cage cultured in pond, which was also higher than the findings of the present study. Results of the present study were mainly influenced by water currents that constantly sweeping out the uneaten feed and feces of cultured organisms, which increase the suitability of cage fish farming in running water.

Table 56. Water quality parameters of cages after the culture period of 120 days

Parameters	T_1	T_2	T_3	T_4
Temperature (ºC)	25.21±0.39[a]	25.17±0.33[a]	25.11±0.33[a]	25.20±0.24[a]
pH	7.49±0.06[a]	7.41±0.02[a]	7.51±0.16[a]	7.54±0.13[a]
DO (mg/l)	7.15±0.04[a]	7.18±0.10[a]	7.09±0.08[a]	7.19±0.11[a]
NH_3 (mg/l)	0.002±0.000[a]	0.001±0.001[a]	0.001±0.001[a]	0.001±0.000[a]

Values in each same raw having different superscripts are significantly different ($P<0.05$)
T_1=Pangas 100/m^2, T_2=Magur 100/m^2, T_3=Pabda 100/m^2, T_4=Gulsha tengra100/m^2.

Growth performance of fish in cages

At the end of 120 days of fish rearing in cages, biological performances and production of fishes at different treatments were presented in Table 57. All growth parameters in terms of final weight, weight gain, percent weight gain, average daily gain (ADG) and specific growth rate (SGR) were significantly varied among the treatments. Significantly higher final weight, weight gain, percent weight gain, average daily gain (ADG) and specific growth rate (SGR) were highest at T_1 and at T_3. Significantly higher survival was observed at T_4 and lowest at T_2. There was also significant difference in the FCR value among the three treatments. Best performance of FCR was found T_1 with the fish species Pangas and the lowest performance of FCR was recorded at T_3 where the fish species was Pabda. Significantly ($P<0.05$) higher total and net production per cage were also recorded at T_1 where the fish species was Pangas and lowest at T_3 with the species of Pabda. Significantly higher growth and production performance was recorded at T_1 for Pangus followed by Magur at T_2, Gulsha tengra at T_4 and Pabda at T_3. The variations in growth performance in the present study might be due to the variation of species specific inherent differences in genetic makeup and feeding behaviour (Umanah and Harry, 2017; Martins *et al.*, 2005; Sundstrom *et al.,* 2003). Different fish species have different protein and amino acid absorption ability (Sogbesan and Ugwumba, 2008), which might responsible for the variation of growth performance of fishes in the present study. On the other hand, maximum weight is also a factor responsible for growth variations in different catfish species. Pangas is well-known for its faster growth (Malik *et al.,* 2014) and can achieve a maximum weight of 872 g in pond culture (Sayeed *et al.*, 2008). Moreover, Magur also have potential to grow larger in size in culture condition. Therefore, higher increment of growth performance for Pangas and Magur was common than Pabda and Gulsha tengra. The final weight obtained by Pabda and Gulsha tengra were lower than the findings of Kohinoor *et al.* (2011), whereas they reported mean final weight of 35.33 and 28.21 g for Pabda and Gulsha tengra, respectively during the culture period of six months. During the study period, the higher survival rate of Pangas was coincided with the finding of Mian *et al.* (2019), who have reported the survival of Pangas ranged between 87-93% in their study period. Moreover, SGR and FCR of treatment T_1 were also more or less similar with the findings of Sayeed *et al.* (2008) and Azad *et al.* (2004), respectively. Lower survival for Magur during the study period was due to their escaping tendency from the cage, which causes physical injury and much mortality.

Table 57. Growth performance of fishes in cage culture system

Parameters	T_1	T_2	T_3	T_4
Initial weight (g)	5.50±0.05^a	5.60±0.10^a	5.25±0.05^a	5.10±0.10^a
Final weight (g)	101.19±2.46^a	58.58±0.92^b	17.56±0.27^d	22.67±1.07^c
Weight gain (g)	95.69±2.48^a	52.98±0.95^b	12.31±0.32^d	17.57±1.11^c
% weight gain	1740.21±50.85^a	946.33±26.79^b	234.46±8.30^d	344.66±25.72^c
ADG	0.80±0.02^a	0.44±0.01^b	0.10±0.01^d	0.15±0.01^c
SGR (%/day)	2.43±0.04^a	1.96±0.02^b	1.01±0.02^d	1.24±0.05^c
Survivability (%)	91.16±1.54^a	80.10±3.53^b	89.94±0.20^a	90.67±2.00^a
FCR	1.21±0.09^d	1.30±0.06^c	2.50±0.04^a	1.81±0.13^b
Total production (kg/cage)	332.92±5.57^a	164.16±4.84^b	55.27±0.88^d	71.95±4.20^c
Net production (kg/cage)	303.67±5.56^a	144.56±4.65^b	36.89±1.05^d	54.10±4.22^c

Values in each same raw having different superscripts are significantly different (P<0.05)
T_1=Pangas, T_2=Magur, T_3=Pabda, T_4=Gulsha tengra (100/m^2 each)

Economics of cage culture

The cost-benefit analysis of fish culture under different treatments is given in Table 58. The analysis revealed that total cost were significantly (P<0.05) higher in T_1 followed by T_2, T_3 and T4. However, total income from fish sale was highest at T_2, which was not significantly different from T_4. But, when comparing total net return, the value was higher for T_4 followed by T_2 and T_3. Significantly higher BCR was recorded at T_4 (0.73±0.09) followed by T_2 (0.19±0.04), T_3 (0.12±0.01) and T_1 (0.03±0.01). However, after conducting the economic analysis it was observed that Pangas at T_1 showed lower net income and BCR. During the study period, voracious feeding habit of Pangas resulted in significantly higher feed cost at T_1. Therefore, total cost was also varied significantly among the treatments and the highest total cost was recorded from treatment T_1. On the other hand, although growth performance of the studied fishes was found better for Pangas, significantly (P < 0.05) higher net return was recorded for Gulsa Tengra T_4, and finally benefit cost ratio also showed higher economic performance for Gulsa Tengra. This was due the fact that the market price of Gulsa Tengra was comparatively higher than other fish species selected in the present experiment. Not only that, cage culture of catfish species was more profitable than Tilapia (Moniruzzaman et al., 2015).

Table 58. Economic performance of fishes at different treatments under cage culture system after 120 days of culture period

Parameters	T_1	T_2	T_3	T_4
Feed cost	17196.30±1236.50^{a}	18743.40±155.67^{b}	9217.20±139.56^{c}	9768.30±162.85^{c}
Fry cost	4200.00±0.00	5250.00±0.00	5950.00±0.00	5250.00±0.00
Cage cost	2000.00±0.00	2000.00±0.00	2000.00±0.00	2000.00±0.00
Labour cost	1666.00±0.00	1666.00±0.00	1666.00±0.00	1666.00±0.00
Total cost	25062.30±1236.50^{a}	27659.40±155.67^{b}	18833.20±139.56^{c}	18684.30±162.85^{c}
Total income	25833.49±361.96^{c}	32833.13±967.41^{a}	21002.07±334.28^{b}	32376.31±1889.53^{a}
Net income	771.19±1593.78^{d}	5173.73±1110.30^{b}	2168.87±204.43^{c}	13692.01±1741.13^{a}
BCR	0.03±0.01^{c}	0.19±0.04^{b}	0.12±0.01^{b}	0.73±0.09^{a}

Values in each same raw having different superscripts are significantly different ($P<0.05$)
T_1=Pangas, T_2=Magur, T_3=Pabda, T_4=Gulsha tengra (100/m^2 each)

Plate 36. Treatmentwise production and BCR values of different fish species in case culture.

11.14.2. Expt. 2: Optimization of stocking density of Gulsha tengra in cage culture system in Chalan Beel : Growing fish within cages are stressful to fish at higher stocking densities. Higher stocking density caused a series of biochemical and physiological changes in fish (Conceiçao *et al.*, 2012). The negative impact of density on growth, survival, size heterogeneity, immune function, disease resistance and final products of farmed fish has been widely reported when raising catfish (Lupatsch *et al.*, 2010; Telli *et al.*, 2014). Density stress also known to affect the functioning of liver and kidneys and modulates metabolic activities in fish (Pakhira *et al.*, 2015). However, under stocking is leading to underutilization of available space, resulting in lower fish production (Rahman *et al.*, 2006). Stocking density also influences the economics of cage culture, where optimum stocking is more economical considering the cost and benefit of the system. In this context, establishing the most appropriate stocking density for gulsa tengra is a precondition factor to permit the economic sustainability without compromising the adequate welfare of fish for cage aquaculture system in floodplain ecosystem. In the present experiment, we wanted to assess optimal stocking density of Gulsha tengra for sustainable and economically profitable culture system in floodplain wetland. Therefore, the present study was designed to optimize stocking density of Gulsa tengra in cages installed in Chalan beel and to assess the effects of stocking density on the growth performance, health status and physiology of this fish species.

Study design : For the second-year cage farming trial (selection of suitable stocking density of Gulsa tengra for cage culture system in Chalan beel) was conducted for four months (From July to October 2019). Four types of potential stocking density (50, 100, 150 and 200 fish/m^3) were selected and treated as treatment -T_1, T_2, T_3 and T_4, respectively and stocked in the experimental cages. Preparation of cages, evaluation of water quality and growth parameters, and economic analysis were done following same procedure described in experiment one (1).

Results and discussion

Water quality parameters : Water quality parameters measured during the study period are shown in Table 59. There was no significant difference (P<0.005) in the mean value of water quality parameters among the treatments. As changes in temperature are mainly regulate by seasonal changes in weather condition, increasing stocking density had no impact on this parameter. Stocking density also had no any influence on pH, DO, NH_3-N content of the cage water. This was because the cage culture was performed in running water system. Hence, the pollutant in terms of NH_3-N was mainly washed out by the river water. However, in the present study, levels of stocking density did not affect the water quality parameters since the cages were installed in running water system. Moreover, all the water quality parameters tested were within the suitable range for tropical fish culture (Boyd, 1982).

Table 59. Water quality parameters of studied cage water at different stocking densities

Parameters	T_1	T_2	T_3	T_4
Temperature (ºC)	26.86 ± 0.10^a	27.16 ± 0.03^a	27.01 ± 0.45^a	27.07 ± 0.18^a
pH	7.27 ± 0.04^a	7.33 ± 0.11^a	7.38 ± 0.16^a	7.46 ± 0.12^a
DO (mg/l)	6.46 ± 0.14^a	6.54 ± 0.08^a	6.42 ± 0.13^a	6.55 ± 0.09^a
NH_3-N (mg/l)	0.002 ± 0.001^a	0.002 ± 0.001^a	0.002 ± 0.002^a	0.003 ± 0.001^a

Values in each same raw having different superscripts are significantly different (P<0.05)
T_1: 50 fish/m^3; T_2: 100 fish/m^3; T_3: 150 fish/m^3; and T_4: 200 fish/m^3

Overall growth performance of cultured fish

Growth performance of fish over the culture period is shown in Table 60. Significant difference ($P<0.05$) was observed in all the growth parameters among the different stocking densities. During the study period, the highest final weight was obtained from the fish stocked at a stocking density of 50 fish/m^3 at T_1. Followed by final weight, weight gain, %weigh gain, average daily gain (ADG), specific growth rate (SGR) was significantly higher at T_1 compared to the other treatment. Increase in stocking density caused a reduction in the growth parameters might be due to the factors associated with interspecific competition for food and living space. Therefore, the lowest growth performance was observed in the fish stocked at 200 fish/m^3 at T_4. Overcrowding of fish due to higher stocking density also caused lower survivability at T_4. On the other hand, lower stocking density at T_1 results in reduced stress condition and favoured the higher survivability of fish. Higher amount of feed was needed to feed the fish at T_4 that caused the lower performance of FCR. However, FCR was lower at T_1 followed by T_2 and T_3. At the end of the study period, the highest total and net production were obtained from T_3 where the stocking density was 150 fish/m^3. In terms of total production, difference between T_3 and T_4 was insignificant. While there was significant difference was in net production might be due to the lower survival rate of fish at T_4. Although the growth performance was higher at T_1, significantly lower total and net production was recorded at this stocking density. Overall growth performance of Gulsha tengra was higher at lower stocking density (T_1) and inverse at higher stocking density (T_4). Similar observation was also made by Garcia *et al.* (2013) and Costa *et al.* (2017) who demonstrated an inverse relationship between stocking density and growth performance in tilapia cultured in net cages. Fish at higher stocking density at T_4 were experienced extreme crowding which affected fish behavior, health and feeding. This observation is in agreement with the findings of Enache *et al.* (2016), Moniruzzaman et al. (2015), Ronald *et al.* (2014), M'balaka *et al.* (2012) and Sanchez *et al*. (2010). Overcrowding of fish at T_4 also influenced survivability, which is in agreement with Garcia et al. (2013), where they have reported negative influence of higher stocking density on fish survival. Study conducted by Biswas *et al.* (2015) and Debnath *et al.* (2012) also reported the negative effect of higher stocking density on survival of *Labeo rohita* and *Cirhinnus mrigala*, respectively. FCR, in the present study varied significantly among the treatment, whereas the better performance was observed at lower stocking density at T_1. FCR expresses the ability of fish to effectively convert feed into body flesh and, therefore, the higher FCR values observed in this study at higher stocking density indicated poor food utilization efficiency. The results of this study are also in agreement with Kapinga *et al.* (2014) and Asase *et al.* (2016), who indicated that feed conversion ratio increased with an increase in stocking density in tilapia culture. However, lower FCR value at lower stocking density cages suggests the better ability of fish to extract more nutrients from feed and their subsequent conversion into body flesh (Alhassan *et al*., 2018).

Table 60. Growth monitoring of fish at different stocking densities

Parameters	T_1	T_2	T_3	T_4
Initial weight (g)	5.68±0.56^a	5.58±0.55^a	5.53±0.42^a	5.42±0.45^a
Final weight (g)	24.38±1.26^a	21.47±1.22^b	18.97±1.99^c	14.08±0.78^d
Weight gain (g)	18.70±1.37^a	15.90±0.89^b	13.44±1.77^c	8.66±0.99^d

% weight gain	332.97±47.08[a]	286.92±25.92[b]	243.39±29.77[c]	161.97±32.36[d]
ADG (G)	0.16±0.01[a]	0.13±0.01[b]	0.11±0.02[c]	0.07±0.01[d]
SGR (%/day)	1.22±0.09[a]	1.13±0.05[b]	1.03±0.07[c]	0.80±0.10[d]
Survival rate (%)	95.84±0.85[a]	92.88±1.61[b]	88.92±3.35[c]	86.66±1.73[d]
FCR	1.75±0.26[c]	2.04±0.15[c]	2.52±0.30[b]	4.09±0.55[a]
Total production (kg)	40.89±2.10[c]	69.83±4.66[b]	88.31±6.72[a]	85.38±3.94[a]
Net production (kg)	30.95±2.37[c]	50.31±3.48[b]	59.27±5.79[a]	47.45±5.75[b]

Values in each same raw having different superscripts are significantly different (p<0.05)
T_1: 50 fish/m^3; T_2: 100 fish/m^3; T_3: 150 fish/m^3; and T_4: 200 fish/m^3

Economic performance of cultured fish

At the end of the culture period an economic analysis was conducted to evaluate the suitable stocking density of Gulsha tengra for cage culture system in Chalan beel area (Table 61). Increase in the stocking number of fish in cages significantly increased the feed cost at T_4. However, lowest feed cost was shown in T_1 as the stocking density of this treatment was lower among the other treatments. In case of total cost, significantly higher cost was recorded at T_4, which was due to increase feed cost. Finally, total income, net income and BCR were beneficial for the treatment T_2, where the stocking density of fish was 100 fish/m^3. During the study period, with increase in stocking density, total and net production was decreased significantly. Many authors reported stocking density to have an effect on fish production (El-Sayed, 2002; Kohli *et al.*, 2002; de Oliveira *et al.*, 2012), whereas, along with competition for food and space, the stress level also increases at higher stocking density (Timalsina *et al.*, 2017; Ellis *et al.*, 2002). Hence, fish kept at higher density tend to have lower production (Hengsawat *et al.*, 1997). Higher operational cost due to higher stocking density caused higher total cost at T_4. While the highest total income was incurred from T_3, and net income from T_2. However, T_2 with the stocking density of 100 fish/m^3 was considered as the most economic stocking density, whereas the BCR was 1.14±0.10.

Table 61. Economic performance of cage culture at different stocking densities

Parameters	T_1	T_2	T_3	T_4
Feed cost	3431.48±254.39[d]	6550.60±538.35[c]	9454.40±385.22[b]	12252.30±681.53[a]
Fry cost	3062.50	6125.00	9187.50	12250.00
Cage cost	2000.00	2000.00	2000.00	2000.00
Labour cost	1600.00	1600.00	1600.00	1600.00
Total cost	10093.98±254.39[d]	16275.60±538.35[c]	22241.90±385.22[b]	28102.30±681.53[a]
Total income	20447.29±1050.43[c]	34914.02±2332.53[a]	35326.52±2687.13[a]	29882.91±1378.80[b]
Net income	10353.31±1189.36[c]	18638.42±1970.21[a]	13084.62±2747.27[b]	1780.61±1709.24[d]
BCR	1.03±0.13[b]	1.14±0.10[a]	0.59±0.12[c]	0.06±0.07[d]

Values in each same raw having different superscripts are significantly different (p<0.05)
T_1: 50 fish/m^3; T_2: 100 fish/m^3; T_3: 150 fish/m^3; and T_4: 200 fish/m^3

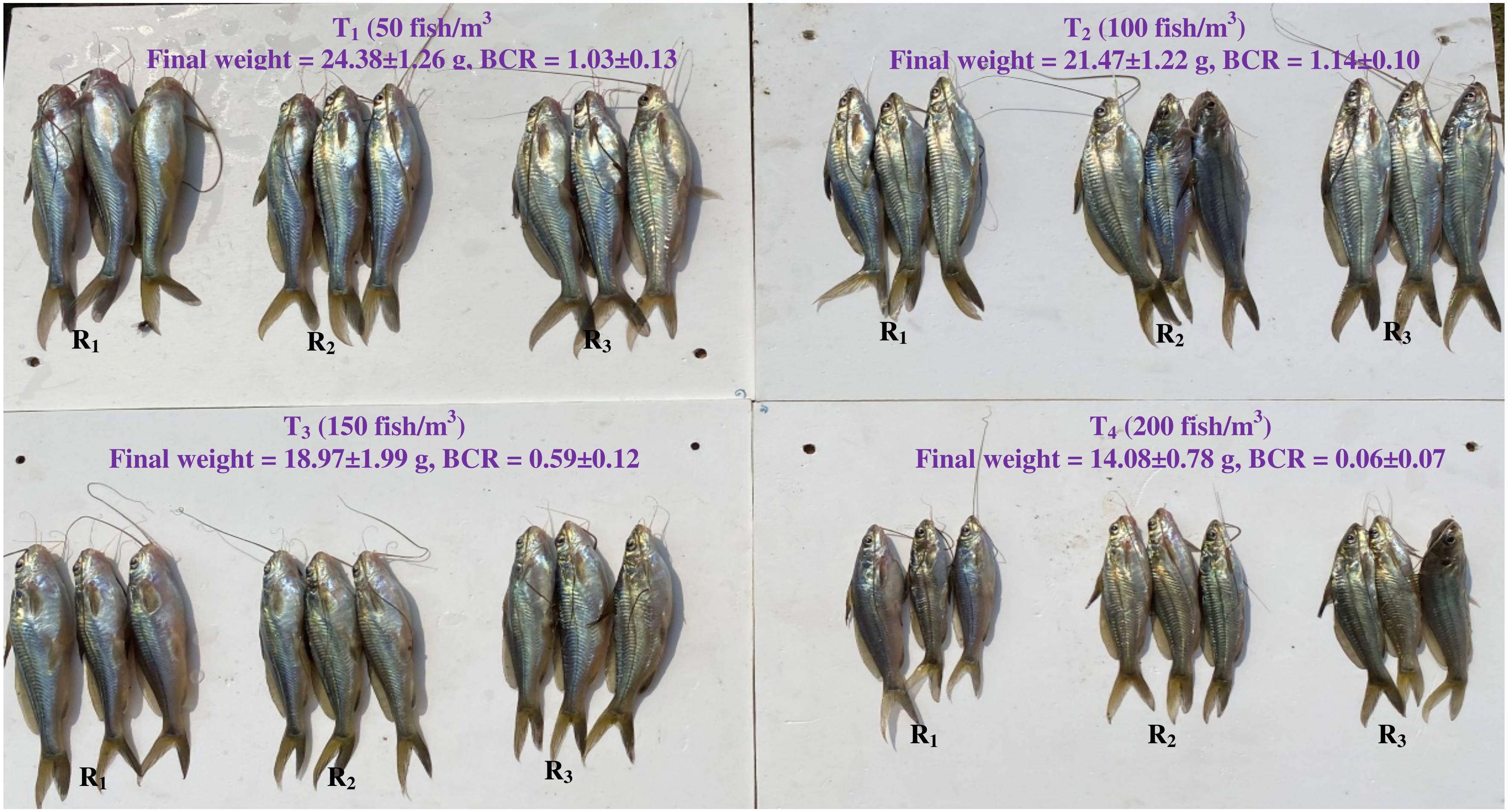


Plate 37. Photography of final harvested fish sample in Experiment 2.

11.14.3. Experiment 3: Effects of supplementary feeds with different feeding restriction period on the production and economics of cage farming in Chalan *beel* : After the successful completion of species selection and optimization of stocking density for Gulsa tengra in cage culture system in Chalan beel, major concern was achieved was feed cost which needs to be minimized for sustainable farming of Gulsa tengra in cages. Therefore, to make the cage fish farming of Gulsa tengra more sustainable in Chalan beel area, experiment was conducted following different feeding regime. Starving fish for some days within culture period is a common practice for farmers to reduce feed cost and to increase profit margin (Gaylord and Gatlin, 2000). Nowadays starving fish are now a familiar strategy applied by fish farmer to reduce feed cost in fish in aquaculture as because being an important factor in commercial fish farming feed costs account for 40-60% of the production cost in fish culture (Marimuthu et al., 2011). However, restoration of adequate feeding can overcome the effect of starvation and was also known to give faster growth than the continuously fed fish, which is called growth compensation. But it is always not the case as because compensatory growth may sometimes causes developmental abnormalities due to faster growth and can reduce immunocompetence and disease resistance. Therefore, it is necessary to know how many days a fish can be starved and what will be the optimal feeding rate to increase feed efficiency, growth performance of fish, maintain water quality and finally to increase profit of fish production (Dwyer *et al*., 2002).

Study design : Third experiment was conducted for a period of four months (From July to October 2020). 4 different treatments were assigned for this experiment, whereas fish were distributed among regular feeding, 1 restriction and 6 day feeding, 2 day restriction and 5 day feeding; and 3 day restriction and 4 day feeding, respectively in one week period. Thus, over the culture period 120 days, regular feeding was maintained at T_1, 18 day restriction at T_2, 36 day restriction at T_3 and 52 day restriction at T_4. Stocking density (100 fish/m^3) was similar in all the treatmets. Initial weight of the stocked fish was 8.00±0.35g. Preparation of cages, evaluation of water quality and growth parameters, and economic analysis were done following same procedure described in experiment one.

Result and discussion

Water quality parameters : There was no significant difference (P<0.005) in the mean value of water quality parameters among the treatments (Table 62). This was because the cage culture was performed in running water system. Hence, the pollutant in terms of NH_3-N was mainly washed out by the river water.

