Fisheries Research in Bangladesh: Needs and Priorities

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PIU-BARC, NATP-2

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Project Implementation Unit
National Agricultural Technology Program-Phase II Project (NATP-2)
Bangladesh Agricultural Research Council
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Minister
Ministry of Agriculture
Government of the People's Republic of Bangladesh

Message

In Bangladesh, unfortunately like other areas, fisheries natural resources are also under the process of rapid degradation as cumulative effect of population growth, climate change and other natural disasters, limited water resource management efforts and various other human interventions. Apart from low production and productivity, genetic erosion, high post-harvest loss, inadequate fish processing, high input cost and inadequate market intelligence system remains the key challenges constraining the desired growth. However, in spite of the difficulties, Bangladesh is keeping in line with the world-wide fisheries progress with a remarkable growth to secure fifth position globally. In the recent years, the country has achieved self-sufficiency in fish production with per capita consumption of about 63.0 g/day against the required level of 60.0 g/day.

To meet the future demand of increasing population and to ensure the sectoral contribution toward nutrition security, emphasis should be paid through outlining of pertinent research issues with appropriate implementation strategies. Thus the country has to continue with the pace of sectoral progress facing a number of anthropogenic and climate driven challenges. The 8th FYP of the sub sector has also focused due importance on addressing strategy of existing issues and challenges to attain desired growth by 2024-25. Owing to the importance and potentials of the sub sector for ensuring future food security, fish production has been targeted about 5.0 million ton at the end of the 8th FYP and about 8.33 million ton in 2041. That will facilitate to a reality of country's dream of having a 'Bowl of Rice cum Fish'.

I duly acknowledge the timely initiative taken by PIU-BARC, NATP-2 with funds from the World Bank and IFAD towards formulating priority research for the fisheries sub sector for innovating knowledge and sustainable technologies of realistic nature. I also appreciate the contribution and sincere efforts of all scientists and experts, related stakeholders and academicians for undertaking hard labor in preparing this invaluable document.

I conclude that this would be a guiding document for future researchers, policy makers, academicians, investors, non-government organizations and development partners in order to culminate vicious cycles of malnutrition in facilitating a prosperous fisheries

Joy Bangla, Joy Bangabandhu
Long live Bangladesh

Dr. Muhammad Abdur Razzaque, MP

Minister
Ministry of Fisheries and Livestock
Government of the People's Republic of Bangladesh

Message

The fisheries sub-sector is a prospective supplier of palatable and safe protein for majority of country's people. It is potential to compensate the less efficient production system driven by climate change effects to a highly productive one through poly-culture and integration with crops. During the last decade the technological innovations and institutional reforms in the sub-sector contributed to a production level that transformed the country to a reliant one in fishes. One of the main driver of such achievement is the research endeavors undertaken following priority research areas published in 2012 by the Bangladesh Agricultural Research Council, among others.

The attempt for further production increase is threatened by a number of challenges like population increase, scarcity of farm land and destruction of fish sanctuaries, biodiversity loss, increased safe fish demand along with intensified natural climate change impacts. All these limitations could not be addressed but to formulate a pertinent priority document. Also, fortunately, there exists scope for an incessant fisheries sub-sectoral growth through a number of interventions. Given that, revising and updating of fisheries research needs prioritizing based on research issues captured from the grass root level workers and already adopted national policies. Undoubtedly, the development of the sector requires a coordinated holistic approach for implementing research with a view to maximize production in respect of environmental stewardship and efficient utilization of available resources, skills and capacity.

I am extremely happy that Project Implementation Unit-BARC, NATP-2 has taken necessary initiative in compiling the document on identification and prioritization of research areas of the fisheries sub sector wherein appropriate thematic areas and meaningful implementation strategies are duly incorporated. I hope that this document will serve as a guide for present and future researchers, policy makers and donors in conceptualizing a climate resilient and nutrition sensitive fisheries sub-sector. As such, the life-long dream of the ever-great Bangalee, the Father of the Nation, Bangabandhu Sheikh Mujibur Rahman for a hunger free and thriving nation would be a reality.

I thankfully recognize the contributions of all stakeholders for their utmost support in producing such an instrumental guiding document facilitating a smart Bangladesh by 2041.

Joy Bangla, Joy Bangabandhu
Long live Bangladesh

SM Rezaul Karim, MP

Secretary
Ministry of Agriculture
Government of the People's Republic of Bangladesh

Message

Bangladesh agriculture demonstrated a paramount progress in respect of food production and nutrition security in crops, livestock and fisheries from a food deficit one. This has been made possible due to toiling farmers accompanied by government stringent political commitment and support and innovations following the research priority set on 2012 by the Bangladesh Agricultural Research Council. But due immense global warming, population increase, climate driven natural calamities, rapid food habit change on account of increased income, dwindling natural resources, pest attack etc. the earlier research priority is not supportive but to the updated.