Table 62. Water quality parameters of studied cages water at different feeding regime

Parameters	T_1	T_2	T_3	T_4
Temperature (ºC)	$30.35±1.57^a$	$30.02±1.96^a$	$29.90±1.67^a$	$29.94±1.20^a$
pH	$7.08±0.21^a$	$7.10±0.26^a$	$7.05±0.20^a$	$7.04±0.33^a$
DO (mg/l)	$5.58±0.44^a$	$5.61±0.52^a$	$5.54±0.47^a$	$5.56±0.41^a$
NH_3-N (mg/l)	$0.03±0.01^a$	$0.04±0.02^a$	$0.03±0.01^a$	$0.03±0.02^a$

Values in each same row having different superscripts are significantly different (p<0.05)
T_1: Regular feeding; T_2: 1 day restriction and 6 day feeding; T_3: 2 day restriction and 5 day feeding; and T_4: 3 day restriction and 4 day feeding in a week.

Overall growth performance of cultured fish : Final growth performance of fish over the culture period is shown in Table 63. Significant difference (P<0.05) was observed in all the growth parameters among the different feeding regime. During the study period, the highest final weight was obtained from the fish stocked at T_1. Followed by final weight, weight gain, %weigh gain, average daily gain (ADG), specific growth rate (SGR) were significantly higher at T_1 compared to the other treatment. These results are in agreement with those obtained by Limbu and Jumanne (2014) who reported inceased growth performance of fish feeding with 1 day restriction per week. This is due to compensatory growth, defined as a period of unusually fast growth shown by individuals encountering abundant food following a period of food deprivation (Zhu *et al*., 2001). Increased restriction time caused a reduction in the growth parameters might be due to the factors associated with interspecific competition for food and stress. Therefore, the lowest growth performance was observed at T_4. Regular feeding of fish also caused higher survivability at T_1. On the other hand, 3 day feeding restriction at T_4 resulted in increased stress condition and lower survivability of fish. Although lower amont of feed was needed at T_3, reduction in growth caused lower performance of FCR. However, FCR was lower at T_2 followed by T_4 and T_1. Better performance of FCR for fishes fed with 1 day restricted feeding at treatment T_3 might be due to optimum consumption of the diets and efficiency utilization of the nutrients contained in the diets (Aderolu *et al*., 2010). During fasting period, hyperphagia (an increase in appetite) was occurred which caused rapid food consumption and improved growth efficiency (Limbu and Jumanne, 2014; Zhu *et al.*, 2001). Therefore, nutrients contained in the diet at treatment T_2 were efficiently converted by fish into growth, which was responsible for better performance of FCR in this treatment. However, continuous feeding at T_1 significantly reduced the performance of FCR.

Table 63. Growth monitoring of fish at different feeding regime

Parameters	**T_1**	**T_2**	**T_3**	**T_4**
Initial weight (g)	7.90±0.43^a	7.98±0.28^a	8.11±0.40^a	8.02±0.30^a
Final weight (g)	38.27±1.07^a	38.20±1.14^a	31.14±2.41^b	25.54±2.35^c
Weight gain (g)	30.37±1.16^a	30.23±1.06^a	23.03±2.46^b	17.53±2.28^c
% weight gain	385.89±31.00^a	379.35±16.79^a	284.71±36.19^b	218.72±27.64^c
ADG (G)	1.32±0.05^a	1.30±0.03^a	1.12±0.08^b	0.96±0.08^c
SGR (%/day)	0.25±0.01^a	0.24±0.01^a	0.19±0.02^b	0.15±0.02^c
Survival rate (%)	94.17±1.44^a	94.39±1.29^a	89.33±2.83^b	83.06±5.87^c
FCR	1.69±0.14^{ab}	1.45±0.07^b	1.78±0.24^a	1.64±0.38a^b
Total production (kg)	126.14±4.48^a	126.23±4.52^a	97.36±8.18^b	74.19±7.82^c
Net production (kg)	98.50±4.76^a	98.32±4.24^a	68.97±8.46^b	46.13±7.82^c

Values in each same row having different superscripts are significantly different (P<0.05)
T_1: Regular feeding; T_2: 1 day restriction and 6 day feeding; T_3: 2 day restriction and 5 day feeding; and T_4: 3 day restriction and 4 day feeding in a week.

Economic performance of cultured fish : At the end of the study period, significantly higher total and net production were obtained from T_2. At the end of the culture period an economic analysis was conducted to evaluate the best treatment for cage culture system in Chalan beel area (Table 64). Result demonstrated the best performance of total income, net income and BCR from treatment T_2, where the restriction of feeding was 1 day per week.

Table 64. Economic performance of cage culture at different feeding regime

Parameters	T_1	T_2	T_3	T_4
Feed cost	10613.12±572.35^a	9111.27±314.27^b	7723.89±381.04^c	4668.91±176.02^d
Fry cost	7000.00	7000.00	7000.00	7000.00
Cage cost	2000.00	2000.00	2000.00	2000.00
Labour cost	1600.00	1600.00	1600.00	1600.00
Total cost	21213.12±572.35^a	19711.27±314.27^b	18323.89±381.04^c	15268.91±176.02^d
Total income	56763.30±2015.04^a	56803.45±2032.23^a	38946.40±3274.14^b	25967.37±2738.44^c
Net income	35550.18±2108.90^a	37092.18±1934.56^a	20622.50±3339.70^b	10698.47±2732.25^c
BCR	1.68±0.12^b	1.88±0.10^a	1.13±0.19^c	0.70±0.18^d

Values in each same row having different superscripts are significantly different ($P<0.05$)
T_1: Regular feeding; T_2: 1 day restriction and 6 days feeding; T_3: 2-day restriction and 5 day feeding; and T_4: 3 day restriction and 4 day feeding in a week.

Treatment T_1 (Regular feeding of 7 days in a week

Treatment T_2 (1 day restriction and 6 day feeding in a week)

Treatment T_3 (2 days restriction and 5 days feeding in a week)

Treatment T_4 (3 days restriction and 4 days feeding in a week)

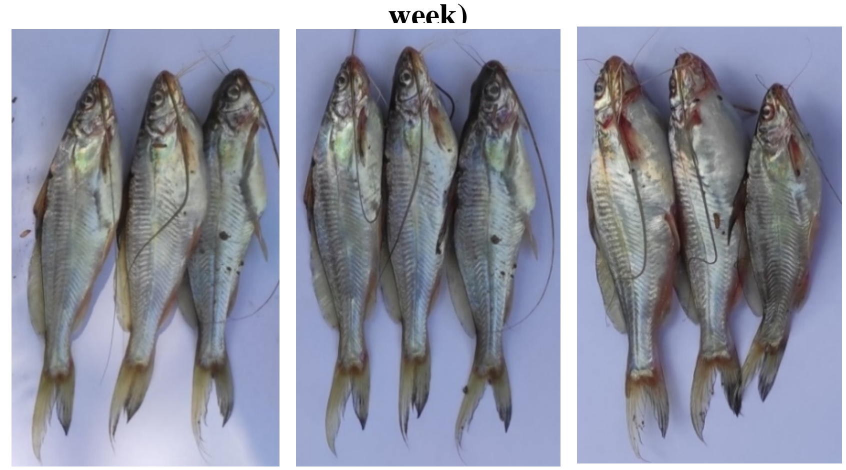


Plate 38. Fish at final harvest at different treatments of Experiment 3.

11.15. Determination of species-specific differences in sensitivity due to coal-mining effect

During catch assessment in 2018-19 fiscal year, maximum number of fish species in the Shari-Goyain River was found during the month of October (48) followed by November (45), April (38), December (37), January (34), June (33), February (30), March (27) and May (26) (Fig 43 & 44). Normally, it is a familiar concept that fish diversity increases with increasing water volume. Hence, the lowest number of fish species was found in May 2019, it was due to acute exposure of chemicals and fish kill incidences in mid-April and early-May 2019 in the river. In April-May 2019, coal mine drainage made the water and sediment toxic that made fishes easy to harvest by the fishers. A total of 3 fish mass mortality incidences (Low: 24-26 December 2018, High: 8-11 April 2019 and Medium: 1-4 May 2019) were recorded in different sites of the Shari-Goyain River with estimated fish damage of 1,845, 12,474 and 3,248 kg, respectively where 14% was dead, 56% injured/moribund and rest 30% was less affected. This study revealed that Sal baim is to be the most sensitive species, exhibiting significant mortality after coal mine drainage exposure. Due to COVID-19 lockdown, direct fish catch assessment was discontinued from 25 March to 15 May 2020. We collected catch data via cell phone discussion with the fishers. Fishers confirmed that fish mass mortality incidences were occurred during mid-April to early May 2020 in different locations of the Shari-Goyain River. No direct catch assessment of the fish mortality incidences was possible due to Covid-19 situation. However, few catch data and some pictures of fishes from different sites were collected via cell phone of the fishers. All of the respondents affirmed that coal mining drainage came and damage fisheries resources like previous year. Fishers explained that weak and dead fishes were rapidly moved downward by high water flow from the upstream of the river. All the respondents claimed coal mining effluents as the main reason for fish mortality and damage of fisheries resources in the river. During study, it was found that combined effects of some chemicals come from coal mining areas were responsible for loss of fish biodiversity in the study area.

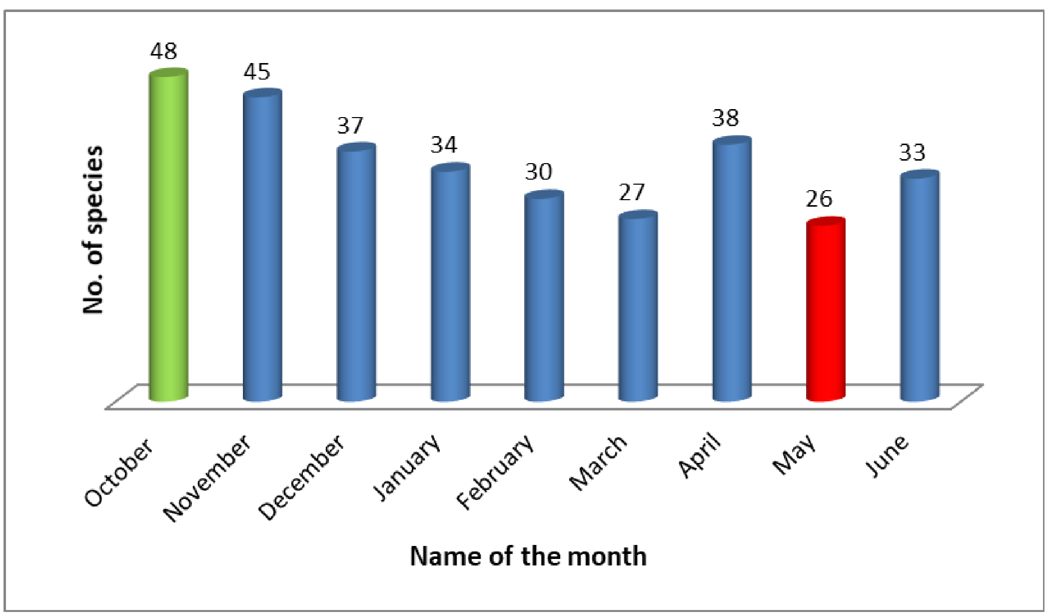


Fig. 43. Number of fish species recorded from catch monitoring data in 2018-19

Fish species diversity of the Shari-Goyain River was found in decreasing trend in all sites except Jalurmukh site which is an adjacent site of sanctuary (Fig 44). Possible reasons are the discharges of polluted water from mining activities mix with both surface and ground water and thus deteriorate their quality (Khan *et al.,* 2005; Singh *et al.,* 2010; Zakir *et al.,* 2013). The primary cause of water quality degradation and biodiversity depletion in the waters of the coal mining areas are mainly imposed to the Acid Mine Drainage (AMD) which makes water extremely acidic and loaded with harmful heavy metals (Pentreath, 1994). The obnoxious coal mine effluents damage the flora and fauna of the ecosystem thus have a significant negative impact on the primary productivity (Ghosh, 1993), water quality and fish diversity of river (Talukdar *et al.* 2016).

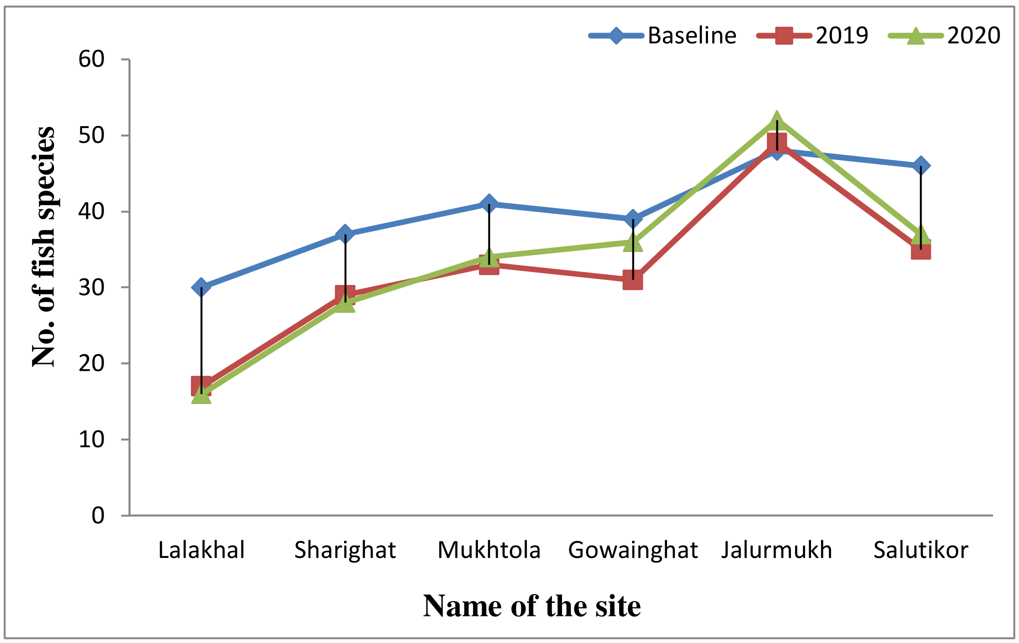


Fig. 44. Spatial and temporal variation of fish species diversity in the Shari-Goyain River.

Average fish catch (mean±SD) was in decreasing from 1.39±0.41 to 1.34±0.61 kg/fisher/day comparing baseline and final year in the Shari-Goyain River. This is a clear picture that fish production is gradually decreasing in the wetland. In a recent study, Shumi *et al.* (2019) mentioned that water pollution is one of the major problems for decreasing fish catch and income from fishing in the river. On the other hand, average catch in three sites of the river downstream showed increasing production in 2020 comparing 2019 (Table 65). This might be the positive impact of sanctuaries.

Table 65. Changes in harvesting of fish in the Shari-Goyain River

Name of the site	Average catch (kg/fisher/day)		
	Baseline	2019	2020
Lalakhal	0.78±83	0.63±0.96	0.61±0.97
Sharighat	0.97±78	0.94±0.9	0.89±0.79
Mukhtola	1.58±97	1.45±0.8	1.43±0.9
Gowainghat	1.60±1.15	1.41±0.73	1.42±1.25
Jalurmukh	1.76±2.98	1.97±3.11	2.18±3.26
Salutikor	1.64±1.78	1.49±1.14	1.52±1.29
Average	**1.39±0.41**	**1.32±0.47**	**1.34±0.61**

11.16. Determination of bioaccumulation of heavy metals due to coal-mining effect

All the respondents claimed coal mining as the only one reason for those fish mortality incidences and damage of fisheries resources. It was supposed that combined effects of some chemicals come from coal mining areas were responsible for loss of fish biodiversity in the study areas. In Boal, liver contains highest concentration of Cu (13.77±6.11mg/kg) which crossed the acceptable limit for human consumption followed by kidney, muscle, and gill. Short term exposure to copper may lead to gastrointestinal distress, impaired immune systems and even impotence (sexual dysfunction). High dose of copper may be potentially deadly.

Cadmium is toxic at extremely low levels. Kidney of Boal accumulated highest amount of Cd (1.12±0.30mg/kg) followed by liver and gill where all of the values are above the food safety guidelines by the WHO and FAO. However, the concentration of Cd in muscle was found below the detection limit. Cadmium can cause mutations and kidney damage.

In Boal, gill contains highest concentration of Fe (130.15±85.06mg/kg) followed by liver, kidney and muscle where all of the values are above the food safety guidelines by the WHO and FAO. Gill contains highest concentration of Mn (40.21±28.25mg/kg), followed by muscle (1.16±1.17mg/kg), liver (0.97±0.67mg/kg) and kidney (0.95±0.17mg/kg). Fish gill contains high amount of Pb (7.04±2.12) in Boal which is above the food safety guidelines by the WHO and FAO. No Pb was detected in the other organs of the body (Table 66). Nickel may cause some morphological transformations in numerous cellular systems and chromosomal aberrations. Ni was only found in the gill of Boal which is within acceptable limit. Zinc is an essential element for metabolic activities in humans as well as animals. However, concentrations above the threshold in fish may cause damage of gill epithelium, which could result in hypoxia, growth retardation, and mortality.

In Boal, gill contains highest concentration of Zn (53.50±21.40mg/kg) which crossed the acceptable limit for human consumption followed by kidney (16.47±11.66mg/kg), muscle (19.64±5.74mg/kg), and liver (11.02±3.04mg/kg). Highest concentration of selenium was found in liver (18.31±7.48mg/kg), followed by muscle (2.80±1.17mg/kg), kidney (0.94±0.55mg/kg) and gill (0.75±0.66mg/kg). Effects of selenium poisoning are growth inhibition, skin discoloration, and gastrointestinal problems.

Table 66. Concentration of heavy metals in different organs of *Wallago attu* in the Shari-Goyain River

Name of the organ	Average concentration of heavy metals (mg/kg)								
	Cu	**Cr**	**Cd**	**Fe**	**Mn**	**Pb**	**Ni**	**Zn**	**Se**
Gill	1.10± 0.82	BDL	0.18± 0.09	130.15 ±85.06	40.21±2 8.25	7.04± 2.12	0.51± 0.06	53.50 ±21.4	0.75± 0.66
Muscle	1.31± 0.57	BDL	BDL	17.43±1 2.56	1.16± 1.17	BDL	BDL	16.47 ±11.6	2.80± 1.17
Liver	13.77±6 .11	BDL	0.48± 0.08	50.69±2 2.28	0.97± 0.67	BDL	BDL	11.02 ±3.04	18.31 ±7.48
Kidney	2.09± 0.34	BDL	1.12± 0.30	30.98±1 3.51	0.95± 0.17	BDL	BDL	19.64 ±5.74	0.94± 0.55
MAC (WHO/ FAO)	4.50	1.00	0.10	5.60	1.00	0.50	0.80	30.00	1.00

*BDL= Below Detection Limit **MAC = Maximum Allowable Concentration

In Gulsha, liver contains highest concentration of Cu (61.84±31.90mg/kg) which crossed the acceptable limit for human consumption followed by kidney, muscle, gonad and gill. Short term exposure to copper may lead to gastrointestinal distress, impaired immune systems and even impotence (sexual dysfunction). High dose of copper may be potentially deadly. Cadmium is toxic at extremely low levels. Kidney of Gulsha accumulated highest amount of Cd (4.84±1.90mg/kg) followed by liver, gill, muscle, and gonad where all of the values (except gonad) are above the food safety guidelines by the WHO and FAO. Cadmium can cause mutations and kidney damage. Liver contains highest concentration of Fe (400.44±153.45 mg/kg), followed by kidney, gill, gonad and muscle where all of the values are above the food safety guidelines by the WHO and FAO. In Gulsha, gill contains highest concentration of Mn (16.04±5.40mg/kg), followed by liver, kidney, gonad and muscle (Table 67). Fish gill contains high amount of Pb (8.79±1.83 mg/kg) in Gulsha followed by gonad, kidney, liver, and muscle which all are above the food safety guidelines by the WHO and FAO. Nickel may cause some morphological transformations in numerous cellular systems and chromosomal aberrations. Highest concentration of Ni was found in kidney (6.10±3.36 mg/kg) followed by gill, muscle, and liver where all of the values are above the food safety guidelines by the WHO and FAO but gonad contains lower amount of Ni than MAC. Zinc is an essential element for metabolic activities in humans as well as animals. However, concentrations above the threshold in fish may cause damage of gill epithelium, which could result in hypoxia, growth retardation, and mortality. In Gulsha, liver contains highest concentration of Zn (73.88±27.40mg/kg) which crossed the acceptable limit for human consumption followed by gonad, kidney, gill and muscle. Highest concentration of selenium was found in kidney (2.74±0.55mg/kg) which is above the acceptable limit. Effects of selenium poisoning are growth inhibition, skin discoloration, and gastrointestinal problems.

Table 67. Concentration of heavy metals in organes of *Mystus cavasius* in the Shari-Goyain River

Name of the organ	Average concentration of heavy metals (mg/kg)								
	Cu	**Cr**	**Cd**	**Fe**	**Mn**	**Pb**	**Ni**	**Zn**	**Se**
Gill	4.44±1.55	BDL	0.21±0.08	348.59±129.2	16.04±5.40	8.79±1.83	1.98±0.53	50.29±13.01	0.71±0.19
Muscle	5.31±2.80	BDL	0.14±0.02	19.06±7.64	1.02±0.25	2.34±1.05	1.64±0.85	27.31±13.38	0.20±0.16
Liver	61.84±31.90	BDL	1.45±1.14	400.44±153.5	7.72±2.27	4.51±1.40	1.20±0.54	73.88±27.40	0.83±0.41
Kidney	7.08±0.06	BDL	4.84±1.90	360.74±200.9	5.45±1.47	4.95±2.45	6.10±3.36	67.20±32.17	2.74±0.55
Gonad	4.94±1.44	BDL	0.06±0.05	95.08±73.04	1.42±0.18	5.68±2.77	0.68±0.61	71.65±51.99	0.52±0.18
Whole body	2.34±1.31	BDL	0.13±0.02	151.48±146.4	10.40±12.77	1.33±0.69	0.43±0.07	60.57±40.36	2.46±1.03
MAC (WHO/FAO)	4.50	1.00	0.10	5.60	1.00	0.50	0.80	30.00	1.00

*BDL= Below Detection Limit **MAC = Maximum Allowable Concentration

Heavy metals contamination is a serious threat for the toxicity and bioaccumulation in food chain. Aquatic environment contamination has become a global concern because of the toxic effects on fishes. These heavy metals are toxic in nature and can come to human food chain through fish consumption. It was an alarming news that the mean concentration of Cu, Cd, Fe, Pb, and Zn of fish species were found to be higher than Food and Agriculture Organization (FAO)/(WHO) tolerable concentration assuming these metal pose risk to human. It could be because of mine drainage coming from coal mining areas from the upstream.

11.17. Physiological stress response

In both boal and ghagla, the mean serum cortisol and glucose levels in the Shari-Goyain River are significantly higher than the Kura River (Table 68). The results indicated that the cortisol and glucose levels were at higher level indicating that fishes are under stressful conditions and this could be because of coal mine drainage. The mean T_3 and T_4 levels were not significantly changed. The results also indicated that the cortisol and glucose levels were at higher level in Boal then Ghagla indicating that fishes are two different species so secretion capacity is different. The mean T_3 and T_4 levels were not significantly changed. Plasma glucose level is typically elevated with increased cortisol secretion (Shrimpton and McCormick, 1999; Carr and Norris, 2006). Plasma thyroid hormones (T_3 and T_4) levels are also influenced by cortisol (Brown *et al.* 1991). Cortisol can increase the conversion of T_4 to T_3 and increase the clearance of T_3 from the plasma (Brown *et al.* 1991). Exposure to chemical stressors may increase plasma T_3 and T_4 levels (Miller *et al.* 2007). Present study suggests that serum cortisol, glucose, T_3 and T_4 were influenced by fish species and coal mine drainage stress.

Table 68. Physiological stress responses (Cortisol, glucose, T_3 and T_4)

River name	Species name	Cortisol (µg/dl)	Glucose (mmol/l)	Triiodothyronine (T_3) (nmol/l)	Thyroxine (T_4) (µg/dl)
Shari-Goyain	Ghagla	22.15±3.04	5.02±0.68	1.32±0.38	1.49±0.20
Kura (Control)		19.20±2.13	3.5±0.87	1.49±0.26	1.53±0.22
Shari-Goyain	Boal	25.65±3.75	7.47±0.47	1.52±0.08	1.61±0.21
Kura (Control)		21.30±2.78	4.64±0.45	1.15±0.12	1.39±0.20

11.18. End line survey by SUST copmponent on the impact of the sub-project

End line survey followed the same methodology applied in base line survey. The data collection of end line survey is completed, quantitative data is organized, and transcription process of qualitative data is completed, objective based findings are prepared. The data shows that the sub-project has a very positive impact on the fish production and the increase of disappeared local indigenous fish varieties. The socio-economic condition of fishers is also increased, they have learned about some alternative livelihood skills including cultivation of cage fishing. From the income of cage fishing goats and lams were distributed among the members. They showed their deep satisfaction on this initiative and requested to continue same initiatives. Before distribution of goats and lams, the members were motivated for alternative livelihood. Some members are found to involve in rearing ducks and that was also profitable, and they could earn some additional income from that alternative sources. Due to the supply of IEC materials including leaflets, printed documents on legal issues on fishing and leasing practices, awareness on their rights are increased. Due continuous awareness programs including group discussions, rally and community meetings, the fishermen in the study areas were conscious about the leasing process, their responsibilities in the preservation and protection of fish varieties in their locality. According to the fishers, local fish varieties are also found to be increased. Local community people observed that some of the locally extinct fish varieties are increased due to project intervention. The idea of cage fishing has become attractive among the participants. The cage cultivators showed their deep satisfaction as the intervention benefited them. They want to continue cage fishing even after the project is phased out. Desire on alternative livelihood is also increased. They are found to be motivated in protecting sanctuary and could understand the importance of protect and preserve sanctuary made by the project. According to villagers, tendency of overfishing is decreased due to regular motivational and awareness camping. Local varieties of fishes are increased, and some lost varieties are regained. They are motivated to form fishermen association and one new fisherman association is already got registration with the support of research team. This has created confidence and trust among themselves as this might be the only association formed by the real fishers with their own initiatives.

A comparison between baseline and end line survey can be seen to observe the changes due to project intervention (Table 69).

Table 69. Comparison between Endline and Baseline data

Baseline survey	Endline survey
Literacy rate 44%	Literacy rate 51%
Number of single bread earner 98%	Number of Single Bread Earner 73%
66% had less than 10 thousand take income per month	51% had less than 10 thousand take income per month
96% had insufficient income to run family expenditure	78% had insufficient income to run family expenditure
28% of the villagers were the members of fisherman association	41% of the villagers were the members of fisherman association
There was no skill on earning other thank fishing	Around 51% of the respondents gained knowledge on cage fishing, cattle rearing and sewing.
Around 21% had some idea about the government policies on open water bodies	62% knew government policies on water bodies
None of the respondents was conscious about the negative impact of upstream coal mining	74% of the respondents have known about the upstream coal mining impacts on fish by the project intervention
Around 70% of fishers worked as fish laborers.	Around 59% of fishers work as fish laborers and the increased 11% have involved in cage fishing.
All of the respondents told that they were suffering from decreased income from fishing for the last couple of years	58% of the respondents mentioned that their income form fishing is increased in last two year
All of the respondents noticed that the local and indigenous fish varieties were decreasing continuously and many of indigenous fishes are already extinct.	74% of the respondents mentioned that the local and indigenous fish production including *Dhela* and *Mola* fishes are increased and at least 6 extinct fish varieties (Chitol, Bailla, White Chanda, Chapila, Shorputi, Rita) are regained in the open water bodies surrounded by them.

11.19. Assessing the nature of access to market system of fishers

FGDs were conducted with fishers staying at marketplaces and almost all of them explained how they are helpless in getting actual price of their fishes. According to them, lease owners of the marketplace give sublease the marketplace to non-fishers where fishes are sold. These non-fisher fish traders create hostile environment for original fishers to sale their fish directly; fishers are usually forced to sale their fishes to traders and the price is syndicated by them. If someone is interested to sale fish directly, high rate of tool is imposed so that he is discouraged. Everything relating to marketing and pricing of fishes are mostly controlled by those traders. Same results came out from the surveyed fishers, and they preferred to sale their fish on the fishing spots. The brokers and small fish traders who have contact with market system collect fishes from spots and sale it to the large traders in the market directly. The research team visited fishing spots as buyers but failed to purchase fish and found both brokers and small fish traders who became the sellers of caught fishes by fishers.

11.20. Development and distribution of IEC materials, media coverage

IEC materials were developed, printed, and distributed among the people living in the study areas. A large number of posters and leaflets were hanged and circulated in all research sites and their adjacent areas. Printed posters were also hanged on the walls of home in the research sites. The data enumerator circulated good number of handouts to villagers adjacent to sub-project areas relating to the objectives and interventions of our project interventions. Some posters were also collected form NGOs working for protecting fish varieties in Sunamganj areas and was hanged on the walls of sub-project areas. Contents of posters and leaflets included the importance of protecting sanctuary, fishers' rights, leasing system, key points of 'Jalmahal' policy, cage fishing process, alternative livelihood prospects, water-sanitation, and hygiene etc. Compiled brochures were prepared with all legal documents and is circulated among the fishermen associations and the community leaders. TV and newspaper coverage was also made and published on the overall progress of the project. The journalists of various national and local newspapers and TV journalists visited research sites, interacted with target population, and directly observed the interventions of the project especially cage fishing and income generating activities through alternative livelihood.

11.21. Awareness raising and motivational campaign

Research team conducted several awareness raising campaign, rallies and motivational meetings in both research sites at regular basis.

Awareness rising camping covered

- Importance of sub-project in fish conservation, regeneration of fish varieties and resources in the locality.
- Importance of fish conservation and regeneration of fish varieties and resources for the well being of fishers and villagers (food, nutrition, shelter, health, hygiene, education etc.).
- Discuss the role of local community in protecting fish and water bodies adjacent to their locality.
- The role of sanctuary in fish conservation and regeneration of fish varieties and resources in the locality.
- Information about the causes of disappearance of fish varieties in the locality.
- Discussion on the impact of overfishing and unskilled fishing.
- Make people aware of fish marketing and process of getting access to them.
- Make fishers aware of the existing 'Jalmahal' policy.

Motivational campaign covered

- Motivate and sensitize people in favour of sub-project intervention.
- Motivate people to become part of sub-project both physically and psychologically.
- Motivate people to protect sanctuary and fish resources focusing their own interest.
- Motivate fishers to work for a better life.
- Motivate fishers to get access to open market system for getting proper price of fish.

- Motivate fishers to get involved in income generating activities other than fishing during banning period of fishing
- Motivate fishers to know about their rights and responsibilities as per 'Jalmahal' Policy.

11.22. Socio-economic impact of sanctuary on Chalan beel and adjacent fishers

Before-after comparison of housing condition at Site-1(Singra, Natore) showed a little difference, whereas number of Paka house was increased about 10% and number of Kacha house decreased about 10%. However, number of Semi-paka house remained unchanged. After the successful operation of sanctuary, economic condition of the selected committee members (fishers) were improved, as there was no committee members within the income category of >3000 BDT. Morover, number of beneficiaries within the income category of 3001-500 BDT was increased 20% and within the income category of <5000 BDT was increased 10% at the end of the study period (Table 70).

At Site-2(Chatmohor, Pabna), number of Paka house was increased about 10% and number of semi-paka house decreased 10%, while number of Kacha house remained unchanged. Beneficiary with the income category >3000 BDT was decreased to 0% at the end of the study period compared to the 40% at the beginning of the study. Again, the number of beneficiaries with the income category of 3001-5000 BDT and <5000 BDT were increased 15% and 25% compared to the intial income before the establishment of the sanctuary (Table 71).

Table 70. Socio-economic conditions of the committee members after the successful management of established sanctuary at Site-1 (Singra, Natore)

Sl. No.	Name	Before		After	
		Housing condition	Financial condition (Monthly income-BDT)	Housing condition	Financial condition (Monthly income-BDT)
1	Md. Merazul Islam	Paka	5000	Paka	6420
2	Md. Abdul Kader	Kacha	3000	Semi-paka	5250
3	Md. Abdus Salam	Paka	6000	Paka	6500
4	Md. Aiyub Ali	Kacha	3000	Kacha	4500
5	Md. Yeakub Ali	Semi-paka	5000	Semi-paka	6500
6	Md. Emran Ahmed	Semi-paka	6000	Semi-paka	6500
7	Md. Rajibul Islam	Kacha	2000	Semi-paka	4500
8	Md. Joynal Abedin	Kacha	3000	Kacha	4000
9	Md. Nayem Shek	Semi-paka	4000	Semi-paka	5500
10	Md. Nurul Islam	Kacha	2000	Kacha	3600
11	Md. Rasedul Islam	Semi-paka	3000	Semi-paka	4500
12	Md. Rifatuzaman	Semi-paka	5000	Semi-paka	6500
13	Mst. Chaina Begum	Semi-paka	4000	Semi-paka	5000
14	Md. Ariful Islam	Semi-paka	4000	Semi-paka	5400
15	Md. Soukin Aziz	Semi-paka	5500	Paka	6000
16	Md. Mozibor	Semi-paka	3600	Semi-paka	4500
17	Md. Borkot Ali	Semi-paka	5000	Semi-paka	5700

Sl. No.	Name	Before		After	
		Housing condition	Financial condition (Monthly income-BDT)	Housing condition	Financial condition (Monthly income-BDT)
18	Md. Mukul Alam	Semi-paka	4500	Semi-paka	5000
19	Md. Salim Mia	Semi-paka	6000	Paka	6300
20	Md. Zakir Hossain	Paka	7500	Paka	8000

Table 71. Socio-economic conditions of the committee members after the successful management of established sanctuary at Site-2 (Chatmohor, Pabna)

Sl. No.	Name	Before		After	
		Housing condition	Financial condition (Monthly income-BDT)	Housing condition	Financial condition (Monthly income-BDT)
1	Sri Sukumar Haldar	Paka	6000	Paka	6500
2	Amolesh Haldar	Semi-paka	4800	Semi-paka	5400
3	Md. Khairul Hasan	Paka	4400	Paka	5000
4	Khokon Haldar	Semi-paka	3000	Semi-paka	4500
5	Somor Halder	Kacha	3000	Kacha	4000
6	Suresh Chandro Haldar	Semi-paka	3000	Semi-paka	5500
7	Doial Chandro Haldar	Semi-paka	4200	Semi-paka	4500
8	Suzon Haldar	Semi-paka	3650	Semi-paka	4500
9	Sunil Chandro Haldar	Semi-paka	4000	Paka	5000
10	Nitai Haldar	Semi-paka	3500	Semi-paka	5500
11	Choton pramanik	Semi-paka	6000	Semi-paka	6500
12	Md. Rofiqul Islam	Paka	7250	Paka	7500
13	Md. Sobuz	Semi-paka	2000	Semi-paka	3500
14	Md. Saiful Islam	Semi-paka	6000	Paka	6200
15	Md. Mamun Ali	Kacha	3000	Kacha	4500
16	Md. Sona Mia	Semi-paka	4000	Semi-paka	4000
17	Md. Shaheb Ali	Semi-paka	3000	Semi-paka	4500
18	Md. Korban Mia	Semi-paka	4600	Paka	6000
19	Al-amin Sarkar	Kacha	3000	Semi-paka	5400
20	Md. Sukkur Ali	Kacha	2000	Kacha	3500

11.23. Causes of fish biodiversity reduction in the Shari-Goyain River

It was reported by the respondent fishers that the availability of fish in the Shari-Goyain River has been declining day by day due to various man made and natural causes. Main reasons for declining fish diversity were as follows:

- Coal mine drainage from the upstream of the Shari-Goyain River is the main cause for reduction of biodiversity and fish production in the study area due to mass mortality.

- Over and indiscriminate harvesting of fishes for meeting the demand of increased population. In pre-monsoon season, brood fish and fish fry are indiscriminately caught by using different nets and gears that are declining biodiversity.
- Fishing by creating bush piles or *katha* fishing in the rivers is dangerous for fishes. Fishes accumulated in the *katha* are caught by fencing and seining with fine meshed net. During katha fishing fishers also use poison to easily catch the fish.
- Fishing by dewatering of a small portion of rivers is dangerous for fishes.
- Catching of fishes by using fine meshed seine net (*ber jal*) and *current jal* (monofilament gill nets) is responsible for destroying all fishes including eggs.
- Use of pesticides in the paddy field is so harmful for fishes and other aquatic organisms living there. This causes death to fishes including fry and eggs in the river when comes to river through canals.
- Poisoning fishing is done in winter and early monsoon season that destroys all organisms in the waters.
- Navigation and tourism have also some bad impacts on fish biodiversity.
- Due to sand/coal mining and flash floods, the river remains turbid almost round the year which is also responsible for biodiversity loss.
- Use of irrigation water from river and haor badly impacted on fish biodiversity.
- Construction of road, dam, enclosure also responsibe for decreasing of aquatic diversity.

Plate 39. *Katha* fishing in the Shari-Goyain River.

Plate 40. Fishing by dewatering in the upstream of the Gurukchi River.

11.24. Recommendations for effective management of haor and beel fisheries

The suggestions given by the fishermen for conserving biodiversity are as follows:

- Coal mine drainage should be reduced or stopped. As it is a trasnboundary problem and policy level issue, government should be taken into account to solve the issue.
- Establishment of more fish sanctuaries and must be linked with respective community.
- Illegal fishing gears should be stopped.
- Stocking of fish fry of different species must be done in every year.
- Fishing rules and regulation must be implemented.
- Alternate livelihood options (such as pond fish farming, cage culture, pen culture etc.) should be introduced and implemented.
- Fishing by dewatering should be stopped.
- Katha fishing should be stopped or regulated.
- Stocking of endangered/less available fish species.

12. Research highlight

12.1. Component-1 (SAU)

Title of the sub-project : ***Techniques Adoption and Formulation of Guidelines for Sustainable Management of Haor and Beel Fisheries***

12.1.1. Research highlight: 1

Background : The north-east region of Bangladesh possesses a special type of inland water ecosystem called '*haor*' and rich with plenty of fishery's resources. Many fishers' households depend on the Shari-Goyain River for their livelihood (Shumi *et al.* 2019). However, due to various man-made and natural causes fish production in this river and adjacent *haors* are decreasing day by day. Therefore, it is essential to assess the present status of the resources for further research and development planning (Huda *et al*., 2009; Pandit *et al.*, 2015a). After intervention survey carried out until the end of the sub-project.

Objective : To evaluate the status of fisheries resources in the study areas before and after intervention of the project.

Methodology : The baseline survey of the fish biodiversity has been conducted through Personal Interview (PI), Focus Group Discussion (FGD), and Key Informant Interview (KII) using well-structured questionnaire and checklist. **A** total of 150 PIs, 50 FGDs, and 20 KIIs were performed in the studied sites. After intervention survey also continued in the same procedure along with catch assessment. Secondary information was collected by direct visits to UFO of Jaintiapur, Gowainghat and Golapganj, reports from different NGOs, national and international journals, newspapers, websites, etc. To authenticate and cross check the primary and secondary data, KIIs were performed with resource persons.

Key findings : According to the perception of all respondents, total 93 species of fishes were enlisted in the Shari-Goyain River where 8% species are Abundantly Available (AA), 15% Commonly Available (CA), 23% Moderately Available (MA), 39% Rarely Available (RA) and 15% Not Available (NA) species or disappeared species. During the baseline study, most of the fish species were rarely available that fishes were found only one or two times in the study areas. During baseline survey, highest number of indigenous fish species was documented in the Kura River (71) followed by the Shari-Goyain River (67), Ratargul Swamp Forest (65), and the Gurukchi River (57). During catch assessment in final year, total 69 and 71 species of native fishes were observed in the Shari-Goyain and the Kura Rivers, respectively which were 67 and 71, respectively during baseline study.

Key words : Baseline survey, Catch assessment, Focus Group Discussion, Personal Interview, Key Informant.

12.1.2. Research highlight: 2

Background : The *haor* and *beel* fisheries of Bangladesh as an important source of income and employment for the rural people can hardly be highlighted before. Fishing is the main livelihood option for thousands of people in the *haor* region and plays a significant role in food security as well as poverty alleviation. The management of *haor* fishery has often excluded poor fishers and encouraged leaseholders who are responsible for non-sustainable levels of exploitation. Due to over exploitation, biodiversity of the haor region is decreasing day by day. By addressing these concerns, the present sub-project is implementing its activities in Sylhet district to evaluate the effects of management on aquatic ecosystem through community participation.

Objective : To evaluate the effects of management on aquatic ecosystem through community participation

Methodology : Two sanctuaries were establidhed in Ratargul Swamp Forest and Gurukchi River covering an area of 0.5 ha each. For community-based conservation of those sanctuaries, two sanctuary management committees were formed consisting of 50 fishers in Gurukchi and 30 fishers in the Ratargul Swamp Forest. Awareness meeting, banning on fishing and hands on training, etc. were also performed for better management.

Key findings : Target group fishers directly involved in the sub-project activities-such as taking care of sanctuaries and pens so that nobody can destroy. During the final period, perceptions of fishers towards the effectiveness of the overall management activities were evaluated where 170 fishers were responded. Out of the respondents, more than 90% respondents indicated that sanctuaries are helpful for protecting indigenous and threatened fish species as well as increased biodiversity and availability of fishes. Catch data showed that average fish catch (mean ± SD) per fisher was increased in the Ratargul Swamp Forest (2.46 ± 2.23 to 3.68±2.97 kg/day) and in the Gurukchi River (1.78±2.11 to 2.98±2.61 kg/day).

Key words : Sanctuary, Fish catch, Target group, Ratargul Swamp Forest, Gurukchi Rive.

12.1.3. Research highlight: 3

Background : Due to man-made and natural cause’s biodiversity of indigenous fish species, especially small indigenous species (SIS) are decreasing day by day in the winter season, the water of the wetlands dries up and very little or almost no water remained to survive the fishes. Two important nutrient rich endangered SIS mola and dhela were selected to boost up in the wetlands

Objective : To enhance availability of nutrient rich small indigenous species (SIS) of fish in the *haor* region

Methodology : Established 2 pens (each o.1 ha) in Ratargul Swamp Forest and Guruchi River adjacent to the sanctuaries. In each pen previously collected 60 kg mola and 10 kg dhela were stocked during mid April 2019. After few days of breeding, mola and dhela were allowed to go in the open water by removing the net of the pens.

Key findings : According to fishers' statement and result of the catch monitoring data it is evident that mola and dhela has been increased along with other indigenous fishes. According to the catch monitoring data, nine native species (*Labeo nandina, Ompok pabo, Bagarius bagarius, Labeo pangusia, Megarasbora elanga, Chitala chitala, Channa marulius, Clupisoma garua,* and *Labeo angra*) which were unavailable in the respective sites were found during the final year.

Key words : Mola, Dhela, SIS, Pen, Wetland

12.1.4. Research highlight: 4

Background : North-eastern region of Bangladesh, Sylhet has vast seasonal and perennial water bodies which can be used for cage culture activities, but annual production from cage culture of this division is very poor (112 MT). However, it is a good sign that commercial cage culture of tilapia has recently been started in three districts (Habiganj, Moulvibazar and Sunamganj) of this division, but no commercial cage culture activities was found in the Sylhet district (DoF, 2018). Not only that this technology can be adopted by the fshers as an alternate livelihood options and it is essential to disseminate the technology among the fishers as well as fish farmers.

Objective : To develop appropriate cage fish farming technology as alternate livelihood options of fishers.

Methodology : Establishment of cages, stocking of different fish species in the cages and regular feeding of fishes, formation of cage management committee were the main key's of the methodology. As an alternate livelihood option of the fishers a total of 9 cages were set up inside the Ratargul Swamp Forest and 9 cages in the Gurukchi River of Gowaingaht upazila, Sylhet. The size of each cages were 6mX3mX2m. Three trials were made to find out the suitable species and suitable technique of cage aquaculture.

Key findings : According to the findings tilapia and pangas are the most suitable candidate for cage culture in sylhet region. The result of the present study showed that pangas with 30 fish/m^3 and tilapia with 60 fish/m^3 stocking density were performed well as considered to investment, production and economic return in a short period of time. Another important finding is that in case of tilapia weekly one day gap in supplementary feed supplies similar production performance as regular, but better performance in respect to economic return.

Key words : Tilapia, Pangus, Cage culture, Stocking density, Supplementary feeding

12.1.5. Research highlight: 5

Background : Once upon a time, there was copious aquatic biodiversity in the haor region. However, over time, the fish species diversity and production have significantly decreased due to various natural and anthropogenic causes. Incredibly, one of the major causes of decreasing aquatic biodiversity of Shari-Goyain River is the effluent of coal mining from Meghalaya, India. The Shari-Goyain is an aquatic resources enriched river in this Sylhet district, which is part and parcel of haor. Every year the hilly flash flood from April to Mid-May carries waste water emitted from coal mining activities; thus, the effluents instantly polluted the water, resulted instant mass mortality of fishes and other aquatic organisms. Moreover, a lot of moribund fishes are found to be floating on the water surface and riverside people easily catch these fishes and consume it which is hazardas for human health. So it is important to know the effect of coal-mining on fish, water and sediment of the Shari-Goyain River.

Objective : To determine species-specific differences in sensitivity due to coal-mining effect in the Shari-Goyain River

Methodology : Observation of coal mining effect, determination of heavy metal concentration in different parts of fish body and fish blood samples were collected to test the species specific sensitivity. Fish Samples were tested from the laboratory of SGS Bangladesh Limited, Dhaka; Food safety Institute of Bangladesh Agricultural University, Mymensingh and Bangladesh Council for Scientific and Industrial research (BCSIR), Dhaka.

Key findings : Fish mortality occurs when high amount of effluents flow in pre-monsoon season (April-May). Heavy metals like copper, chromium, cadmium, lead, nickel, etc. were detected in the river water, sediment, and fish bodies more than tolerable limit. Combined effects of some chemicals come from coal mining areas were responsible for loss of fish biodiversity in the study areas.
Key words : Coal mining effluent, Heavy metal, Shari Goyain River, Haor region, Biodiversity

12.2. Component-2 (SUST)

12.2.1 Research highlights: 1-2

Background : Shari-Goyain River is an important water body with rich biodiversity, originated from the hilly areas of the Meghalaya State of India. The River plays an important role as a nursery ground of many small indigenous fish species. There is an adverse impact of coal mining comes through run-off from Meghalaya, India which is one of the main reasons of loss of biodiversity. Considering the importance of this river and adjacent haor areas the study was designed to asses their water quality, identify the causes of water pollution and impact of upstream coal mining on water quality. To compare the water quality another river, Kura, is also considered for assessment.

Objectives

- To assess the water quality of Shari-Goyain and Kura River and their adjacent haor areas;
- To analyze the impact of coal mining on water quality of Shari- Goyain river.

Methodology : Water samples were collected over a stretch of 50 km while selecting four important points to monitor the water quality. Sampling points are Zero-Point (25.120691N, 92.184670E), Sharighat (25.089258N, 92.11830E), Gowainghat (25.088829N, 91.981020E) and Ratargul (25.012269N, 91.915231E). Laboratory experiments were conducted for determining water quality. Total 24 parameters were tested: DO, BOD5, Temperature, Electric Conductivity, pH, Turbidity, Total Dissolved Solids, Total Suspended Solids, Nitrate, Hardness, Total Coliform, Faecal Coliform, Chloride, Arsenic, Iron, Manganese, Aluminium, Sulfate, Potassium, Calcium, Copper, Chromium, Zinc, Nickel. Water Quality Index was determined for every location using the model of CCME WQI (Canadian Council of Ministers of the Environment Water Quality Index). Using the statistical software SPSS (Statistical Package for Social Science, 25.0 version) co- relations among the water quality parameters were identified.