I realize that fishes are the principal sources of premium quality and most safe protein from time immemorial. Previously most of the fishes were from free water bodies but siltation, overfishing, high post-harvest loss, unconsciousness gradually contributed to reduce fish production accompanied by loss of fish biodiversity. It is a matter of great hope and pleasure that Bangladesh is now sufficient in inland cultured fish and 1st in Hilsha production globally. But we cannot be satisfied but to be vigilant in formulating a new research priority in order to mitigate the present and upcoming challenges. The fisheries sub-sector is potential and capable to contribute in future, like present, to meet up the higher food demand and malnutrition. Moreover, the sub sector is also well known as a source of substantial income from the less efficient production system impacted by global warming.

I am extremely happy that PIU-BARC, NATP-2 has taken a great initiative for preparing a priority research document in order to adopt pertinent research programs against the prevailing challenges to secure a productive, profitable and safe food fish production system. This document would help the future researchers, policy makers, investors and donors to undertake due measures to ensure a vibrant fish sub-sector.

I would like to congratulate Dr. SM Bokhtiar, Executive Chairman, BARC and Dr. Md. Harunur Rashid, Director, PIU-BARC, NATP-2 and concerned team members for their tireless effort for compiling such an awesome document towards building a food and nutrition reliant nation through envisioning a commercial fisheries sub-sector.

Wahida Akter

Joy Bangla
May Bangladesh live forever

Secretary
Ministry of Fisheries and Livestock
Government of the People's Republic of Bangladesh

Message

Just several decades ago people of Bangladesh used to rely on fish and rice as menu for almost every meal, based on which the myth 'Machee Bhatee Bangalee' was well conceptualized. Almost all of these fish resources were being naturally grown but minimum cultured fishes. Later, with the invent of modern technologies following the Agricultural Research Priority for Fish Sub-sector prepared by the Bangladesh Agricultural Research Council in 2012 and supported by policies, production incentives and private interventions have contributed towards enough fish production. The country has achieved self-sufficiency in fish production with per capita consumption of about 63.0 g/head/day against the requirement, 60.0 g/head/day. Over the days, emerging and novel challenges like fish biodiversity were mostly lost as a cumulative effect of siltation, overfishing, destruction of spawning ground, population growth, climate change driven disasters, scanty water resource management efforts and human interventions impacted to reduced fish production.

Under these backdrop, the unique emerging challenges could not be mitigated without undertaking new dimension research after an updated version of priority research areas. To satisfy the future demand and ensuring nutrition security, emphasis should be paid for outlining pertinent research issues with appropriate implementation strategies. As such, BARC undertaken right initiatives to grasp field level limitations through organizing regional workshops as bottom up approach along with reviewing policies and plans in formulating priority research. Such a prepared document would facilitate increased future food security and fish production to a target of about 5.0 million ton at the end of the 8th FYP and about 8.33 million ton in 2041.

My heartfelt thanks and sincere felicitations is due for Dr. SM Bokhtiar, Executive Chairman, BARC, Dr. Md. Harunur Rashid, Director, PIU-BARC, NATP-2 and the team responsible for taking difficulties in preparing this prestigious guiding document in building a prosperous and pulsating fisheries sub-sector.

I well aware and confident that this compilation would undoubtedly enable materializing the Vision 2041 and SMART Bangladesh reinforced with talent citizens.

Joy Bangla

May Bangladesh Live Long

Dr. Nahid Rashid

Executive Chairman
Bangladesh Agricultural Research Council

Foreword

Marine and freshwater aquatic system of Bangladesh is considered as a potential source for food supply, livelihood of millions and foreign exchange earning sub-sector along with a huge stock of biodiversity. To derive more benefit from the ecosystem for the future increasing population of the nation, research based sustainable management and production plan and its appropriate implementation is of immense importance. In this respect, adequate strengthening of research organizations and ensuring availability of sector wise expert scientist is equally essential in addition to setting priorities and research need. Over the decades with the invention of scientific technologies of aquaculture and fisheries and concomitant increased contribution of inland freshwater culture fish production elevated the per day intake. However, past research attempts are recognized inadequate to address the living challenges like increased production and profitability, high input cost, efficient management of natural resources, climate change mitigation, safe food, minimize yield gap and popularizing aquaculture technologies and management strategies etc.

Under the perspectives, it is important to transform fisheries sub-sector into a dynamic, market oriented and sustainable commercial sector through higher productivity, profitability, scientific management of inland and marine fisheries resources, intensification and diversification, value addition and development of effective market linkage toward a blue growth to envisage Vision 2041. In the line PIU-BARC, NATP-2 has undertaken a worthy drive to compile a document titled Fisheries Research in Bangladesh: Needs and Priorities to realize a flourishing sector through undertaking appropriate research programs.