Key findings : It was found that the pH of water is almost always low and some heavy metals like Aluminium, Copper, Chromium and Zinc etc. along with Sulphate are at high rate in the water resulted from upstream coal mining impacts. The study tested the water of Kura River as control site as it was found that water quality is almost normal for aquatic life. According to the CCME-WQI scores, the water quality of this river ranges from poor to marginal throughout the study and does not support the aquatic life. Zero-point (upstream) is ranked as poor throughout the year and this is due to the impact of coal mining and industrial effluent around this river in further upstream.

Key words : Shari-Goyain River, Aquatic Life, Coal mining, Water Quality, Kura River

12.2.2 Research highlight: 3

Background : In addition to upstream coal mining, siltation is also has an adverse effect on the production of fish in the river. Siltation is high in this river due to upstream mining activities, frequent flash flood, river bank erosion, high turbulence in rainy season, extraction of excessive sand and coal from riverbed etc. Siltation rate of this river is also important to know for restoration of fish production.

Objective : To assess the level of siltation of Shari- Goyain river and their adjacent Haor areas.

Methodology : To determine the rate of siltation in River Shari-Goyain well known Hossain's sediment transport equation was used. Water Current Meter (Vertical Axis Cup Type; made by 'Virtual Hydromet', India) and Depth Finder Device (STRIKER 4 – fish finder; made by 'Garmin', USA) were used to measure water velocity and depth of the river respectively at different places and water discharge, average depth of flow were calculated from the obtained data, to be used in that equation. River bed materials were also collected by the sampler to perform grain size analysis for median diameter of bed materials (D50), which is required for the equation. In addition, a device named 'Sediment Trap' was manufactured locally and used to asses the siltation level directly.

Key findings : It is noticeable that the annual sediment load ranges from 2 to 12.82 million tons and 0.98 to 5.10 million tons according to the data of sediment trap and Hossain's equation respectively. The annual sediment load was found substantially high in Shari-Goyain river compare with the river Surma, where, the annual sediment load varies from 1.563 to 3.966 million tons and from 1.67 to 3.924 million tons computed using the data of suspended sediment load and Hossain's equation respectively (Kamrunnessa, 1994).

Key words : Siltation, Sedimentation, Sediment trap, Hossain's equation

12.2.3 Research highlight: 4

Background : Socio- economic condition of fishers living near the Rive is also responsible for depletion of fishes in the river and adjacent haor areas. So, baseline and end-line surveys are needed to be done to asses the socio- economic condition of fishers and their occupational behavior.

Objective : To assess the socio-economic conditions and to identify the nature of access to market system of fishers living in the study areas.

Methodology : Baseline survey has been conducted to know the socio-economic condition of fishers, market access, their understanding about the conservation of biodiversity and fish production in the study area. Development of Information, Education and Communication (IEC) materials was made, printed and circulated among the fishers and local community people for raising awareness on alternative livelihood, fish and fisheries related policies, process of forming fisher's association, climate change, importance of biodiversity conservation etc. Motivational camping, awareness rally with banners and festoon were arranged round the years with the participation of fishers and local community people on the protection and preservation of biodiversity in the water bodies of the study areas.

Key findings : Indiscriminate harvesting was identified another reason for the cause of the disappearance of different indigenous fish varieties in the study areas. Based upon the findings of baseline survey, the study took several steps to increase awareness of local people relating to the protection and preservation of local fish varieties and the after the end line survey it was found that the people were aware of them, due to the involvement of alternative livelihoods arranged by the project their income was increased. Locally extinct fish varieties were started to regain, and the production of fishes were increased. Particularly, the overall fish production of the study areas was increased which impacted upon to increase their income. Fishers were also aware of their rights and existing rules relating to leasing and management of open water bodies. They were capable of forming their own association with the support of project. Several discussions with all stakeholders were made to increase the access to market system. Several motivational steps were taken to reduce water pollution presenting the issue of coal mining impacts nationally for the first time with the support of both electronic and printings Medias.

Key words : Socio-economic Condition, Baseline survey, End-line survey, IEC materials, Motivation, Awareness

12.3. Component-3 (RU)

12.3.1. Research highlight: 1

Background : Fisheries baseline survey is conducted to establish a basic inventory of fishery resource in a given aquatic ecosystem. It aims at collecting information on (i) success and failures of existing fish sancturay and (ii) causes of decreasing fish diversity in Chalan beel. It can also be used to provide information on the socio-economic and demography of fishing communities. Information generated from the survey has paramount importance for planning and development activities in the fisheries sector, interventions for fishery management and also help in preparing fisheries management plan.

Objective : To identify failures of existing fish sanctuary and causes of decreasing fish diversity in Chalan beel

Methodology : The base-line survey of failures of existing fish sanctuary and causes of decreasing fish diversity has been conducted through personal interview and Focus Group Discussion (FGD) using well-structured questionnaire and checklist. The questionnaire and checklist were pretested and corrected before using for data collection. Secondary information was collected from Department of Fisheries (DoF), IUCN, different NGO's and internet to cross check of the information. Baseline survey has been conducted for a period of 5 months. For baseline survey a total of 200 respondents (100 from each location) were selected from 2 respective study locations (site 1: Singra and Site 2: Chatmohor).

Key findings : Lack of monitoring & renovation, and lack of improved structure were identified as the main causes of failure of existing fish sanctuary in Chalan Beel. Complete dewatering, khata fishing and construction of roads and highways were the main causes of decreasing fish diversity in this Beel.

Key words : Baseline survey, Chalan beel, IUCN, Sanctuary, Biodiversity

12.3.2. Research highlight: 2(a)

Background : Bangladesh is blessed with the world's richest and most diverse inland aquatic ecosystem having a wide variety of living aquatic resources such as ponds, canals, ox-bow lakes, haors, baors, river, floodplain, beel etc. But over the years, due to natural and man-made causes, aquatic bio-diversity especially species diversity of fish and other aquatic organism in Chalan Beel have been declining sharply. It is very essential to undertake necessary attempts on conserving and enhancing aquatic biodiversity by establishing fish sanctuary.

Objective : To establish well structured sanctuary in Chalan beel for protection and conservation of fish species from extinction.

Methodology : Two fish sanctuary was established (one is Singhra Upazila of Natore district and another one is Chatmohor Upazila of Pabna district) each with 0.5 hactare. Sanctuary in both of the two study sites were manufactured from bamboo (bamboo with branches and without branches), tree branches (Hizol, Eng: *Indian oak*; Babla, Eng: *Babul*; Tetul, Eng: *Tamarind* and Gub, English: *Indian Persimmon*), sand bags, R.C.C. ring pipes and R.C.C. hexapods. Ring pipes and hexapods were made from rod, cement, bricks and sand. Placement of the ring pipes and hexapods was done from the small, mechanized boat. From the base line survey, a total of 10 fish species were fond as less available (rare) species in Chalan beel and this species were collected from different wild sources and stocked in the experimental sanctuary.

Key findings : Addition of R.C.C. hexapods and ring pipes in experimental sanctuary creates better shelter for fishes and improve their habitat. Total fish abundance and number of species were higher in the established sanctuary than partially protected sanctuary (made by DoF) and open site (control). Abundance of 10 less available species are increasing day by day in both sanctuary sites of Chalan beel. Fish catch of fishermen increase in sanctuary sites than before which improve their livelihood status.

Key words : Sanctuary, Habitat, Abundance, Hexapods, Ring pipe

12.3.3. Research highlight: 2(b)

Background : As a riverine country, Bangladesh endowed with a huge number of rivers which are distributed all along the country. However, fish production of these natural water resources are decreasing day by day. But ensuring the higher fish production of these natural habitats can meet the demand of essential nutrients and create employment opportunity for increasing population of this country. Therefore, cage fish farming would be the best option for the proper utilization of these natural waterbodies.

Objective : To promote cage fish farming as an alternative livelihood option in Chalan beel area.

Methodology : The sub-project has developed alternate livelihood option through appropriate cage fish farming to reduce the fishing pressure during ban on fishing for sanctuary operation. Fish farming groups for cage culture was selected from one upazila (Singra upazila under Natore district). Connection of beel to the river water and water current was given major considerations during selection of site. Medium sized cage (6 m x 3 m x 2 m) was used for this trial. A total of 12 cages have been installed for this experiment. Duration of cage fish farming was 4 months culture period.

Key findings : Among the 4 catfish species (Magur, Pabda, Pangus and Gulsha tengra), Gulsha tengra has been found economically profitable for cage culture system in Chalan beel. Gulsha tengra with a stocking density 100 fish/m^3 and feeding with 1 day restriction in a week was a good option for cage fish farming in Chalan beel area which was economically viable.

Key words : Cage fish farming, Magur, Gulsha, Pabda, Pangus

B. Implementation Status

1. Procurement (Component wise)

1.1. Coordination Component (BARC): *Not applicable*

1.2. Component-1 (SAU)

Description of equipment	PP Target		Achievement		Remarks
	Physical (No.)	Financial (Tk.)	Physical (No.)	Financial (Tk.)	
(a) Office equipment	02	371000.00	02	366660.00	Completed as per target
(b) Lab & field equipment	02	755000.00	04	751400.00	
(c) Other capital items	01	175000	01	173000	

1.3. Component-2 (SUST)

Description of equipment	PP Target		Achievement		Remarks
	Physical (No.)	Financial (Tk.)	Physical (No.)	Financial (Tk.)	
(a) Office equipment	02	440000.00	02	439400.00	Completed as per target
(b) Lab & field equipment	03	792000.00	03	790392.00	
(c) Other capital items	-	-	-	-	

1.4. Component-3 (RU)

Description of equipment	PP Target		Achievement		Remarks
	Physical (No.)	Financial (Tk.)	Physical (No.)	Financial (Tk.)	
(a) Office equipment	02	286500.00	02	284900.00	Completed as per target
(b) Lab & field equipment	04	2484000.00	04	2460900.00	
(c) Other capital items					

2. Establishment/renovation facilities

2.1. Coordination Component (BARC): *Not applicable*

2.2. Component- 1 (SAU): *Not applicable*

2.3. Component- 2(SUST): *Not applicable*

2.4. Component-4 (RU) : *Not applicable*

3.Training/study tour/ seminar/workshop/conference organized by the sub-project

Description	Number of participants			Duration (Days)	Remarks
	Male	Female	Total		
Inception Workshop (1 no)	56	7	63	1 day	All wprkshops held at the Conference room of BARC as per schedule of activity of the Coordination component
Half yearly Research Prog. Review Workshop (2 no.)	65+ 62	9+8	144	1+1 days	
Annual Research Prog. Review Workshop (2 no.)	60+63	7+8	138	1+1 days	
Project Completion Report Review Workshop (1 no)	45	6	52	1 day	
Project Workshop (SAU)	68	10	78	1 day	Workshop on draft project completion report
Trainings (SUST)	03	01	04	10 days	Training on field data collection techniques, data processing and analysis for Data Enumerator and data collectors/research assistants
	02	02	04	10 days	Training on Laboratory Management for Scientific Assistant and sample collectors

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

1. Financial and physical progress (Combined)

Taka

Items of expenditure/activities	Total Approved budget	Fund Received	Actual Expenditure	Balance /Unspent	Physical progress (%)	Reasons for deviation
A. Contractual Staff Salary	5045891	4830349	4830349	0	95.73	Not applicable
B. Field Research / Lab expenses and supplies	19071264	18990794	18990794	0	99.58	
C. Operating Expenses	2465530	2429396	2429396	0	98.53	
D. Vehicle Hire and Fuel, Oil & Maintenance	1653525	1649922	1649922	0	99.78	
E. Training/Workshop/ Seminar etc.	151000	90000	90000	0	59.60	
F. Publications and printing	465000	418000	418000	0	89.89	
G. Miscellaneous	429230	423715	423715	0	98.72	
H. Capital Expenses	3290560	3288352	3288352	0	99.93	
Total	**32572000**	**32120528**	**32120528**	**0**	**98.61**	

2. Financial and physical progress of Coordination component (BARC)

Taka

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
A. Contractual staff salary	573533	573533	573533	0	100.00	Not applicable
B. Field research/lab expenses and supplies	0	0	0	0	0	
C. Operating expenses	175136	174631	174631	0	99.71	
D. Vehicle hire, fuel, oil & maintenance	74261	74261	74261	0	100.00	
E. Training/workshop/seminar etc.	0	0	0	0	0	
F. Publications and printing	300000	294000	294000	0	98.00	
G. Miscellaneous	77070	77040	77040	0	99.96	
Total	**1200000**	**1193465**	**1193465**	**0**	**99.46**	

3. Financial and physical progress component-1 (SAU)

Taka

Items of expenditure/activities	Total Approved budget	Fund Received	Actual Expenditure	Balance /Unspent	Physical progress (%)	Reasons for deviation
A. Contractual Staff Salary	2071683	1946683	1946683	0	93.97	Not applicable
B. Field Research / Lab expenses and supplies	7150141	7121394	7121394	0	99.60	
C. Operating Expenses	743440	709187	709187	0	95.39	
D. Vehicle hire, fuel, oil & maintenance	525476	525476	525476	0	100.00	
E. Training/workshop/seminar etc.	40000	40000	40000	0	100.00	
F. Publications and printing	65000	25000	25000	0	38.46	
G. Miscellaneous	113200	113200	113200	0	100.00	
H. Capital Expenses	1291060	1291060	1291060	0	100.00	
Total	**12000000**	**11772000**	**11772000**	**0**	**98.10**	

4. Financial and physical progress component-2 (SUST)

Taka

Items of expenditure /activities	Total Approved Tk	Fund Received, Tk	Actual Expenditure Tk	Balance Unspent Tk	Physical Progress (%)	Reasons for Deviation
A. Contractual Staff Salary	1401502	1310960	1310960	00.00	93.53	Not applicable
B. Field Research/ Lab expenses and supplies	1940016	1921673	1921673	00.00	99.05	
C. Operating Expenses	720000	720241	720241	00.00	100.03	
D. Vehicle Hire and Fuel, Oil & Maintenance	430000	429542	429542	00.00	99.89	
E. Training/workshop/seminar etc.	111000	50000	50000	00.00	45.03	
F. Publications and printing	75000	75000	75000	00.00	100.00	
G. Miscellaneous	90482	89393	89393	00.00	98.79	
H. Capital Expenses	1232000	1229792	1229792	00.00	99.82	
Total	**6000000**	**5826601**	**5826601**	**00.00**	**97.11**	

5. Financial and physical progress Component-3 (RU)

Taka

Items of expenditure/activities	Total Approved budget	Fund Received	Actual Expenditure	Balance /Unspent	Physical progress (%)	Reasons for deviation
A. Contractual Staff Salary	999173	999173	999173	0	**100.00**	Not applicable
B. Field Research / Lab expenses and supplies	9981107	9947727	9947727	0	**99.67**	
C. Operating Expenses	826954	825337	825337	0	**99.80**	
D. Vehicle Hire and Fuel, Oil & Maintenance	623788	620643	620643	0	**99.50**	
E.Training/Workshop/ Seminar etc.	0	0	0	0	**0.00**	
F. Publications & printing	25000	24000	24000	0	**96.00**	
G. Miscellaneous	148478	144082	144082	0	**97.04**	
H. Capital Expenses	767500	767500	767500	0	**100.00**	
Total	**13372000**	**13328462**	**13328462**	0	**99.67**	

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

1. Achievement of the sub-project by objectives of Component-1 (SAU)

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 assess the fish biodiversity in the Shari-Goyain and Kura Rivers	Personal interview, Focus group discussion, Key informant interview & catch assessment.	Identified the fish species in the Shari-Goyain and Kura Rivers	Able to compare with the previous situation & helped for designing further research.
To evaluate the effects of management on aquatic ecosystems through community participation	Establishment of two sanctuaries, Community based sanctuary management executed, Ensure implementation of fish act. Arrange several awareness training/ meeting with direct and indirect stakeholders.	Developed better ecosystem management strategy.	Fishers per day catch increased and income increased.
To enhance the availability of nutrient-rich small indigenous species (SIS) of fishes in the *haor* region	Establishment of two pen near the sanctuary, Collection of mola and dhela and rare in a pond, Mola & dhela stocked in the pen for two months Allow mola & dhela in the open water with offspring by removing the pen.	Developed endangered SIS revive technology in the wetland.	SIS of fishes increased, income of the fishers' increased, nutrient rich small fish intake of nearby villagers increased.

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 develop appropriate cage fish farming as alternate livelihood options of fishers	Establishment of 18 cages in two sites, Formation of cage management committee, Three trials were made to find out the suitable species and technique of cage aquaculture.	Developed appropriate technology and suitable species for cage aquaculture in the haor region.	Fishers are getting extra income from cage culture.
To determine species-specific differences in sensitivity due to coal-mining effect in the Shari-Goyain River	Collection of fish and sediment, smples preparation for heavy metal test, blood collection for laboratory test.	Heavy metals like Copper, Chromium, Cadmium, Lead, Nickel etc were identified from fish and sediment samples.	The findings will be helpful to design the further research and probable solution.

2. Achievement of the sub-project by objectives of component-2 (SUST)

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 assess the level of siltation of Shari-Goyain river and their adjacent Haor areas.	Designed a modified version of 'Sediment Trap' to measure the siltation level of Shari- Goyain River.	Modified sediment trap was manufactured locally.	Modified sediment trap was helpful in measuring siltation level. Similar research will be possible for measuring siltation level of any water body through this sediment trap.
To assess the socio-economic conditions and to identify the nature of access to market system of fishers living on the study areas.	Development of IEC materials.	Colorful posters, leaflets, brochures and handoutswere developed and printed	IEC materials were helpful to raise awareness of fishers that led to improve their socio- economic condition.

3. Achievement of the sub-project by objectives of component-3 (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 success and failure of existing fish sanctuaries in the study areas	Baseline survey on success and failure of existing sanctuary, fish catch assessment and socio-economic status of fishermen by questionnaire and FGDs. 200 respondents (100 from site 1: Singra and 100 from site 2: Chatmohor) were selected for this purpose.	The existing sanctuaries (previously made by DoF and other non-government organisations) in Chalan Beel were evaluated and found increase diversity and abundance of fish in sanctuary area than other parts of Chalan Beel but only problem was sanctuaries did not last long time.	Success and failure of existing fish sanctuaries were identified.
To establishment of well- structured sanctuaries	Sanctuary in both of the two study sites were manufactured by Bamboos (bamboo with branches and without branches), Tree branches (Hizol, Eng:*Indian oak* ; Babla, Eng: *Babul*; Tetul,Eng: *Tamarind* and Gub, Eng: *Indian Persimmon*), R.C.C. ring pipes, R.C.C. hexapods Stocking of 10 targeted species (less available species) in sanctuaries.	Addition of R.C.C ring pipes and hexapods with bamboos & tree branches increased facility for shelter and foods for fishes and improved fish habitat. Abundance and diversity of 10 less available fish species increased in both sanctuary sites than other areas of Chalan Beel.	Fish abundance and diversity Increased. Livelihood of fishers improved.
Catfish farming in net cages in Chalan Beel area	12 Cages were setup in study site. Stocking of target fish species in experimental cages. Water quality and growth monitoring. Three cage culture experiments were set up at Singhra site of Chalan Beel.	Gulsha tengra was selected as suitable fish species among Magur, Pabda, and Pangus at experiment 1. 100 fish/m^3 was found suitable stocking density of Gulsha tengra for cage culture system in experiment 2. Finally, supplementary feeding with one day restriction per week was proved economically viable for sustainable culture of gulsha tengra in cages by experiment 3.	Fishers are getting extra income from cage culture.

E. Information/knowledge generated/policy generated

1. Information/knowledge generated/policy generated by component-1 (SAU)

General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output	Outcome (short term effect of the research)
To assess the fish biodiversity in the Shari-Goyain and Kura Rivers	Personal Interview (PI), Focus Group Discussion (FGD), Key Informant Interview (KII).	Species identified at baseline survey: Kura River (71), Shari-Goyain River (67), Ratargul Swamp Forest (65), and Gurukchi River (57).	Baseline status of fish was identified
To evaluate the effects of management on aquatic ecosystems through community participation	Establishment of two sanctuaries, Community based sanctuary management executed, Ensure implementation of fish act, Arrange several awareness training/ meeting with direct and indirect stakeholders.	Fish availability and biodiversity increased comparing to base line survey, such as in Ratargul Swamp Forest area (2.46± 2.23 to 3.68±2.97 kg/day) and in the Gurukchi River (1.78±2.11 to 2.98±2.61 kg/day). Nine unavailable species noticed at the third year.	Fishers per day catch increased and income increased.
To enhance the availability of nutrient-rich small indigenous species (SIS) of fishes in the *haor* region	Establishment of two pen near the sanctuary, Collection of mola and dhela and rare in a pond, Mola & dhela stocked in the pen for two months, Allow mola & dhela in the open water with offspring by removing the net of the pen.	Mola increased robustly, but performance of dhela was not satisfactory. Other small fish also increased from the base line survey.	Daily income of the fishers has been increased. Nutrient rich small fish intake of nearby villagers has been increased.
To develop appropriate cage fish farming as alternate livelihood options of fishers	Establishment of 18 cages in two sites, Formation of cage management committee; Three trials were made to find out the suitable species and technique of cage aquaculture.	Tilapia and pangas were found as most suitable species for cage culture in sylhet region. Another important finding is that weekly one day feeding gap for tilapia showed better performance in respect to economic return.	Fishers are getting extra income from cage culture as alternate livelihood options.
To determine species-specific differences in sensitivity due to coal-mining effect in the Shari-Goyain River.	Determination of heavy metal concentration in different parts of fish body and fish blood samples was collected to test the physiological stress of fishes. Sediment samples and water samples were tested to know the effect of coal mining effluent.	Heavy metals like copper, chromium, cadmium, lead, nickel, etc. were detected in the river water, sediment, and fish bodies more than tolerable limit.	The findings will be helpful to find out the solution of the problem at policy level.

2. Information/knowledge generated/policy generated by Component-2 (SUST)

General/ specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output	Outcome (short term effect of the research)
To assess the water quality of Shari-Goyain and Kura River and their adjacent Haor areas	1. Water samples were collected from different sites and tested in the laboratory. Total 24 parameters were tested: DO, BOD5, Temperature, Electric Conductivity, pH, Turbidity, Total Dissolved Solids, Total Suspended Solids, Nitrate, Hardness, Total Coliform, Faecal Coliform, Chloride, Arsenic, Iron, Manganese, Aluminium,Sulfate, Potassium, Calcium, Copper, Chromium, Zinc, Nickel 2. WQI were prepared	Water quality was determined	Data will be helpful in maintaining the water quality of the studied rivers and haor areas, so that fish varieties are preserved, protected and increased.
To analyze the impact of coal mining on water quality of Shari-Goyain river	1. Correlation among the water quality parameters was established 2. Identified relation of water quality of Shari- Goyain River with AMD	Impact of coal mining on the water body was determined.	Result will be helpful in reducing the impact of coal mining on the water body of Shari- Goyain River, so that indigenous fish varieties of the river and adjacent areas were protected and increased.
To assess the level of siltation of Shari- Goyain river and their adjacent Haor areas	Periodical assessment of depth and width of riverbed through 'Depth Finder Device' and water speed by 'Water Current Meter' and determination of siltation level. Besides, 'sediment trap' was used to measure the siltation level practically.	Trend of siltation level was determined.	Data will be helpful in reducing siltation level of the studied river and adjacent haor areas to create a sustainable environment for aquatic life.
To assess the socio-economic conditions and to identify the nature of access to market system of fishers living on the study areas	Development of data collection instruments, motivational campaign instruments, IEC materials.	Socio- economic condition was determined, nature of access to market system of fishers was determined and impacts of sub-project intervention was determined.	Data was helpful to improve the socio-economic condition of fishers and mechanisms will be developed to increase the accessibility of market system for fish trading. Through impact assessment the merits of the sub-project are established.

3. Information/knowledge generated/policy generated by Component-3 (RU)

General/specific objectives of the sub-project	Maj or technical activities performed in respect of the set objectives	Output	Outcome (short term effect ofthe research)
To establishment of well- structured sanctuaries	Sanctuary in both of the two study sites were manufactured with bamboo with branches and without branches, Tree branches (Bn.Hizol, Eng:*Indian oak* ; Bn.Babla, Eng: *Babul*; Bn,Tetul, Eng:*Tamarind* and Bn.Gub, English: *Indian persimmon*), R.C.C. ring pipes, R.C.C. hexapods, stocking of 10 targeted (less available) species in sanctuaries.	Increased facility for shelter and foods for fishes and improved fish habitat. Abundance and diversity of 10 less available fish species increased in both sanctuary sites than other areas of Chalan Beel.	Fish biodiversity and production increased.
Catfish farming in net cages in Chalan Beel area	Twelve cages were setup in study site. Stocking of target fish species in experimental cages. Water quality & growth monitoring. Three cage culture experiments were set up at Singhra site of Chalan Beel.	Gulsha tengra is suitable fish species for Chalan beel and 100 fish/m^3 was found suitable stocking density. Supplementary feeding with one day restriction per week was proved economically viable for sustainable culture of gulsha tengra in cages.	Appropriate cage fish farming technology for Chalan beel area developed.

F. Materials Development/Publication made under the Sub-project

Publication	Number of publication		Remarks (e.g. paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Technology bulletin/ booklet/leaflet/flyer etc.		6	• Farming of Gulsha tengra in floating cages in the running waters (leaflet) • Establishment of well structured fish sanctuary in Chalan Beel (Booklet) • IEC materials (posters) • IEC materials (leaflets) • IEC materials (brochures) • IEC materials (handouts)

Publication	Number of publication		Remarks (e.g. paper title, name of journal,
	2 (Leaflet in Bengali & English)		• খাঁচায় মাছ চাষ ঃ হাওর এলাকার জনগণের জন্য সম্ভাবনাময় একটি প্রযুক্তি (Cage fish culture: A prospective technology for the haor region) • মৎস্যজীবিদের অন্তর্ভুক্তির মাধ্যমে সমন্বিত মৎস্য অভয়াশ্রম ব্যবস্থাপনায় দেশীয় প্রজাতির মাছের উৎপাদন বৃদ্ধির কৌশল (Techniques to enhance production of indigenous fish species by engaging fishers' community in the fish sanctuary management)
Joumal publication		5	1. Checklist of fish species in the Shari-Goyain River, Bangladesh: threats and conservation measures. *Indian Journal of Geo-Marine Sciences,* ***SCIE & Scopus indexed journal (IF 0.328)***
			2. Socio-demographic observation of fishing community of the Shari-Goyain River, Bangladesh. *Bangladesh Journal of Fisheries*
			3. Socio-economic conditions of fishermen at Jaintiapur upazila in Sylhet. *Journal of Sylhet Agricultural University*
			4. Availability and diversity of fish fauna in the Gurukchi River of Sylhet district in Bangladesh. *Journal of Sylhet Agricultural University*
			5. Determination of suitable species for cage fish farming in Chalan beel, Bangladesh. *International Journal of Fisheries and Aquatic Studies*.
	15		1. People's Perception on the causes of water pollution and fish-kill incidences in the Shari-Goyain River Ecosystem of Bangladesh
			2. Ecological risk assessment, contamination level, and source identification of heavy metals in different organs of fish body in the Shari-Goyain River
			3. Species-specific differences in sensitivity due to coal-mining effect in the Shari-Goyain River
			4. Species-specific differences in sensitivity due to coal-mining effect in the Shari-Goyain River
			5. Impact of fish sanctuary on fish biodiversity in and around Ratargul Swamp Forest of Bangladesh
			6. Spatial and temporal variations of plankton abundance and diversity in the Shari-Goyain River
			7. Katha fishing badly impacted on fish biodiversity: A case study of the Shari-Goyain River
			8. Impact of fish sanctuary on fish biodiversity and production of Gurukchi River of Bangladesh

Publication	Number of publication		Remarks (e.g. paper title, name of journal,
			9. Effective supplementary feeding strategy can boost up economic return in cage aquaculture
			10. Comparative study of production performance and economics among commercially important catfish species under cage aquaculture system in the Ratargul Swamp Forest of Bangladesh
			11. Optimization of stocking density of tilapia (*Oreochromis niloticus*) for cage culture in a riverine environment of Bangladesh
			12. Determination of appropriate stocking density of pangas (*Pangasianodon hypophthalmaus*) in cage aquaculture haor region of Bangladesh
			13. Optimization of stocking density for better growth, physiological indices and economic profitability of *Mystus cavasius* cultured in cages. *Aquaculture Research*.
			14. Effects of supplementary feeds with different feeding restriction period on the production and economics of Gulsa tengra cage farming in Chalan *beel*. *Aquaculture*.
			15. Artificial Habitat Complexity Promotes Habitat Utilization by Macro invertebrates and Fish in the Wetland Ecosystem. *Ecological Complexity*.
Video clip/TV program		8	**BTV:** https://youtu.be/yGhGZ3SpYac
			Jamuna TV: https://youtu.be/O3NQViCv3xw
			Ntv: https://youtu.be/BBK-dlAky0g
			ATN News: https://cutt.ly/LvE79Lb
			Facebook page of the Department (SAU) https://cutt.ly/OvE5Bor (Video clip)
			Channel I (Krishi Songbad): https://youtube.com/watch?v=Us3Vob6GGLA&feature=share
			MY TV: https://m.facebook.com/story.php?storyfbid=2887399131544539&id=100008234409763
			Qtv Bangla: https://www.facebook.com/1416860361719909/posts/5325063777566195/

Publication	**Number of publication**		**Remarks (e.g. paper title, name of journal,**
News Paper/Popular Article		17	AgriLife 30.11.2020 Daily Jalalabad: 01.12.2020 Desh Rupantar: 05.12.2020 Dhaka Trubiune: 05.12.2020 Ekattorer Kotha: 30.11.2020 Financial Express: 03.12.2020 Krishi Sangbad: 01.12.2020 Manabjomin: 01.12.2020 Quantapedia: 01.12.2020 Sangbad: 02.12.2020 Somokal: 15.1.2021 Somoyes Alo: 01.12.2020 Sylhet Mirror: 02.12.2020 Sylhet Sun: 30.11.2020 The New Nation: 01.12.2020 Financial Express: 31.12.2020 The Daink Sokaler Somoy: 05.4.2021
Conference/Seminar Papers	3	4	1. An overview of heavy metal pollution in the rivers of Bangladesh 2. Fish sanctuary of Bangladesh: pros and corns 3. Abundance and diversity of plankton in relation to quality parameters in Shari-Goyain river of Bangladesh 4. Impact of katha fishing on fisheries resources in the Shari-Goyain River of Bangladesh 5. Evaluation of water quality of Shari-Goyain River, Sylhet, Bangladesh. ***In Proceedings of '1st International Conference on Sustainable Fisheries (ICSF 2019)', SAU, Sylhet.*** 6. How does leasing practices of wetlands uproot fish and fishers: an observation. In Proceedings of '1st International Conference on Sustainable Fisheries (ICSF 2019)', SAU, Sylhet. 7. The Application of CCME-WQI for the Protection of Aquatic Life in Shari-Goyain River, Sylhet, Bangladesh. In Proceedings of '6th International Conference on Engineering Research, Innovation and Education (ICERIE 2021)', SUST, Sylhet.
PhD Thesis	2		1. Title: Impact of coal mine drainage and heavy metal pollution in the Shari-Goyain River of Bangladesh **(SAU student)** 2. Title: Evaluating the effectiveness of fish sanctuary for sustainable fisheries management of Chalan Beel **(RU student)**

G. Description of generated technolory/knowledge/policy

i. Technology fact sheet (title of the technology, introduction, description, suitablelocation/ ecosystem, benefits, name and contact address of author)

Technology fact sheet: 01

Title of the technology: Cage fish farming: A prospective technology for *haor* and Chalan *beel* region

1. Introduction : Cage aquaculture is a profitable business. It is widely practiced in many Asian countries including China, vitenam, Thailand, Taiwan, and Malaysia. Though it is practiced in many areas of Bangladesh, it is not yet widely spread to the fish farmers in the Sylhet and Chalan *beel* region. Therefore, to promote cage fish farming as an alternative income generation for the fishermen a research sub-project (ID 035) was undertaken by the Department of Aquatic Research Management of Sylhet Agricultural University and Department of Fisheries, Rajshahi University through the support of NATP Phase-2 under Bangladesh Agriculture Research Council.

2. Description

2.1. Cage preparation and installment : Cage aquaculture is suitable in water with low current. Water body with high current and waves are not suitable for cage culture. Water depth should be at least 15-18 cm. Medium sized cage (6m X 3m X 2m) is suitable for cage fish culture. GI pipe frame is covered with nylon net to prepare the cage. 2.5 cm meshed net is suitable, so that more water and aeration passes through the nets. Empty capped drums of around 200L capacity can be used to float the cage. Two drums should be placed in between and at the ends of the cages. Bamboos can be tied at the periphery of the cage series for movement required during fish feed supply and cage maintenance. Nylon string should be used to tie cage net with GI pipe and bamboo. Each end of cage should be tied with an anchor so that they could not be displaced away with water current. The top end of cage should be float at least 30 cm above the water level. A fine meshed net of 20-25 cm height should be used to cover the upper four sides in order to prevent floating feed going out of the cage by current. Considering 12000-15000 Taka for each cage preparation, the total cost for 10 cages could be 120,000-150,000 Taka including all cost to set up the cages.

2.2. Culture procedure

2.2.a. Species selection: Such fish species should be selected which are fast growing, high market demand, high price and have ability to cope with the environmental changes. In the project research it is found that tilapia, pangas, pabda and catfish is suitable for cage aquaculture; however, tilapia and pangas are most profitable for culture. Fish production mainly depends on the quality of fish seeds; thus for better fish seed it should be contacted with trusted fish seed producers in advance.

2.2.b. Culture density: The stocking density of fishes in the cages depends on the species. In case of cages made as per the above instruction, the water volume inside a floating cage will be around 4-5 square meter. According to the result of the research sub-project the stocking densities for tilapia, pangas, pabda and gulsha can be recommended at the rate of 50-60, 30-40, 50-60, and 100-120 fishes per cubic meter, respectively. During stocking the suggested sizes of fingerlings are 5-6g, 8-10g, 5-6g and 2-3g for tilapia, pangas pabda and gulsha, respectively. However, the stocking sizes will be also dependent of the mesh sizes so that fish seeds could not fled away from the cages.

2.2.c. Feed supply: Commercially available floating feeds with sufficient protein content can be used. If 5-6g size fingerlings are stocked, feed at 10-12% of total fish body weight should be given and gradually this amount should be reduced to 5% at second month and 4% from the third month to throughout the culture period. At every 15 days interval the total amount of the feed should be adjusted by direct sampling of fishes. If all feeds are not fed within 30 minutes of feed supply then the amount of feed should be decreased and if all feed are fed within 15 minutes of feed supply then the amount can be slightly increased. However, this amount can be varied according to species. In case of tilapia and pangas half of the total amount of feed should be given within 8-9am and the rest half should be given within 4-5pm. As the pabda and catfish are nocturnal feeder, half of their total feed should be given around 7-8pm and the rest half could be given 4-5am. From our research it isrevealed that weekly only one day feed off has very little effect on their growth, thus save a huge feed cost and maximize the profit level.

Plate 41. Cage fish farming

2.2.d. Cage management: It is necessary to properly maintain the cages. Naturally the meshes of the cage nets become clogged due to growth of algae and trapping of wastes which cause oxygen depletion inside the cages from less water flow. Therefore, it is necessary to wash the nets at least once a week. However, during such cleaning operation it should be careful that the joints of the nets do not become loose or tear off. Moreover, it should be checked whether there is any portion of the nets damaged and should be instantly mended in order to prevent fishes from escaping out of the cages.

2.2.e. Fish harvest: The total duration of fish culture depends on the species. For tilapia fishes can be harvested after 3-4 months of rearing; thus maximum 3 crops can be obtained in a year from perennial water bodies. In case of pabda and magur the culture period is usually 5-6 months; thus maximum 2 crops can be obtained from a perennial water body in a year.

3. Suitable location: Any type of water body with low current and with a water depth at least two meters.

4. Benefits: For a successful cage culture operation it is necessary to get the calculation of profit-expenditure, and for this purpose all types of expenditure should be instantly noted. Considering the duration of cage frame of around 5 years and net of around 2 years as well as the frequency of annual fish harvest the cost of a cage should be calculated. The profit can be easily calculated by deducting all expenditures from the total fish sell. The profit-expenditure of tilapia cage culture for one cage is given below :

Table 72. Benefit-cost ratio of tilapia cage farming based on the research findings

Items	For 40 fish/m^3 stocking density	For 60 fish/m^3 stocking density
Seed cost	6,000 Taka	9,000 Taka
Feed cost	18,223 Taka	25,471 Taka
Cage cost	2,000 Taka	2,000 Taka
Total cost	26,283 Taka	36,471 Taka
Total sell	39,747 Taka	54,639 Taka
Net profit	13,464 Taka	18,168 Taka
Benefit-cost ratio	1.512	1.499

If the cage culture technology could be spreaded in the vast haor regions of Sylhet division and in the Chalan *beel* area, it will definitely create income generation and would also be helpful to fulfill the animal protein demand of the nation. Moreover, it could be very much suitable for large water bodies under Ashrayan and Cluster Village (আশ্রয়ণ/গুচ্ছগ্রাম প্রকল্প) project areas of government or other large joint family where fish culture is not possible by only one family member. It will also decrease poverty and alleviate the social status of women if they could be engaged in cage aquaculture; especially for those women who live nearby the rivers

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Technology fact sheet: 02

Title of the technology: Techniques to enhance production of indigenous fish species by engaging fishers' community in the fish sanctuary management.

1. Introduction : Fish sanctuary is an important method for increased fish production in the open water bodies as well as to protect endangered fish species from extinction. For this reason, many fish sanctuaries are established in the natural water bodies by the government as well as NGOs. However, after completion of the sub-project, management of the sanctuaries and ban of fishing inside the sanctuaries could not be maintained properly in most cases due to lack of proper initiative of government and fishers' community hardly care about the maintenance of the sanctuaries. To get rid of this situation it is necessary to engage the fishing community to manage these sanctuaries which is not yet widely practiced in our country. Therefore, for the purpose of adoption of this technology in the Sylhet and Rajshahi region a research sub-project (ID 035) was undertaken with the financial assistance of PIU-BARC, NATP-2. Under a part of that project two sanctuaries are established in the haors of Sylhet and two in Chalan *beel*. Additionally, a pen is established beside each of the sanctuaries in Sylhet region in order to enhance some endangered small fishes. Most importantly, in order to keep the sanctuaries functional the local fishing communities are made engaged to the management activities of those sanctuaries. The experiences and results gained from this sub-project can be applied to the other sanctuaries of the country.

2. Description

2.1. Establishment of sanctuary : Usually, around 8-10% of a water body during dry season is required for an effective sanctuary. Generally, sanctuary is established in deep and low current place of haor, beel or river where siltation rate is low. It should be far away from common navigation route to avoid agitation from the water vehicles to avoid disturbance for living and breeding of fishes. It is as essential step to select suitable materials for santuary establishment. Therefore, bamboos, branches of trees and roots of trees (Bn: Hizol, Eng: *Indian oak* ; Bn:Koros, Eng: Indian Beech and Bn:Jaam, Eng, Black berries etc.) are suitable for construction of such sanctuaries. Afterwards highly branched tree brancees are set inside the sanctuary and tied with the bamboo poles, so that they were remained under the water.

Plate 42. Established sanctuary in Ratargul swamp forest.

Cemented hexapode and ring pipe can be used added for effectiveness of the sanctuary. Afterwards water hyacinth or morning glory are put in some parts of sanctuary so that fishes can shelter under these aquatic plants and thus breed there. Moreover, some red flags and signboard indicating inhibition of fishing around 200 meters of the sanctuary need to be set on the periphery of the sanctuary.

2.2. Pen set-up : Pen should be set-up nearby the sanctuary. Threatened indigenous fish species should be reared as brood inside the pen. As pen preparation bamboo poles should be dig around the selected area for the pen and then encircled with find meshed nets so that fishes outside this pen could not be entered. Then, very fine meshed nets should be towed several times inside the pen and the catches should be thrown out in the nearby water.

Plate 43. Established pen in the Ratargul swamp forest.

Endangered or unavailable small fishes should be collected from available sources and then stocked in a nearby pond during February-March for rearing. After rearing of 1-2 months, they will be suitable as brood and then should be released in the constructed pens at the end of March until the end of April for breeding. After 1 - 2 months when they will produce sufficient seedlings, then the nets of the pens should be kept out of the water so that the produced fishes can spread out in the sanctuary as well as throughout the water body and other nearby water bodies.

2.3. Management of sanctuary and pen : Fish production will be increased if sanctuaries and pens could be successfully established and well managed. Due to set-up of sanctuaries and pens fishermen are affected for a short period of time. However, as a long run they become benefitted as fish production increase in the upcoming rainy season as well as next years. In spite of that, to compensate this short time problem, engage the fishers in alternative income generating activities has shown good results through the sub-project. For instance, the fishermen families were supported with training and financial help from cage fish culture, cattle, duck or chicken rearing, sewing machine, etc. However, these supports must be done through forming a co-operative so that they can pay their due from their profit and thus this process could be expanded without further support of the sub-project. The yearly maintenance cost of the cage and pens can also be done from such earnings of the co-operative organization. Following the mentioned process long term management of the prepared sanctuaries in Ratargul Swamp Forest and the Gurukchi River become successful.

3. Suitable location : All type of open water body with low current, such as Haor, Baor, Beel, River, Canal etc.

4. Benefits : Fish production increased in many folds in the Ratargul Swamp Forest and the Gurukchi River during the last three years as a result of sanctuary and pen establishment and its proper management. According to the result of the survey conducted through the sub-project it is found that production of mola and many other small indigenous fish species increased a lot. Before establishment of the fish sanctuary daily average fish catch of a fisherman was only 1-2kg which is now increased to 3-4kg. Moreover, 9 endangered fishes and many unavailable fishes are now commonly found in the catches at the third year of this sub-project period after establishment of the sanctuary. According to the statements of the local fishermen in the nearby water bodies mola, chital, foli, boal, pabda catch was very much high in the last year which was not experienced during the previous 20 years. A number of sanctuaries are established in different types of water bodies of the country which can be effectively run by the incorporation the fishing communities in the management activities. It is expected that proper management of existing sanctuaries and establishment of new sanctuaries will be of helpful to enhance fish biodiversity and production in the natural water bodies, thus ensure food and nutrition security as well as contribution in the national economy.

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Technology fact sheet: 03

Title of the technology: Conserving small indigenous species (SIS) of fishes in the wetland through pen-based production of fish seeds

1. Introduction : Bangladesh is endowed with huge low-lying waters like *haors, baors, beels*, freshwater swamps, lakes, reservoirs, ponds, canals, etc. along with rivers and its tributaries. Due to various anthropogenic and natural causes fish diversity is decreasing day by day. Many fish species especially small indigenous species of fishes of the wetlands are becoming unavailable or threatened and few of them already lost from the country. To get rid of this situation rearing of broods for breeding of small indigenous fish species in pens could be a suitable alternative. Pens assume importance as the material required for fabrication is cheaper, readily available in the market and even unskilled personnel can erect them without involving engineering skill. The pen structure can also be relocated at other suitable sites. The material may last for 3 to 4 years for raising several crops. Thus, pen culture can serve as one of the cheaper alternatives to costly land-based rearing space. However, pen culture technology in Bangladesh is in preliminary stage and is usually observed in the seasonal waterlogged areas in south-west region of Bangladesh. The only one purpose of this pen culture is to rear fish for fish production, good economic return, not for conservation purpose. Therefore, present study was initiated to demonstrate a new approach of historical pen culture technique for conserving small indigenous species of fish in the wetlands of Bangladesh. For the purpose of adoption of this technology in the Greater Sylhet region a research sub-project (sub-project ID 035) was undertaken by the Department of Aquatic Research Management in Sylhet Agricultural University with the financial assistance of PIU-BARC, NATP-2. Under a part of that sub-project two pens were established in two sample wetlands of Sylhet district in order to rare and ranching of some endangered small fishes. Most importantly, in order to keep the pens functional, the local fishing communities are made engaged to the management activities of those pens. This leaflet is prepared based on the light of success of that sub-project. The experiences and results gained from this sub-project can be applied to other wetlands of the country.

2. Description

***2.1. Establishment and set up of pen* :** Generally, pen is established in deep and low current place of *haor*, *beel* or river where siltation rate is comparatively low. It should be far away from common navigation route to avoid agitation from the water vehicles to avoid disturbance to living and breeding of fishes. Threatened indigenous fish species should be reared as brood inside the pen. During pen preparation bamboo poles should be dig around the selected area and then encircled with fine meshed nylon nets which are fixed to 30 cm beneath the mud, tied with bamboo that resisted the net to come out of the cervices so that fishes outside this pen could not be entered. The height of a pen should be at least 3 meters (1 meter above the water level of the wetland) to prevent fish escaping by jumping the nets or predators entered inside the pen. Then, very fine meshed nets should be towed several times inside the pen and the catches should be thrown outside the pen. Afterwards some tree branches, bamboo with branches, and water hyacinth or morning glory are put in some parts of the pen so that fishes can shelter under these aquatic plants, and thus breed there. Endangered or unavailable small fishes should be collected outside this pen could not be entered. The height of a pen should be at least 3 meters (1 meter above from available sources and then stocked in a nearby pond during February-March for rearing. After rearing of 1-2 months they will be suitable as brood and then should be released in the constructed pens at the end of March for breeding. After 1-2 months when they will produce sufficient seedlings, then the nets of the pens should be kept out of the water so that the produced fishes can spread out the waterbody and other nearby waterbodies.

2.2. Management pen : Fish production will be increased if pens could be successfully established and well managed. Due to set-up of pens fishermen are affected for a short period of time as fishes are banned inside and nearby the pen area. However, as a long run they become benefitted as fish production increase in the upcoming rainy season as well as next years. In spite of that, to compensate this temporary problem of fishermen, engage them in alternative income generating activities has shown good results through the sub-project. For instance, the fishermen families were supported with training and financial help from cage fish culture, cattle, duck or chicken raring, use of sewing machine, etc. However, these supports must be done through forming a co-operative so that they can pay their due from their profit and thus this process could be expanded without further support of the project. The yearly maintenance cost of the cage and pens can also be done from such earnings of the co-operative organization. Following the mentioned process management of the prepared pens in Ratargul swamp forest and the Gurukchi River had a remarkable success.

3. Suitable location : All type of open water body with low current comparatively shallow area with at least one meter water depth, such as Haor, Baor, Beel, River, Canal etc.

4. Benefits : Fish production increases a lot in the natural water bodies as a result of pen-based SIS fish breeding. For instance, fish production increased in many folds in the Ratargul Swamp Forest and the Gurukchi River during the last three years as a result of pen establishment and its proper management. According to the result of the survey conducted through the sub-project it was found that production of mola and many other small indigenous fish species increased a lot. Before establishment of the pen daily average fish catch of a fisherman was only 1-2 kg which is now increased to 3-4 kg within two years of this intervention. Moreover, 9 endangered fishes and many unavailable fishes are now commonly found in the catches at the third year of this sub-project period after establishment of two pens along with two sanctuaries. It is also observed that effectiveness of pen become more effective if there is any previously established or newly established sanctuary nearby the pen. According to the statements of the local fishermen in the nearby water bodies mola, chital, foli, boal, pabda catch was very much high in the last year which was not experienced during the previous 20 years. It is expected that proper establishment and management of pens along with establishment of sanctuary will be of helpful to enhance fish biodiversity and production in the natural water bodies, thus ensure food and nutrition security as well as contribution to the national economy. Considering the importance of the program government will have to take comprehensive plan to establish new pens and sanctuaries. This is the new established knowledge and it has created a strong logic to take initiative for future conservation policy. Establishment of pen and sanctuary and its community-based management should be implemented all over the country to enhance biodiversity and production of fishes. Pen culture technology can be adopted in the wetlands of Bangladesh to enhance, protect and revive the native endangered SIS biodiversity.

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Technology fact sheet: 04

Title of the technology: Developmemt of eco-friendly modified sediment trap/device

1. Introduction : Fine Sediments within lakes and rivers originate from the weathering and erosion of rocks. Following rainfall, soil can enter lakes and rivers which cause the finest particles to become suspended in the water, causing it look turbid; this is called siltation. Particles may eventually find their way to the lake or riverbed where they become deposited; this is known as sedimentation. Excessive siltation or sedimentation may degrade the spawning grounds, cause behavioral changes in spawning fish, increase egg mortality, decrease larval growth and affect the development rate and survival of larval fish, cause Gill irritation, change blood physiology, alter movement or swimming performance, change foraging behavior and decrease territoriality. That is why it is very important to know the sedimentation rate of a river for the desired fish production. Therefore, to measure sedimentation rate of River Shari-Goyain practically, a device named 'Sediment Trap' is manufactured locally and used.

2. Description : Sediment Trap' is a simple technology, made of steel tube (Figure- 10.2.4) of diameter 94 mm and height 570 mm. Stainless steel sheet of thickness 1.27 mm was used to make the trap body. MS rod was used to make the frame for the trap. In the field two types of sediment traps were employed: one is with deflector inside and the other one is without deflector. The traps were fixed to the river bottom in the littoral zone at a distance approximately 3 m from the shore line at a depth of 1.6 m. the trap was attached to a steel frame which ensured maintenance of traps on the river bottom and stabilized the vertical position. To position the trap vertically, a cross-brace was placed on the upper edge of the trap and a spirit level and pile above the water level was used to achieve the desired position of the trap. The accumulated sediments in the traps were collected at 7-18 days interval depending on the degree of turbid water and transported to the laboratory to determine solid mass. Using obtained data, the rate of sedimentation was calculated.

It is to mention that the sedimentation rate can be calculated theoretically too using empirical equations like Hossain's equation. Calculations of sedimentation rate by 'Sediment Trap' and comparison with theoretical result is shown in SUST: Appendix Table 7.

3. Suitable location: Any kind of water body.

4. Benefits : Modified sediment trap was helpful in measuring sedimentation level practically for the River Shari- Goyain, which is very turbulent in rainy season. Similar research will be possible for measuring siltation level of any water body through this sediment trap.

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ii. Effectiveness in policy support

- The Study findings have established the impacts of upstream coal mining on fish resources human health, and the socio-economic conditions of fishers living in Gowainghat Upazila of Sylhet district. This is the new established knowledge and it has created a strong logic to take initiative for Bi-lateral dialogue between India and Bangladesh so that India can take actions to stop pollution due to coal mining inside their land. Joint research between Bangladesh and India can be initiated for fine tuning the research and to find a way out of the problem.
- Establishment of adequate number of sanctuaries and its community-based management should be implemented all over the country to enhance biodiversity and production of fishes.
- Pen culture technology can be adopted in the wetlands of Bangladesh to enhance, protect and revive the native endangered SIS biodiversity.
- Cage aquaculture as an alternative livelihood for fishers found to be helpful in ensuring their voluntary participation in implementing fish banning and sanctuary management. This lesson can be followed for national wide for increasing fish production and conservation.
- The study found that the genuine fishers do not get easy access to the local market system and do not get the actual price of their caught fish which reduces their income. Therefore, in Jal mahal policy, the issue of market access for fishers can be included.

H. Technolory/Knowledge generation/Policy Support

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

- Fish increased in the open water
- Catch increased
- Fishers' income increased
- Fish produced from cage culture as alternate income generating activities
- Effect of pollution from coal mining effluents was identified.
- Modified sedimentation trap is being used to calculate siltation level of water.
- IEC materials created social awareness regarding conservation of fish and adopting cage fish farming as an alternate livelihood option.

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

- Applied research on community-based fish sanctuary management.
- Fine tuning of cage aquaculture research in different places of haor region.
- Joint research with India is needed to mitigate pollution from coal mining effluents.
- More research is needed for water and sediment quality parameters.

- Impact of coal mining pollution can be investigated with more fishes and its impact on human health need to identify.
- Further modification sedimentation trap to calculate siltation level more accurately.

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

- Community based sanctuary management
- To enhance biodiversity and production of small indigenous species of fish (SIS) seed production techniques using pen culture technique.
- Cage fish farming technique for haor and Chalan *beel* region.

iv. Policy support

- Community based sanctuary management techniques should be applied all over the country through its adoption in the policy.
- To enhance biodiversity and production of small indigenous species of fish (SIS) seed production techniques using pen culture technique should be applied all over the country through its adoption in the policy.
- Bilateral agreement with India should be initiated from policy level to mitigate the destructive pollution from coal mining effluent.
- Policy needs to be taken to identification of high siltation level areas throughout the country and measures need to be taken to reduce the pollution caused by siltation.

I. Information regarding Desk and Field monitoring

i. Desk monitoring [description & output of consultation meeting, monitoring workshops/ seminars etc.)

- Three coordination/consultation meeting (dated 14.10.2019, 10.06.2020 and 13.12.2020) were organized by the Coordinating unit at BARC, Dhaka where PI & Co-PI of all components attended. Research updates and field related issues were discussed in all meeting. Suggestions given by the coordinating unit were implemented in the field. Moreover, component-wise desk monitoring reports are given below:
- Consultation meeting with Deputy Director (DD), Department of Fisheries, Sylhet Division, Sylhet before establishing the sanctuaries during December 2018. Different technical issues of establishment of sanctuaries were discussed and suggestions given by the DD were implementd.
- Consultation meeting with Deputy Commissioner, Sylhet and Upazila Nirbahi Officer (UNO) to raise the issue of devastating effect of coal mining effluent comes from Meghlaya, India during bi-latteral meeting between Bangladesh and India held in Shilong, India. Accordingly, the issue discussed in the meeting.
- Consultation meeting with Deputy Director, Department of Fisheries, Sylhet Division, Sylhet and District Fisheries Officer (DFO), Sylhet regarding management of sanctuary and implementation of fish act.

- Several consultation meetings were organized with the Upazila Nirbahi Officer (UNO) and Upazila Fishery Officer (UFO), Goyainghat regarding management of sanctuary and implementation of fish act.
- Meeting with Social Welfare Officer of Goyainghat for the registration of the fishers group and Upazila Women Officer for the training on sewing for fishers women. Because as per our advice they purchse sewing machine with the money getting from selling of fish produced by cage aquaculture.
- Consultation meeting with Divisional Forest Officer regarding protection of sanctuaries established in Ratargul Swamp Forest. Before that we have got written permission from Chief Conservator of Forest (CCF) to use the wetland of Ratargul Swamp Forest to carry out researches for a period of five years.
- Prof. Dr. AMM Mukaddes, Dean, School of Applied Sciences & Technology and Prof. Dr. Muhammad Azizul Hoque, Head, Dept. of Civil & Env. Eng., SUST monitored the sub-project activity and consult with PI & Co-PI regarding thre progress of the sub-project.
- Meeting with Social Welfare Officer of Goyainghat for the registration of the fishers group and Upazila Women Officer for the training on sewing for fishers women. Because as per our advice they purchse sewing machine with the money getting from selling of fish produced by cage aquaculture.
- Monitoring meeting about 'Straightening programm of fish sanctuary and cage fish farming in Chalan Beel'- organized in the Department of Fisheries, University of Rajshahi (Date: 19.12.2018). From this meeting some guidelines were found out about how to successfully establish a well-structured sanctuary in Chalan Beel and about technical knowledge on catfish culture techniques and feeding management.

ii. Field monitoring (date& no. of visit, name and addresses of team visit and output)

Visit no.	Monitoring team	Date(s) of visit	Output
1	Dr. Md. Monirul Islam, Member Director (Fisheries), BARC	23 Feb'2019	Visited research sites and laboratory. Instructions given by the Coordinator was executed.
2	1. Dr. M. Baktear Hossain, Director, Training and Manpower Unit, BARC 2. Mr. Md. Mustafizur Rahman, Principal Technical Officer, BARC	11 April 2019	Visited research field & laboratory; some advice was given; action was taken accordingly.
3	Emeritus Professor Dr. Abdus Sattar Mondol & Syndicate Member, SAU	13 April 2019	Visited research field & laboratory; some advices were given; action was taken accordingly.
4	1. Prof. Dr. Md. Motiar Rahman Howlader, Honourable Vice-Chancellor, SAU 2. Prof. Dr. Abul Kasem, Convener, Dean Council, SAU, Sylhet	18 April 2019	Field visit and open fry stocking program in cages; advice to carry out the research perfectly
5	1. Upazila Nirbahi Officer, Goyainghat 2. Upazila Fisheries Officer, Goyainghat	6 May 2019	Field visit, Fish act implementation and awareness meeting with stakeholders.

Visit no.	Monitoring team	Date(s) of visit	Output
6	1. Dr. Md. Serajul Islam, Environmental and Social Safeguard Specialist of PIU-BARC, NATP-2. 2. Kbd. Md. Abdur Rahman, Monitoring Associate. PIU-BARC, NATP-2. 3. Kbd. Dipak Kumar, Monitoring Associate, PIU-BARC, NATP-2.	24.06.2019	Visited research sites and aboratory. Instructions given by the team was executed.
7	1. Dr. Md. Monirul Islam, Member Director (Fisheries), BARC	13 July 2019	Visited research field & laboratory; some advice was given; action was taken accordingly.
8	UNO/UFO, Shingra, Natore	25 August 2019	Visited research sites and given administrative helps to implement the fish act.
9	1. Prof. Dr. AMM Mukaddes, Dean, School of Applied Sciences & Technology, SUST 2. Prof. Dr. Muhammad Azizul Hoque, Head, Dept. of Civil & Env. Eng., SUST	14 Nov' 2019	Laboratory were visited, some advice was given to increase the capability of laboratory.
10	1. Dr. Md. Serajul Islam, Environmental and Social Safeguard Specialist of PIU-BARC, NATP-2. 2. Kbd. Md. Abdur Rahman, Monitoring Associate. PIU-BARC, NATP-2. 3. Kbd. Dipak Kumar, Monitoring Associate, PIU-BARC, NATP-2.	11 March 2020	Visited research field & laboratory; some advice were given; action was taken accordingly.
11	Chairman, Department of Fisheries, Rajshahi University	23 Sept' 2020	Visites research sites and aboratory. Advised to carry out research perfectly
12	1. Professor Dr. Md. Shahidul Isam, Direscor (SAURES), SAU 2. Md. Jahidul Islam, Chairman, Dept. of Aquatic Resource Management, SAU	03 Oct' 2020	Visited research field and talk to the stakeholders and encourage them for better management of the fish sanctuary.
13	UNO/UFO, Chatmohor, Pabna	21 Oct' 2020	Visited research sites and given administrative helps to implement the fish act.
14	1. Dr. Harunur Rashid, Director, 2. Dr. Md. Abdul Jalil Bhuyan, Research Management Specialist 3. Dr. MA Nowsher Ali Sarder, Monitoring and Evaluation Specialist, PIU-BARC, NATP-2	14 Nov' 2020	Visited research field & laboratory; some advice was given; action was taken accordingly.

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

1. Three years average weather information of Sylhet region (2018 -2020)

Parameters	**Seasons**						**Remarks**
	Pre-Monson (January – April)		**Monson (May – August)**		**Post Monson (Sept – December)**		
	Max	Min	Max	Min	Max	Min	
Av. Rainfall(mm)	349	0	789	132	452	0	
Av. Temperature (^{O}C)	31	19.7	34.3	27.7	33.2	20.1	
Av. Humidity (%)	81	66	85	75	85	76	
Flood (year & category)			2 times occurred (2018), 1 time occurred (2019)				
Av. Salinity (ppt)	-	-	-	-	-	-	
Natural calamity (Frequency & category)	80 Nos (Thunder storm)		109 Nos (Thunder storm)		45 Nos (Thunder storm		

Ref: Compilation of Bangladesh Environment statistics' 2020. Statistics and Informatics Division, Government of the People's Republic of Bangladesh.

2. Three years average weather information of Rajsahi region (2018 -2020)

Parameters	**Seasons**						**Remarks**
	Pre-Monson (January – April)		**Monson (May – August)**		**Post Monson (Sept – December)**		
	Max	Min	Max	Min	Max	Min	
Av. Rainfall(mm)	98	20	425	398	25	10	
Av. Temperature (^{O}C)	5	23	35	29	28	14	
Av. Humidity (%)	80	67	90	82	77	70	
Flood (year & category)	Not reporting						
Av. Salinity (ppt)	Not applicable						
Natural calamity (Frequency & category)	No reportable natural calamities						

Ref: Ragional meterological office, Rajsahi and Water Developmemt Board office, Rajsahi.

J. Sub-project Auditing

1. Coordination component (BARC)

Types of audits	Major observation/ issues/objections raised; if any	Amount of Audit (Tk.)	Status at the sub-project end	Remarks
Financial & Performance Audit by FAPAD on 31.10.19 for the year 2018-2019	No objection raised, found all relevant documents updated as per guideline	129893.00	Financial management of the component found running smoothly till the end of the sub-project. No query or objection raised at any stage of operation by the audit teams.	Financial management & project performance found satisfactory
Financial & Performance Audit by FAPAD on 09.12.20 for the year 2019-2020.	No objection raised, found all relevant documents updated as per guideline	334162.50		
Financial & Performance Audit by FAPAD on 12.110.21 for the year 2020-2021.	No objection raised, found all relevant documents updated as per guideline	334851.00		

2. Sub-project auditing report for Component-1 (SAU)

Types of audits	Major observation/ issues/objections raised; if any	Amount of Audit (Tk.)	Status at the sub-project end	Remarks
FAPAD (2018-2019)	No objection was raised	5297339.00	Financial management of the component run smoothly till the end of the subproject. No query or objection raised at any stage of operation by the audit teams.	Satisfactory
FAPAD (2019-2020)	No objection was raised	3663373.00		
MH Chowdhury Audit Farm (2019-2020)	No objection was raised	Same amount as above		
FAPAD (2020-2021)	No objection was raised	2811288.00		

3. Sub-project auditing report for Component-2 (SUST

Typesof audits	Majorobservation/ issues/objections raised; if any	Amount of Audit (Tk.)	Status at the sub project end	Remarks
For financial year 2018- 19 By FAPAD 13.11.19	No objection was raised	2,195,176.00	Financial management of the component run smoothly till the end of the sub- project. No query or objection raised at any stage of operation by the audit teams.	Satisfactory
For financial year 2019- 20 By FAPAD 10.12.20	No objection was raised	2,297,665.00		Satisfactory
For financial year 2020- 21 By FAPAD 12.10.21	No objection was raised	1133760.00		Satisfactory

4. Sub-project auditing report for Component-3 (RU)

Types of audits	Major observation/issues /objections raised; if any	Amount of Audit (Tk.)	Status at the sub-project end	Remarks
Audited by FAPAD (2018-2019)	No objection raised. All relevant documents found updated	4814109.00	Financial management of the component run smoothly till the end of the sub-project. No query or objection raised at any stage of operation by the audit teams.	Satisfactory
Audited By FAPAD(2019-2020)	No objection raised. All relevant documents found updated	3656252.50		Satisfactory
Audited by FARD (2020-2021)	No objection raised. All relevant documents found updated	3674584.00		Satisfactory

K. Lessons Learned

i. Establishment of sanctuary and its community-based sanctuary management could be one of the best options to enhance, protect and revive the native fish biodiversity. Government, non-government and political supports are needed for its sustainable management.

ii. Pen culture system (endangered SIS collected from different places and stocked into the pen before breeding season, feeding them for until took part breeding and allow them to go into the open water after few days of breeding) could be one of the best options to enhance and revive the native endangered SIS biodiversity.

iii. Cage aquaculture could be one of the best options for alternate livelihood of the fishers as well as local people and will be helpful to engage fishers in community-based fisheries management.
iv. Coal mining effluent has been decreasing fish diversity and availability, deteriorating water quality and accumulated heavy metal in the fish body and sediment of the river bed which are hazards for human health.
v. Peoples' attitude can be changed by continuous motivational works
vi. Locally modified sedimentation trap is more suitable than imported one to measure siltation level from local water bodies
vii. Excessive sedimentation process has been decreasing the fish breeding ground and nursery ground.

L. Challenges

- Fiels visit, survey, sample collection and data collections were hampered due to COVID-19 pandemic situation, especially during April to June 2020. Laboratory facilities were limited during COVID.
- Implementation of fishing ban was very challenging, because fishers are hardly motivated not to fishing and try to fish very close or inside the sanctuary.
- During data collection fishers are unwilling to spend much time, especially difficult to arrange FGD and social data collection.
- In the Gurukchi River due to irrigation in the paddy field, water remains very limited to survive fish during February to April.
- Good quality fish fry is unavailable in sylhet region.
- Cage materials and skill manpower for cage set up is unavailable in sylhet region.
- Lack of secondary data on water level, water discharge, satellite images of the river, siltation, heavy metal existence, impacts of coal mining on the studied water bodies, fish varieties etc. Due to lack of sufficient secondary data, we have to depend on continuous monitoring, collection of filed data, tests etc. Insufficient data is a constraint for trend analysis.

M. Susgestions for Future Planning

- Well structured fish sactuaries should be established throughout the country as required and its long-term management should be ensured. Government, non-government and political supports are needed for its sustainable management.
- Promotion of SIS through pen culture technique should be implementd throughout the country to revive the endangered species and make it available.
- Similar program-based research sub-project can be continued to increase, regenerate and protect the local fish biodiversity and enhance fish production, which can improve the socio- economic condition of fishers' community.
- To assess the trend of water quality, environmental pollution, siltation level and climatic impact; long term research project should be undertaken.
- Bi-lateral dialogue should be initiated with India to stop or minimize the entrance of coal mining effluent in Shari-Goyain River and in case of other transboundary river also.

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Signature of the Coordinator	**Counter signature of the Head of the organization/authorized representative**
	
(Dr. Md. Monirul Islam) Date: 25.11.2021 ***Member Director (Fisheries)*** ***Bangladesh Agricultural Research Council***	**(Dr. Shaikh Mohammad Bokhtiar)** Date: 25.11.2021 ***Executive Chairman*** ***Bangladesh Agricultural Research Council***

Appendices

1. Coordination component (BARC)

Appendix – BARC: A

Recommendation of the inception workshop and status of action taken

Recommendations	Action Taken
General comment	
Revision of the title of the sub-project suggested	Title revised as follows: "Techniques, Adoption and Formulation of Guidelines for Sustainable management of Haor and Beel Fisheries"
Component 1 (SAU)	
Selenium content as causes of fish gill blockage due to coal mine flushed water should be described properly with justification.	Required justification included be shown in the reports
Component 2 (SUST)	
Analysis of heavy metals from accredited labs (like SGS in Bangladesh) suggested instead of present practice with BCSIR and Atomic Energy Commission lab.	Followed on the basis of availability of fund
Identification of other heavy metal substances in the mine flow waters in addition to selenium emphasized;	Followed on the basis of availability of fund
Farmers motivational training, exchange visits, rally, field days etc as effective means should be reflected under the awareness building program of the project instead of organizing workshop, seminars etc.	Action taken as per recommendation
Component 3 (RU)	
Training and capacity increase of fishers under specific objective 3 not require to mention	Necessary correction done
Capacity building of Ph. D and MS students under the project not require to show as research outcome.	Necessary correction done

Appendix – BARC:B

Recommendation of the half yearly workshops

Recommendations of the first half yearly workshop	Action taken
Component 1 (SAU)	
• Reference value "Cr" should be rechecked with the international standard and confirmed the present result.	Verification done before reporting
• Reasonfor siltation study and justification for selecting the study points need to be described properly.	Justification explained accordingly
Component 2 (SUST)	
• No comment made	
Component 3 (RU)	
• No comment nade	

Appendix – BARC: C

Recommendation of the Annual workshop

Recommendations of the First Annual Workshop	Action taken
Component 1 (SAU)	
• Baseline study should be a separate study. It should not be merged with the project objective.	Baseline study done separately.
• No research output shown in the presentation.	Followed in the next presentations.
• Both “Nitrate and Nitrite” should be done under water quality parameter study program.	Included under revised study
• Reference of laboratory for chemical sensitivity test should be mentioned in the report.	Cited accordingly
• Standard value of stress pressure should be mentioned in the respective column of the table.	Followed accordingly
• Investigation on form of Cr (hexavalent or tetravalent) and Arsenic (organic or inorganic) suggested.	Not considered
• Heavy metals and micro-nutrients are not to be overlapped in any case and their analysis should be performed at least in one accredited analytical laboratory.	Attention given
• Probable existence of Uranium and its label should be included under the study.	Not included at this stage
• Characterization of type of planktons and bacteria in Haor water, seasonal variation and its role in nutrition balancing study suggested.	Done partially
Component 2 (SUST)	
• Results of baseline study not presented in the workshop	Included in the next presentations
• As per specific objective of the sub-project, no finding of siltation study presented in the report.	Will be followed in the next part
• Heavy metals and micro-nutrients are not to be overlapped in any case and their analysis should be performed at least in one accredited analytical laboratory.	Attention given
Component 3 (RU)	
• No baseline information was presented.	Presented in the next review meetings
• All possible sources like water, fish and soil should be taken into account for heavy metal analysis.	Included as per budget provision
• Nature of growth and culture cycle of each species under culture should be considered separately. Long term culture fish (like Pangas etc) cand not be measure for growth of short cycle fish (like Tengra etc). In such cases the results will mislead the research findings.	Necessary correction done
Recommendations of the Second Annual Workshop	**Action taken**
Component 1 (SAU)	
• Complete picture of the findings of comparative study before and after intervention of the sub-project suggested to include in the report.	Focused accordingly
• Adequate and proper justification including possible	Included in the respective discussion

effecting factors need to be shown in favor of increased average fish catch due the project activities.	chapters
Component 2(SUST)	
• As per recommendations of the previous review meetings, study on the form of Cr (hexavalent or tetravalent), Arsenic (organic or inorganic) and possibility of existence of Uranium in the water of study areas were not taken into account,	It depends on the provision of budget and duration of the sub project
Component 3(RU)	
• Inclusion of a comparative picture of fish species diversity before and after the project intervention suggested.	Comparative information on fish species diversity discussed in the result
• Ways/methods of community participation for livelihood improvement of fishers through involvement of cage culture activities and benefit sharing process need to be focus specifically in the repot.	Done accordingly

Appendix – BARC: D

Recommendation of the coordination meetings

Central Coordination meeting at BARC	
Recommendations	**Action taken**
• Community members organizing, culture activities, water quality and heavy metal studies should run parallel. Both the components of Sylhet region will pay due attention in the matter.	Instructions of the meting followed accordingly
• Analysis of “Nitrate and Nitrite” and forms/types of “Arsenic” as per recommendation of Inception workshop should be taken into consideration by the respective component.	Necessary action taken
• RU component should maintain regular liaison with other two components of the sub project. Component PI’s should sit together time to time for review their research findings and further planning of activities.	Several joint meetings ornanized
• Implementation of some of the recommendations of the review workshop or on-going field activities may demands few new areas of research or analysis. In such a situation re-appropriation of budget to meet the research demand become an obligation that requires concurrence of the PIU BARCauthority. Respective PI will take initiative in the matter and the Coordination section will provide necessary support.	Information transmitted to the PIU-BARC authority through the sub-project Coordinator
Two Other virtual Coordination meetings	
Component 1 (SAU)	
• Fish biodiversity related data from Sari Guaiyn river will continue up to December’20 (objective 1).	Followed accordingly

• As an uninterrupted continuous process, study on effect of management on aquatic ecosystem withy special reference to community participation will be continued up to March'21(objective 11).	Followed accordingly
• In addition to Mola fish, effort should be given to increase the population of Dhela fish within the remaining part of the sub-project period. If not locally available, initiative may be taken to collect the species from other available areas like, Kishorgonj, Bhairab or elsewhere of the country.	Recommendation fulfilled partially.
• Harvesting of 3rd culture crop from cage farming is about to finish by next July'20. As per plan of the sub-project necessary initiative for the 4th crop farming experiment urges to be arranged within July'20.	Followed accordingly
• Due to delay in placement of fund, specific species sensitivity test of the third fish samples is still pending. Upon availability of fund necessary step should be taken to complete the analysis with technical support from SGS Bangladesh Limited and BAU central laboratory for heavy metals. Cortisol T_3 and T_4 and blood sugar test are suggested to done locally from the SAU research labs.	Attempts made as per instruction
Component 2 (SUST)	
On-going activities on data and sample collection and their laboratory analysis to understand the impact of coal mine flow (addressing objective no 1 & 111) should be rounding up within March'21.	Followed the recommendation
Hampered program of data collection and analysis interruption for about three months due to Covid -19 epidemic, suggested to resume again and as continuous process this may continue up to May'21. Moreover, collection of secondary data on flow of current and siltation rate from the Bangladesh Water Development Board and Bangladesh River Research Institute will provide additional support in this regard.	Pending all works completed under revised plan of activity
Implementation of awareness building and motivational activities should not continue beyond March'21.	Rounded up within March'21
Component 3 (RU)	
Researchers observation on baseline findings to be added;	Added accordingly
Focussing of the success and failure of sanctuaries to be analysed and presented in the second annual report.	Focused accordingly
In addition to develop appropriate model of sanctuary, aqua-ecological condition should also be observed with special reference to benthos and periphyton growth and impact on fish growth/production.	Observations recorded and discussed

Suitability of feed type and application rate and alternate feeding schedule (maintaining protein level) and cost-benefit analysis for cage fish farming should be completed under the present part of research.	Done as per recommendation
Proper attention for the development of research based scientific papers and extension manuals emphasized.	Attention given.

2. Component-1 (SAU)

Appendix-1

Present Status of Fish Biodiversity in the Shari-Goyain River and Adjacent Waters Baseline & after Intervention Survey

"Techniques Adoption and Formulation of Guidelines for Sustainable Management of *Haor* and *Beel* Fisheries" Sub-project
Department of Aquatic Resource Management,
Faculty of Fisheries, Sylhet Agricultural University

Name of the site:............................ Serial number: |__|__|__| Date: |___|___|______|

General information

Sl. No.	Questions	Answer	Code
1	Name of fisherman/group leader and mobile number	Name:………………………. Mobile no.:………………….	
2	Address	Village :................ … Union :........................ Upazila :………....... District :………………	
3	Age (years)	|__|__|__|	
4	Gender	Male---------------------------------1 Female-----------------------------2	☐
5	Educational qualification	No education---------------------1 Class 1-5 --------------------------2 Class 6-10 -------------------------3 SSC passed-----------------------4 HSC passed-----------------------5 Degree passed---------------------6 Others¨----------------------------7	☐
6	Number of family members	Male:--------------------------- |__|__| Female:-------------------------|__|__|	
7	Land property of the fishers (dec)	|__|__|__|	
8	Experience in fishing (years)	|__|__|__|	

9	Distance of site from home (km)	|__|__|__|		
10	Type of fishers	Full-time---------------------1 Part-time---------------------2 Occasional-------------------3	Other activity	☐
11	No. of fishing days in last month	|__|__|		

Present availability status of species

Sl. no.	Local name	Scientific name	Present availability status of fish				
			AA	**CA**	**MA**	**RA**	**NA**
1	Bamosh	*Anguilla bengalensis*					
2	Kachki	*Corica soborna*					
3	Ilish	*Tenualosa ilisha*					
4	Chapila	*Gudusia chapra*					
5	Mola	*Amblypharyngodon mola*					
6	Chhep chela	*Devario devario*					
7	Darkina	*Esomus danricus*					
8	Dhela	*Osteobrama cotio*					
9	Darkina	*Rasbora daniconius*					
10	Balichata Gutum	*Acanthocobitis zonalternans*					
11	Narkali chela	*Salmophasia bacaila*					
12	Fulchela	*Salmostoma phulo*					
13	Catla	*Catla catla*					
14	Mrigal	*Cirrhinus cirrhosus*					
15	Laccho	*Cirrhinus reba*					
16	Bata	*Labeo bata*					
17	Kalibaosh	*Labeo calbasu*					
18	Gonia	*Labeo gonius*					
19	Ghora Maach	*Labeo pangusia*					
20	Rui	*Labeo rohita*					
21	Chakla Punti	*Pethia conchonius*					
22	Gili Punti	*Pethia gelius*					
23	Mola Punti	*Pethia guganio*					
24	Phutani punti	*Pethia phutunio*					
25	Sarpunti	*Systomus sarana*					
26	Jat Punti	*Puntius sophore*					
27	Teri Punti	*Puntius terio*					
28	Tit Punti	*Pethia ticto*					
29	Ghora Chela	*Securicula gora*					
30	Bou Rani	*Botia dario*					
31	Gutum	*Lepidocephalichthys guntea*					
32	Pahari Gutum	*Somileptes gongota*					
33	Kanpona	*Aplocheilus panchax*					

Sl. no.	Local name	Scientific name	Present availability status of fish				
			AA	CA	MA	RA	NA
34	Corsula	*Rhinomugil corsula*					
35	Chital	*Chitala chitala*					
36	Kanla/Fali	*Notopterus notopterus*					
37	Baila/Bele	*Glossogobius giuris*					
38	Gazar	*Channa marulius*					
39	Raga, Cheng	*Channa orientalis*					
40	Lati, Taki	*Channa punctatus*					
41	Shol	*Channa striatus*					
42	Napit Koi	*Badis badis*					
43	Lomba Chanda	*Chanda nama*					
44	Ranga Chanda	*Pseudambassis lala*					
45	Gol chanda	*Pseudambassis ranga*					
46	Bheda, Meni	*Nandus nandus*					
47	Koi	*Anabas testudineas*					
48	Bara Khailsha	*Trichogaster fasciata*					
49	Chuna Khalisha	*Trichogaster chuna*					
50	Ekthute	*Dermogenys pussillus*					
51	Kaikya, Kakila	*Xenentodon cancila*					
52	Bacha	*Eutropiichthys vacha*					
53	Batasi, Laiya	*Pseudeutropius atherinoides*					
54	Ghagla	*Hemibagrus menoda*					
55	Gulsha Tengra	*Mystus bleekeri*					
56	Golsha (Sada)	*Mystus cavasius*					
57	Bujuri Tengra	*Mystus tengara*					
58	Rani Tengra	*Mystus vittatus*					
59	Rita, Rida	*Rita rita*					
60	Ayre	*Sperata aor*					
61	Guijja Ayre	*Sperata seenghala*					
62	Kani Pabda	*Ompok bimaculatus*					
63	Madhu Pabda	*Ompok pabda*					
64	Pabda	*Ompok pabo*					
65	Boal	*Wallago attu*					
66	Kajuli, Bashpata	*Ailia coila*					
67	Ghaura	*Clupisoma garua*					
68	Deshi Pangas	*Pangasius pangasius*					
69	Magur	*Clarias batrachus*					
70	Shing	*Heteropneustes fossilis*					
71	Chaka	*Chaca chaca*					
72	Kuchia, Kuiccha	*Monopterus cuchia*					
73	Tara Baim	*Macrognathus aculeatus*					
74	Sal Baim	*Mastacembelus armatus*					
75	Guchibaim	*Macrognathus pancalus*					

Sl. no.	Local name	Scientific name	Present availability status of fish				
			AA	CA	MA	RA	NA
76	Potka	*Tetraodon cutcutia*					
77	Baghair	*Bagarius bagarius*					
78	Bali Tengra	*Batasio batasio*					
79	Balitora	*Psilorhynchus gracilis*					
80	Kutakanti, Hara	*Hara jerdoni*					
81	Borali, Koksa	*Barilius barila*					
82	Gang Tengra	*Gagata cenia*					
83	Mohashol	*Tor putitora*					
84	Nanid	*Labeo nandina*					
85	Pipla Shol	*Channa barca*					
86	Shilon	*Silonia silondia*					

Seasonal variation of fish production and diversity

Dry season		Pre-monsoon		Monsoon		Post-monsoon	
Catch (kg/day)	No. of sp.	Catch (kg/day)	No. of sp.	Catch (kg/day)	No. of sp.	Catch (kg/day)	No. of sp.

Seasonal variation of fish abundance

Name of the species		No. of fish catch per day			
Local name	Scientific name	Winter (Dec-Feb)	Pre-monsoon (Mar-May)	Monsoon (Jun-Aug)	Post-monsoon (Sep-Nov)

Change in harvest of fish (kg/fisher/day)

Harvest (present): …………………. Harvest (12-15 years ago): …………………

Causes of fish depletion:

Name of the interviewer: …………………….

Appendix-2

Present Status of Fish Biodiversity in the Shari-Goyain River and Adjacent Waters Fish Catch Monitoring Questionnaire

"Techniques Adoption and Formulation of Guidelines for Sustainable Management of Haor and Beel Fisheries" Sub-project

Department of Aquatic Resource Management,
Faculty of Fisheries, Sylhet Agricultural University

Name of the site :............... Serial number : |__|__|__| Date : |___|___|____|

General information

Sl. No.	Questions	Answer		Code
1	Name of fisherman/group leader and mobile number	Name:………………………. Mobile no.:………………….		
2	Address	Village :................ … Union :........................ Upazila :………........ District :………………		
3	Age (years)	|__|__|__|		
4	Gender	Male-------------------------------1 Female-----------------------------2		☐
5	Educational qualification	No education---------------------1 Class 1-5 --------------------------2 Class 6-10 -------------------------3 SSC passed-----------------------4 HSC passed-----------------------5 Degree passed--------------------6 Others¨-----------------------------7		☐
6	Number of family members	Male:---------------------------- |__|__| Female:-------------------------|__|__|		
7	Land property of the fishers (dec)	|__|__|__|		
8	Experience in fishing (years)	|__|__|__|		
9	Distance of site from home (km)	|__|__|__|		
10.1	Type of fishers	Full-time---------------1 Part-time---------------2 Occasional------------3	Other activity	☐
10.2	Annual income (tk) from	Fishing:	Others:	
11	No. of fishing days in last month	|__|__|		

12) Description of fishing gears used by fisherman today:

Sl no	Local name	Types of gear	Description of gears (m)			Mesh size (cm)	Total no.(net/ hooks)	No. of hauls	Total no. of fishers	Water depth (m)
			Length	Height/ Width	Diameter					

i										
Ii										

13) No. of gear owners:…… |__|__| ………. Fishers..…………… Non-fishers…………….
15) When fishing started : …… When fishing ended :….. Total time spent for fishing : ……
16) Total amount of fish catch (kg) : …… Amount Sold (kg) : ………….……
17) Price of fish sold (taka) : …………..… Amount will sell (kg) ……….…….
18) Yesterday total catch (kg) :……. …… Amount sold (kg) : …………...…
19) Price of fish sold (taka) : …………… Consumed fish (kg) :…………..……
20) Cost of fishing today (taka) :.. ………………… Cost of fishing yesterday (taka) : …..
21) Sampled catch by species

Sl. No.	**Species name**	**Sampled amount of fish**		**Total weight (kg)**	**Total no. of fish**	**Total price (Tk)**
		Sample weight (kg)	Number of fish			
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						

Remarks:

Name of the interviewer: …………………….

Component-2 (SUST)

Appendix-1

Some of the water quality results

Table- A1: Water quality of the river at zero point when upstream coal water entered to Bangladesh

	DO (mg/L)	BOD5 (mg/L)	Temp.	E.C	pH	Turbidity (NTU)	TDS	TSS	Nitrate (mg/L)	Hardness (mg/L)	T.C	F.C
Standard	*5.5-9*	*2*	*15*	*30-5000*	*6.5-9*	*5*	*165*	*30*	*13*	*20-300*	*30*	*14*
December 2018	7.6	2.6	21	135	4.8	2.2	90	15	10.9	294	4	1
April 2019	3.6	2	23.1	214	3.8	0	141	11	0.2	230	2	0
April 2020	5.6	1.2	27.7	108	4.66	11.95	72	7	0.6	206	2	2
May 2020	6.4	1.2	27.8	115	4.5	2.67	76	1.5	0.5	124	0	0
April 2021	5.6	1.1	19.5	235	3.4	60	32	254	2.7	190	1	0

	Chloride (mg/L)	Arsenic (mg/L)	Iron (mg/L)	Manganese (mg/L)	Aluminium (mg/L)	Sulfate (mg/L)	Potassium (mg/L)	Calcium (mg/L)
Standard	*120*	*0.005*	*0.3*	*0.1*	*0.005-0.01*	*22*	*12*	*36*
December 2018	10	0	0.1373	0.0235	5.23	44	1.6	0
April 2019	18	0	0.0915	0.083	0.326	50	0.3	0
April 2020	40	0	0.04	0.0266	3.112	43	0.6	0
May 2020	38	0	0.03	0	1.768	34	0.6	0.16
April 2021	25	0	0.1648	0.0047	2.05	47	2	0

	Copper (mg/L)	Chromium (mg/L)	Zinc (mg/L)	Nickel (mg/L)
Standard	*0.002*	*0.001*	*0.007*	*0.025-0.15*
December 2018	0.09	0.011	0.34	1.27
April 2019	0.12	0.091	0.42	0.21
April 2020	0.6	0.01	0.23	0.21
May 2020	0.03	0.01	0.33	0.002
April 2021	0.1	0.009	0.25	0.013

Table- A2: Heavy metals in water at zero point

	Aluminium (mg/L)	**Copper (mg/L)**	**Chromium (mg/L)**	**Zinc (mg/L)**	**Nickel (mg/L)**
Standard Value	*0.005-0.01*	*0.002*	*0.001*	*0.007*	*0.025-0.15*
September '18	0.384	1.18	0.263	0.2	0.23
October '18	0.212	0.09	0.007	1.13	0
November '18	0.182	0.02	0.006	0.6	0.24
December '18	5.23	0.09	0.011	0.34	1.27
January '19	1.062	0.03	0.006	0.15	1.43
February '19	0.294	0.05	0.001	0.23	1.02
March '19	0.15	0.03	0.43	0.37	0.79
April '19	0.326	0.12	0.091	0.42	0.21
May '19	0.216	0.04	0.025	0.2	0.014
June '19	0.061	0.01	0.004	0.16	0.13
July '19	0.042	0.01	0.005	0.45	0
August '19	0.029	0.01	0.005	0.46	0.002
September '19	0.075	0	0.019	0.28	0.01
October '19	0.075	0.02	0.012	0.14	0.006
November '19	0.059	0.01	0.011	0.13	0.006
December '19	0.743	0.03	0.011	0.15	0.1
January '20	1.202	0.02	0.01	0.14	0.008
February '20	1.787	0.02	0.004	0.1	0.013
March '20	0.576	0.02	0.003	0.31	0.79
April '20	3.112	0.6	0.01	0.23	0.21
May '20	1.768	0.03	0.01	0.33	0.002
June '20	0.04	0.01	0.005	0.1	0.002
July '20	0.132	0.01	0.009	0.28	0.002
August '20	0.07	0.01	0.011	0.25	0
September '20	0.056	0.02	0.024	0.11	0
October '20	0.07	0.02	0.016	0.19	0
November '20	0.051	0.02	0.017	0.1	0
December '20	0.084	0.04	0.04	0.09	0
January '21	0.474	0.04	0.03	0.26	0.014
February '21	0.629	0.02	0.009	0.14	0.006
March '21	0.353	0.03	0.006	0.068	0.068
April ‘21	2.05	0.1	0.009	0.25	0.013

Table A3: Heavy metals in sediment at zero point

	Amount (mg/Kg)	
Parameter	**September '18**	**March '19**
Nickel	270	330
Zinc	175	405
Copper	175	420
Chromium	12	15

Table A4a: Statistical summary (mean, standard deviation) for water quality parametersin wet season

Variables	River Kura	Ratargul	Gowainghat	Sharighat	Zero-Point	Standard Value
	Mean S.D	Mean S.D	Mean S.D	Mean S.D	Mean S.D	
DO (mg/l)	4.216667 1.173831	4.766667 0.856349	5.116667 0.640786	6.544444 2.186381	6.2444444 1.7184885	5.5-9[b]
BOD 5 (mg/l)	1.1 0.797724	1.166667 1.350645	0.816667 0.500606	1.555556 1.352219	1.1888889 1.0900021	2[a]
Temp. (^{0}C)	27.61667 2.009447	28.08333 1.635311	27.59167 1.572178	26.17222 2.585663	25.661111 2.8213762	25[h]
E.C (µs/cm)	37.91667 25.2279	32.75 19.10319	33.83333 19.9765	50.94444 28.55845	61.777778 41.667529	30-5000[g]
pH	6.330833 0.450201	6.206667 0.827365	6.015 0.759084	6.053889 0.882117	5.8888889 0.9009073	6.5-9[b]
Turbidity (NTU)	17.57167 11.29081	22.53333 26.70615	17.94667 17.25498	20.30444 17.73807	12.210556 9.3053934	5[b]
TDS (mg/L)	26.41667 11.29081	25.75 14.3788	22.25 11.11203	34.55556 18.58279	41.111111 27.392332	165[a]
TSS (mg/L)	22.16667 14.1988	40.83333 50.62488	30.5 20.16072	11.11111 9.436406	6.9666667 5.0049387	30[c]
Nitrate (mg/L)	0.266667 0.214617	0.241667 0.206522	0.291667 0.223437	1.233333 2.395093	2.7611111 4.1675411	13[b]
Hardness (mg/L)	126 104.7143	116.5 96.37852	137.1667 106.5132	165.3333 111.2771	148.11111 77.679499	20-300[d]
T.C (No/100ml)	0.583333 0.900337	0.583333 0.668558	1.25 0.965307	1.166667 0.985184	1 1.0289915	30[c]
F.C (No/100ml)	0.833333 2.124889	2.5 3.089572	1.583333 2.968267	1.888889 2.373602	1.8333333 3.1669247	14[e]
Chloride (mg/L)	30 16.59682	28.75 14.78405	28.83333 15.00808	24.83333 13.66081	22.111111 13.006283	120[b]

Variables	River Kura	Ratargul	Gowainghat	Sharighat	Zero-Point	Standard Value
	Mean S.D	Mean S.D	Mean S.D	Mean S.D	Mean S.D	
Arsenic (mg/L)	0 0	0 0	0.000833 0.002887	0 0	0.0005556 0.002357	0.005[b]
Iron (mg/L)	0.203333 0.143991	0.188333 0.197661	0.123333 0.098381	0.164611 0.211695	0.0726444 0.0595841	0.3[b]
Manganese (mg/L)	0.081942 0.05555	0.074783 0.043889	0.071083 0.056606	0.070772 0.07544	0.0612667 0.090442	0.1[b]
Aluminium (mg/L)	0.02875 0.022596	0.049 0.051482	0.090917 0.128397	0.163111 0.161174	0.2312222 0.3963224	0.005 if pH<6.5, 0.01 if pH≥6.5[b]
Sulfate (mg/L)	2.083333 2.906367	5.333333 2.839121	7.25 6.062178	14.94444 9.396321	17.222222 8.9676251	22[a]
Potassium (mg/L)	1.225 0.625409	0.958333 1.211654	0.733333 0.405268	0.977778 0.524186	1.1888889 1.4298864	12[f]
Calcium (mg/L)	0.901818 0.466601	0.9 0.483848	0.97 0.525184	0.958333 0.505956	0.8394444 0.6360584	36[i]
Copper (mg/L)	0.014167 0.021933	0.013333 0.011547	0.006667 0.006513	0.020611 0.030596	0.0846111 0.2740977	0.002-0.004[b]
Chromium (mg/L)	0.00975 0.007008	0.007333 0.005694	0.00875 0.008593	0.012172 0.022198	0.0251667 0.0597753	0.001[b]
Zinc (mg/L)	0.235 0.182433	0.246667 0.160133	0.250833 0.135476	0.238889 0.119995	0.3033333 0.2439142	0.007[b]
Nickel (mg/L)	0.023917 0.025145	0.014667 0.018647	0.007917 0.013721	0.015561 0.014027	0.0296222 0.0636679	0.025-0.15[b]

Table A4b: Statistical summary (mean, standard deviation) for water quality parameters in dry season

Variable	River Kura	Ratargul	Gowainghat	Sharighat	Zero-Point	Standard Value
	Mean S.D	Mean S.D	Mean S.D	Mean S.D	Mean S.D	
DO (mg/l)	6 1.162148	6.372222 1.281454	6.566667 1.366834	7.266667 1.923233	7.14444444 1.7964744	5.5-9[b]
BOD 5 (mg/l)	1.127778 0.622902	0.905556 0.736024	1.077778 0.974713	1.477778 1.142008	1.48333333 0.99897006	2[a]
Temp. (^{0}C)	23.08889 2.849332	22.66111 2.767487	22.46667 2.763629	22.63889 2.853303	21.9833333 2.96097162	25[h]
E.C (µs/cm)	57.05556 19.07716	70.05556 21.47083	65.16667 19.52449	103.4444 42.8475	118.277778 49.7012316	30-5000[g]

PH	6.269444 0.527697	5.871111 0.79126	5.979444 0.810472	5.258333 0.790668	4.83833333 0.78482107	6.5-9[b]
Turbidity (NTU)	6.335556 4.433184	31.58556 24.04127	22.16944 14.40105	8.413333 5.316521	8.54222222 13.9537444	5[b]
TDS (mg/L)	38.27778 4.433184	51.38889 22.10972	34.77778 15.74262	68.55556 28.58264	77.2777778 32.9666597	165[a]
TSS (mg/L)	10.77778 3.934098	59.44444 47.03969	29.61111 19.73989	5.120556 2.683204	7.03111111 7.62934034	30[c]
Nitrate (mg/L)	0.5 0.16088	0.166667 0.190973	0.183333 0.191741	1.444444 3.548193	2.46111111 3.88740635	13[b]
Hardness (mg/L)	129.8333 57.99214	146.7778 71.23495	135.8889 63.41172	194.6667 71.55418	200.722222 67.3985561	20-300[d]
T.C (No/100ml)	0.666667 0.840168	0.647059 0.701888	0.888889 0.832352	1.777778 1.699673	1.44444444 1.19912822	30[c]
F.C (No/100ml)	1.388889 1.419979	1.352941 1.169464	0.666667 0.766965	1 1.371989	0.5 0.70710678	14[e]
Chloride (mg/L)	29.05556 13.17516	28 14.09213	27.61111 14.24219	21.86111 12.09254	22.3333333 10.4600079	120[b]
Arsenic (mg/L)	0.000556 0.002357	0.000861 0.002622	0 0	0 0	0 0	0.005[b]
Iron (mg/L)	0.054533 0.02682	0.251106 0.125842	0.254922 0.318336	0.065467 0.034399	0.06872778 0.04327115	0.3[b]
Manganese (mg/L)	0.04555 0.028835	0.107452 0.071311	0.064856 0.042287	0.036254 0.020984	0.04538333 0.04941137	0.1[b]
Aluminium (mg/L)	0.0375 0.072439	0.176389 0.344904	0.172 0.340773	0.354556 0.440381	1.02022222 1.3319783	0.005 if pH<6.5, 0.01 if pH≥6.5[b]
Sulfate (mg/L)	0.555556 1.096638	15.38889 8.513926	16.77778 5.946384	32.22222 12.33625	39.3333333 9.4619983	22[a]
Potassium (mg/L)	2.027778 0.883047	1.338889 1.130923	1.4 1.369843	1.211111 0.980329	1.32222222 1.29276519	12[f]
Calcium (mg/L)	1.058889 0.565788	0.888889 0.643455	0.946667 0.686132	0.622222 0.680238	0.20333333 0.46192691	36[i]
Copper (mg/L)	0.011111 0.022723	0.038889 0.093298	0.02 0.037417	0.058333 0.096787	0.07166667 0.13544046	0.002-0.004[b]
Chromium (mg/L)	0.014278 0.015407	0.007717 0.008201	0.006833 0.006318	0.016944 0.016889	0.03916667 0.09976929	0.001[b]
Zinc (mg/L)	0.152111 0.092687	0.179611 0.127627	0.157944 0.122314	0.242 0.290705	0.22655556 0.13950131	0.007[b]
Nickel	0.011389	0.023278	0.031944	0.1475	0.34377778	0.025-0.15[b]

(mg/L)	0.018205	0.02193	0.034978	0.260684	0.48386903	

Sources: **a-** Department of Environment (DoE) Bangladesh; **b-** CCME Water Quality Guideline for the Protection of Aquatic Life; **c-** PHILMINAQ, Water Quality Criteria and Standards for Freshwater and Marine Aquaculture, Mitigating Impact from Aquaculture in the Philippines; **d-** Bhatnagar, A., Devi, P., Water Quality Guideline for the Management of Pond Fish Culture. International Journal of Environmental Sciences. 2013, Volume 3, No. 6.; **e-** Warrington, P.D., Water Quality Criteria for Microbial Indicators. Overview Report. 2001; **f-** Bangladesh Water Quality Standard; **g-** Stone, M.N., Thomford, H.K., Understanding Your Fish Pond and Water Analysis Report, Aquaculture/Fisheries, Cooperative Extension Program, University of Arkansas at Pine Bluff; **h-** Uddin, M.N., Alam, M.S., Mobin, M.N., & Miah, M.A., 2014. An Assessment of the River Water Quality Parameter: A Case of Jamuna River. J. Evniron. Sci. And Natural Resources; **i-** Water Quality Criteria and Standard for freshwater and Marine Aquaculture.

Table A5: CCME-WQI of sampling sites

Name of the site	Season	CCME-WQI	Comment
Zero- point	Wet season, May '18- Oct '18	38.16	Poor
Zero- point	Dry season, Nov '18- April '19	37.81	Poor
Zero- point	Wet season, May '19- Oct '19	41.77	Poor
Zero- point	Dry season, Nov '19- April '20	40.02	Poor
Zero-point	Wet season, May '20- Oct '20	43.84	Poor
Zero-point	Dry season, Nov '20- April '21	38.60	Poor
Gowainghat	Dry season, Nov '18- April '19	44.52	Poor
Gowainghat	Wet season, May '19- Oct '19	44.88	Marginal
Gowainghat	Dry season, Nov '19- April '20	52.43	Marginal
Gowainghat	Wet season, May '20- Oct '20	45.18	Marginal
Gowainghat	Dry season, Nov '20- April '21	45.40	Marginal
Ratargul	Dry season, Nov '18- April '19	43.39	Poor
Ratargul	Wet season, May '19- Oct '19	44.70	Poor
Ratargul	Dry season, Nov '19- April '20	49.17	Marginal
Ratargul	Wet season, May '20- Oct '20	44.33	Poor
Ratargul	Dry season, Nov '20- April '21	42.07	Poor
Sharighat	Wet season, May '18- Oct '18	44.68	Poor
Sharighat	Dry season, Nov '18- April '19	40.47	Poor
Sharighat	Wet season, May '19- Oct '19	39.28	Poor
Sharighat	Dry season, Nov '19- April '20	45.57	Marginal
Sharighat	Wet season, May '20- Oct '20	46.10	Marginal
Sharighat	Dry season, Nov '20- April '21	42.91	Poor
Kura river	Dry season, Nov '18- April '19	56.43	Marginal
Kura river	Wet season, May '19- Oct '19	48.43	Marginal
Kura river	Dry season, Nov '19- April '20	58.98	Marginal
Kura river	Wet season, May '20- Oct '20	45.36	Marginal
Kura river	Dry season, Nov '20- April '21	51.00	Marginal

Table- A6a: Pearson correlation among AMD parameters in wet Season

	E.C	pH	Aluminium	Sulfate	Copper	Chromium	Zinc	Nickel
E.C	1	-0.088	0.349	.461*	-0.023	-0.100	.623**	0.021
PH	-0.088	1	-0.419	-0.295	-0.048	-0.059	-0.065	0.025
Aluminium	0.349	-.419*	1	.519*	0.110	0.091	0.066	0.035
Sulfate	.461*	-0.295	.519*	1	0.173	0.183	0.031	0.160
Copper	-0.023	-0.048	0.110	0.173	1	.991**	-0.064	.762**
Chromium	-0.100	-0.059	0.091	0.183	.991**	1	-0.154	.744**
Zinc	.623**	-0.065	0.066	0.031	-0.064	-0.154	1	-0.258
Nickel	0.021	0.025	0.035	0.160	.762**	.744**	-0.258	1

Table A6b: Pearson correlation among AMD parameters in dry Season

	E.C	pH	Aluminium	Sulfate	Copper	Chromium	Zinc	Nickel
E.C	1	-.494*	0.073	.507*	0.122	0.330	.576**	0.270
PH	-.494*	1	-0.164	-.663**	-0.196	-0.297	0.169	-0.134
Aluminium	0.073	-0.164	1	0.275	.476*	-0.191	0.078	0.379
Sulfate	.507*	-.663**	0.275	1	0.182	0.096	-0.002	0.107
Copper	0.122	-0.196	.476*	0.182	1	-0.058	0.087	-0.020
Chromium	0.330	-0.297	-0.191	0.096	-0.058	1	0.305	0.171
Zinc	.576**	0.169	0.078	-0.002	0.087	0.305	1	0.297
Nickel	0.270	-0.134	0.379	0.107	-0.020	0.171	0.297	1

Table A7: Annual sediment load of the River Shari-Goyain

Year	Annual Average Discharge (cumec)	According to Regression equation developed from Observed Sediment Load data by trap. $Q_s = 193.81Q^{0.8449}$ Annual Sediment Load(MT)	According to Regression equation developed from calculated data by Hossain's equation. $Q_s = 17.131Q^{1.2676}$ Annual Sediment Load (MT)
1966	146.7224	4.78786354	3.485991148
1967	104.9127	3.60634122	2.27864905
1969	108.8196	3.7194862	2.386742763
1970	146.1345	4.7716521	3.468297606
1973	141.0372	4.63063994	3.315666668
1974	154.6009	5.0041965	3.724953412
1975	144.3565	4.72255251	3.414892705
1976	114.8308	3.89235428	2.555086274
1977	149.6944	4.8696765	3.575740376
1978	90.90603	3.19509666	1.90014901
1979	128.8721	4.29083858	2.957418703
1980	94.01989	3.2873232	1.983028348

Year	Annual Average Discharge (cumec)	According to Regression equation developed from Observed Sediment Load data by trap. $Q_s = 193.81Q^{0.8449}$ Annual Sediment Load(MT)	According to Regression equation developed from calculated data by Hossain's equation. $Q_s = 17.131Q^{1.2676}$ Annual Sediment Load (MT)
1981	138.9779	4.57344895	3.254419257
1982	59.70315	2.2397993	1.115140696
1983	123.7372	4.14593428	2.808851352
1985	137.252	4.525418	3.20327659
1986	93.3131	3.26643144	1.964150751
1987	141.2838	4.63748138	3.323018824
1988	175.3531	5.56610647	4.369786849
1989	138.4254	4.55808406	3.238029562
1990	129.5463	4.30979905	2.97704671
1991	150.123	4.88145415	3.588723044
1992	95.65625	3.33559829	2.026878909
1993	156.0729	5.04442182	3.769966025
1998	196.2508	6.12160631	5.040148214
1999	178.4871	5.65004181	4.469021096
2000	220.556	6.75628703	5.844132146
2005	200.7169	6.23910409	5.185981975
2006	144.0107	4.71299303	3.404527181
2007	185.2878	5.83139985	4.685955976
2008	77.0085	2.77718979	1.539756288
2009	65.33237	2.41696878	1.250064302
2010	145.5005	4.75415294	3.449232347
2011	119.7355	4.03236413	2.694208366
2012	115.3808	3.90809925	2.570608395
2013	183.8105	5.79209366	4.638648528
2014	96.8473	3.3706558	2.058923169
2015	131.4579	4.36346828	3.0328396
2016	170.8955	5.44631977	4.229459761
2020-21	90.68327	3.18848042	1.89424881

Appendix-2

List of contract fishermen involve with PBRG fisheries sub-project (ID- 035) Component 2 (SUST)

Upazila: Golapganj
Village: Lalnogor, Union: Bagha Union

SL. No.	Name	Age	Educational Qualification	Marital Status	Cell Phone No.
1.	Abdul Hashim	55		Married	01727353079
2.	Azim Uddin	20		Unmarried	01733704603
3.	Amir Ali	50		Married	01761401755
4.	Sadik Mia	25	Class-4	Married	01762589106
5.	Abdul Gafur Mia	50		Married	01758318089
6.	Rubel Ahmed	20	Class-2	Married	01746269360
7.	Ibrahim	25		Married	01781427147
8.	Md. Ali Asgar	50	Class-9	Married	01734709263
9.	Ali Hossen	33		Married	01912200605
10.	Akbar Hossain	27	Class-6	Married	01775883383
11.	Rasel Ahmed	30		Married	01752784676
12.	Faruk Mia	55		Married	01710027874
13.	Rahim Uddin	45	Class-2	Married	
14.	Shafir Ahmed	40	Class-10	Married	01748134888
15.	Abdul Hamid	45	Class-2	Married	01754304612
16.	Md. Selim Uddin	46	Class-6	Married	01812853660
17.	Nur Uddin	60	Class-3	Married	01722062327
18.	Saro Mia	60		Married	01795974932
19.	Alauddin	39	Class-5	Married	01785477611
20.	Gias Uddin	35	Class-5	Married	01734206867
21.	Surman Ali	65		Married	01726218937
22.	Forman Ali	65	Class-5	Married	
23.	Kadir Ahmad	35	Class-5	Married	01778892937
24.	Fazlu Mia	35		Married	
25.	Abdul Chalik	45		Married	01786636501
26.	Abdul Mannan	60	Class-2	Married	
27.	Emran Ahmed	35	Class-6	Married	01721132000
28.	Jamir Uddin	60	Class-5	Married	01765736642
29.	NurulHaque	30		Married	01741617827
30.	Sahab Uddin	35	Class-6	Married	01782346652
31.	ShamsuddinLiton	25	Class-5	Married	
32.	Md. Salman Ahmed	22	Class-3	Married	01742855108
33.	Md. EmdadulHaque	22	Class-2	Married	01703155852
34.	Md. Roman Mia	38	Class-3	Married	01790184803
35.	Md. Lutfor Rahman	45	Class-8	Married	01753221418
36.	Md. Sahid	40		Married	
37.	Md. Kawsar Ahmed	37	Class-3	Married	01776126460
38.	Md. Imam Uddin	43	Class-2	Married	01739335692
39.	Md. Riaz Ahmed	40	Class-3	Married	01757057346

SL. No.	Name	Age	Educational Qualification	Marital Status	Cell Phone No.
40.	Md. Reshan Ahmed	30	Class-5	Married	01772520904
41.	Md. Majedul Islam	30	Class-6	Married	01860875976
42.	Md. Fakhrul Islam	27	Class-7	Married	01747318663
43.	Md. AbdusSobhan	30	Class-7	Married	01738946271
44.	Md. Anwar Hossain	35	Class-6	Married	01763475012
45.	Md. Sufian Ahmed	40	Class-6	Married	01751080882
46.	Md. Sharif Ahmed	42	Class-8	Married	01716270198
47.	Md. Misbah Uddin	60	Class-8	Married	01748709798
48.	Md. Jasim Uddin	38	Class-8	Married	01774999175
49.	Abdul Hasib	31		Married	01912163052
50.	Abdul Khalique	46	Class-3	Married	01719575483
51.	Nanu Mia	28	Class-5	Married	01717793616
52.	Md. Dulal	36	Class-3	Married	01771895755
53.	Md. Shamsir Mia	30	Class-3	Married	01735024057
54.	Md. Redwan Ahmed	30		Married	01772520904
55.	Md. Akhles Mia	50		Married	01721471889
56.	Md. Bilal	40	Class-3	Married	01724675224
57.	Md. Juru Mia	50	Class-3	Married	01780762311
58.	Islam Uddin	28		Married	01770968753
59.	Shukkur Ali	34	Class-5	Married	01782723076
60.	Sunam Uddin	32	Class-5	Married	01773036425
61.	Bablu	30	Class-5	Married	
62.	Nazrul Islam	27		Married	01734773206
63.	Mohammad Alam	65	Class-5	Married	01726786217
64.	Jahur Uddin	50		Married	01736646709
65.	Nurul Islam	40	Class-5	Married	01758229417
66.	Cherag Ali	38		Married	01735468201
67.	Islam Uddin	28		Married	01798705430
68.	Shajedul Islam	35	Class-2	Married	01731537120
69.	Md. Alim Uddin	22	Class-3	Married	01799713435
70.	Akhtar	35	Class-5	Married	01734525806
71.	Alim	35	Class-5	Married	
72.	Manik	50		Married	01727545100
73.	Anwar	45		Married	01834118786
74.	Jalil	32	Class-4	Married	01706175310
75.	MdSanwarHossen	18	Class-4	Unmarried	01733748866
76.	Md. Saleh Ahmed	55	Class-9	Married	01920126080

Upazila: Gowainghat
Village: Bolla, Nagargram, Union: Alirgaon

SL. No.	Name	Age	Educational Qualification	Marital Status	Cell Phone No.
77.	Dulal Ahmed	23	Class-7	Married	01725371561
78.	Md. Jaamshid Mia	50	Class-5	Married	01772964946
79.	AbdusSattar	45	Class-3	Married	
80.	Monir Uddin	30	Class-2	Married	01758155827
81.	Intaj Ahmad	45	Class-1	Married	
82.	Chandaram Das	55	Class-2	Married	
83.	Jowadullah	55	Class-1	Married	01742284125
84.	Chalik Mia	50	Class-2	Married	01820959711
85.	Ibrahim Ali	33		Married	01752133422
86.	Nirojon	35		Married	
87.	Chami Ali	60	Class-5	Married	
88.	Bodrul Islam	30	Class-5	Married	01755202155
89.	Mohammad Ali	55	Class-2	Married	
90.	Nirmol Chandra	46	Class-5	Married	
91.	Mortuj Ali	35	Class-2	Married	
92.	Krishna Das	36	Class-4	Married	01758424236
93.	Norendro Das	32	Class-5	Married	01729134611
94.	Anonta Das	28	Class-5	Married	
95.	Sarthor Das	36		Married	01737616598
96.	Kiron Das	33	Class-5	Married	
97.	Kanui Das	35		Married	
98.	Girindro Das	37	Class-1	Married	
99.	Surendra Das	29	Class-5	Married	01753217273
100.	Kajolram Das	38		Married	01741077017
101.	Arindro Das	20		Married	
102.	Ripon Das	28		Married	
103.	Badalram Das	38	Class-5	Married	01836975619
104.	Sabulram Das	36		Married	
105.	Kartik Das	30		Married	
106.	Birendro Das	29	Class-4	Married	01753884782
107.	Upendro Das	37	Class-8	Married	
108.	Anil Das	28		Married	01740029728
109.	Anando Das	50	Class-5	Married	
110.	Boloram Das	55	Class-5	Married	
111.	Shushonta Das	50	Class-5	Married	
112.	Babul Das	40		Married	01778462530

Upazila: Gowainghat
Village: Lakkhihaor, Jolurmukh, Union: Nandirgaon

SL. No.	Name	Age	Educational Qualification	Marital Status
113.	Shithil Bishwas	25		Married
114.	Piplu Bishwas	18	Class-8	Unmarried
115.	Nadu Bishwas	42	Class-7	Married
116.	Shree Nitay	35	Class-7	Married
117.	Jadu Bishwas	40		Married
118.	Nikhil Bishwas	35	Class-5	Married
119.	ShosenBishwas	35	Class-5	Married
120.	Nishi Bishwas	32	Class-8	Married
121.	LavoiBishwas	40	Class-5	Married
122.	JagindraBishwas	60	Class-9	Married
123.	Femananda	40		Married
124.	DIrendraBishwas	26	Class-3	Married
125.	RenuNamshudra	40	Class-2	Married
126.	KomudBishwas	40		Married
127.	Nikhil Bishwas	32	Class-8	Married
128.	SokhorBishwas	35	Class-5	Married
129.	KunjuBishwas	35	Class-3	Married
130.	Kanay	28	Class-2	Married
131.	BanuBishwas	25		Married
132.	Monilal	25	Class-3	Married
133.	Femanondo	50	Class-5	Married
134.	Bhutto Bishwas	30	Class-8	Married
135.	SajanBishwas	28	Class-5	Unmarried
136.	BoshontoBishwas	49	Class-5	Married
137.	Suresh Bishwas	35		Married
138.	KuusholBishwas	30	Class-2	Married
139.	LebuNomshudra	35	Class-3	Married
140.	KartikBishwas	30	Class-5	Married
141.	Bhutto Bishwas	30	Class-5	Married
142.	SaduNomshudra	35		Married
143.	Chandomoni	60		Married
144.	KanayBishwas	25	Class-3	Married
145.	Dinesh Bishwas	28	Class-5	Married
146.	Anil Bishwas	40	Class-7	Married
147.	GoneshBishwas	28	Class-7	Married
148.	ProchonnoBishwas	32	Class-4	Married
149.	Sunil Bishwas	35		Married
150.	Hitesh Bishwas	35	Class-6	Married
151.	Shree Fulendra	32		Married
152.	PandoiBishwas	22	Class-3	Married

Upazila: Gowainghat
Village: Noyakhel, Bamti, Union: Lakhnaut

SL. No.	Name	Age	Educational Qualification	Marital Status
153.	Haridash	42	Class-5	Married
154.	Kanchon Das	45	Class-2	Married
155.	Koton Das	45		Married
156.	Subol Chandra	45	Class-5	Married
157.	Choton Das	40	Class-4	Married
158.	Atul Das	30	Class-3	Married
159.	Nikhil Das	31		Married
160.	Sumon Das	22	Class-9	Married
161.	Bolai Das	35	Class-5	Married
162.	Romon Das	50		Married
163.	Nikhil Das	35	Class-2	Married
164.	Shamol Das	25		Married
165.	Bimol Das	22	Class-4	Unmarried
166.	Kajol Das	30		Married
167.	Sumon Das	28	Class-5	Married
168.	Anil Das	26		Married
169.	Kokil Das	25	Class-9	Married
170.	Lori Das	35		Married
171.	Pramud Ram Das	60	Class-1	Married
172.	Shadhan Das	40	Class-3	Married
173.	Ram Peari Das	65		Married
174.	Putul Das	32	Class-4	Married
175.	Radhay Das	50		Married
176.	Porimol Das	45	Class-5	Married
177.	Gedfes Das	55	Class-5	Married
178.	Sorindra Das	40	Class-2	Married

Upazila: Gowainghat
Village: TitkuliHaor, Mukhtola, Union: Alirgaon

SL. No.	Name	Age	Educational Qualification	Marital Status
179.	Nur Uddin	40	Class-7	Married
180.	ShamsulHaque	22		Married
181.	Thandu	35	Class-1	Married
182.	Moyna	40		Married
183.	Ansar	50	Class-2	Married
184.	Borhan	55	Class-2	Married
185.	Dulal	35		Married
186.	Ajahar	40	Class-5	Married
187.	Joynuddin	50		Married
188.	Nasir	45	Class-7	Married
189.	Jinnot	55	Class-5	Married
190.	Ator	50	Class-5	Married
191.	Rohijuddin	40	Class-7	Married
192.	Aiyub	50	Class-5	Married
193.	Ajahar	26	Class-3	Married
194.	AbulKalam	35		Married
195.	Abdul Khaleq	45		Married
196.	AbulKalam	27	Class-5	Married
197.	Abdul Aziz	47	Class-5	Married
198.	Ainuddin	50		Married
199.	Baharuddin	30	Class-5	Married
200.	Jowad Ali	50	Class-2	Married
201.	Hanu	50	Class-3	Married
202.	Alam	30	Class-3	Married
203.	Shahinur	45		Married
204.	Nannu Mia	55	Class-5	Married
205.	Haris	45	Class-5	Married
206.	Abdullah	50		Married
207.	Tojmmul Ali	58	Class-2	Married
208.	Husen Ahmed	67		Married

Upazila: Gowainghat
Village: ShialiarMukh, Union: Lakhnaut

SL. No.	Name	Age	Educational Qualification	Marital Status
209.	PabitraSarker	40	Class-7	Married
210.	Babul Sarker	60		Married
211.	Pobon Das	28	Class-3	Married
212.	Upendra	35	Class-2	Married
213.	Nirmol	40	Class-1	Married
214.	Kiron	25	Class-7	Married
215.	Abu Bishwas	28	Class-5	Married
216.	FulinBishwas	30	Class-2	Married
217.	BhuttuBishwas	45		Married
218.	GhanidraBishwas	60		Married
219.	BarindraBishwas	40	Class-5	Married
220.	DebindraBishwas	40	Class-5	Married
221.	JitendraNomshudra	25	Class-7	Married
222.	Anil Nomshudra	40	Class-5	Married
223.	AnantaBishwas	50		Married
224.	MonnchoLal	60		Married
225.	ShithilBishwas	30	Class-5	Married
226.	ShamolBishwas	30	Class-5	Married

Component-3 (RU)

Appendix-1

PBRG Sub-project (ID-035)
Project title: Techniques adoption and formulation of guidelines for sustainable management of haor and beel fisheries.

Questionnaire for baseline survey

Interviewer information

Name: …………………………………………………………………………...…………..
Designation: ……………………………………………………………………...…………...
Sex: 1/Male 2/Female
Age: ……………………………………………………….........………………………
Interview date ……………………………………………………….......…………………
Time………………...……………

I am collecting data for the project title "Technique's adoption and formulation of guidelines for sustainable management of Haor and Beel fisheries" funded by Bangladesh Agricultural Research Council (BARC), Project ID: 035. Your honest response to these questions will be highly solicited.

Information of responder

1. Your sex 1/ Female 2/ Male
2. Your age………………years old
3. Your education: 1/ No education 2/ Primary school 3/ Secondary school
   a. 4/ High school 5/ College 6/ University 7/Higher than University 7/ Other
4. Your main job: 1/ Government/city officer 2/ Private/state-owned company employee 3/Fisherman 4/Construction worker 5/Others………………………
5. What type of fishing method (s) do you use?
   a) Push net b) Lift net c) Cast net b) Hooks c) Chemicals d) Others……
6. What amount of fish do you collect every fishing event?
   a) 1Kg b) 2Kg c) Others………………………………………………..
7. What type of fish do you found in every fishing event?
   ....……………………………………………………
8. Has your fish catch increased or decreased using the same fishing effort as before?.......……………………………………………………………………………
9. What do you think about declining biodiversity/endangered species in wetland areas?
   a. 1/ Very serious 2/ Serious 3/ No problem 4/ Don't know
10. Which fish species you found in less amount?
    ....
11. Which fish species you think have been lost from the wetland?
    ……..…………………………………………………………………………….........
12. What are the causes you think responsible for biodiversity lost?

……..………………………………………………………………………………………

13. What is the biggest environmental problem facing the wetland?
    1/ Water pollution 2/ Soil erosion 3/ Climate change 4/ Others …....……
14. Do you have any knowledge about the impacts of fish sanctuary? ....
15. Is the exiting fish sanctuaries are sufficient? ....
16. What are the causes you think responsible for failure of fish sanctuary? ………………………………………………………………………………………
17. What is your opinion about the use of R.C.C. ring pipes and hexapods in fish sanctuary? …………………………………………………………………………………………
18. Do you support a stocking program in fish sanctuary? …………………………………………………………………………………………
19. Do you think stocking can improve fish populations? ....
20. What type of fish species you think will be better to stock in the sanctuary? ....

Comments (If any):

Name & Signature of the enumerator

Date:…………………………..

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