I am sure that the document has critically reviewed and identified thematic research areas and strategic plan enabling to achieve fish production, consumption, processing, and export target facilitating a self-reliant fisheries sub-sector and a developed nation by 2041 as dreamt by the Father of the nation Bangabandhu Sheikh Mujibur Rahman.

My felicitation is due for Dr. Md. Harunur Rashid, Director, PIU-BARC, NATP-2 and his team for timely initiatives and efforts in compiling the document for the stakeholders for an incessant growth of the sub-sector.

Dr. Shaikh Mohammad Bokhtiar

Joy Bangla
May Bangladesh live forever

Director
Project Implementation Unit
NATP-2 Project
Bangladesh Agricultural Research Council

Preface

Fisheries sub-sector has been increasingly contributing to aquatic protein food production, food security and as a means of employment and livelihood of millions of the country over decades. The sub-sector is rich in diverse potential aquatic resources with an extended biodiversity of both fresh and marine fish species. For several years the country is enjoying self-sufficiency status in fish production.

With time advancement, increasing population resulted overexploitation and indiscriminating exploitation of the valuable aquatic resources for their food and livelihood which invited a lot of challenges. Habitat destruction, climate change, increased pollution, frequent disease outbreaks, genetic degradation, huge cost of aquaculture commodities, unregulated and unreported fishing emerged as parallel major threats to aquatic ecosystem and aquaculture practices. The situation demands more efficient and fruitful integrated scientific utilization of resources for their conservation, increased production and productivity. It is visualised that the present fish production growth rate cannot be sustained without technological breakthrough under a national perspective plan. Under stated circumstances, PIU-BARC, NATP-2 has come forward with an initiative to prepare a document to identify and prioritize the fisheries research issues realizing most pertinent themes and focuses.

I am extremely glad that we paid a great attention in consulting policies and also capturing the views and woes of fields in compiling the document. A huge interaction with the representative stakeholders from segments engaged in ecosystem based fisheries activities, research, extension, academy, trade, entrepreneurship along with comments and recommendations were considered to reflect the actual research need of field under set thematic areas in the document.

I am happy to extend my compliments and felicitation to all participating stakeholders for their heartfelt support and contributions in preparing this invaluable document for future researchers and policy makers to secure a talent nation and transform the sector as a pulsating one.

Joy Bangla
May Bangladesh live forever

Dr. Md. Harunur Rashid

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Abbreviations and Acronyms

4IR	:	The 4th Industrial Revolution
ARI	:	Agricultural Research Institute
BANBEIS	:	Bangladesh Bureau of Educational Information and Statistics
BARC	:	Bangladesh Agricultural Research Council
BAS	:	Bangladesh Academy of Sciences
BAU	:	Business As Usual
BAU	:	Bangladesh Agricultural University
BCSIR	:	Bangladesh Council for Scientific and Industrial Research
BFDC	:	Bangladesh Fisheries Development Corporation
BFRI	:	Bangladesh Fisheries Research Institute
BINA	:	Bangladesh Institute of Nuclear Agriculture
BLC	:	BRAC Learning Centre
BSMRAU	:	Bangabandhu Sheikh Mujibur Rahman Agricultural University
BSMRSTU	:	Bangabandhu Sheikh Mujibur Rahman Science and Technology University
BFMSTU	:	Bangamata Sheikh Fazilatunnesa Mujib Science and Technology University
CU	:	Chattogram University
CVASU	:	Chattogram Veterinary and Animal Sciences University
DMFRM	:	Digital Marine Fisheries Resource Mapping
DNA	:	Deoxyribonucleic Acid
DoE	:	Department of Environment
DoF	:	Department of Fisheries
DU	:	Dhaka University
ECA	:	Ecologically Critical Area
EEZ	:	Exclusive Economic Zone
FAO	:	Food and Agricultural Organization
FLID	:	Fisheries and Livestock Information Department
FS	:	Freshwater Station
FT-NIR	:	Fourier transform near-infrared spectroscopy
FYP	:	Five Year Plan
GAP	:	Good Aquaculture Practice

GCMS	:	Gas Chromatograph Mass Spectrometer
GDP	:	Gross Domestic Productd
GED	:	General Economic Division
GoB	:	Government of Bangladesh
HAU	:	Habigonj Agricultural University
HPLC	:	High-performance Liquid Chromatography
HSTU	:	Hajee Mohammad Danesh Science and Technology University
IMTA	:	Integrated Multitrophic Aquaculture
IOPA	:	International Plan of Action
IUCN	:	International Union for Conservation of Nature
IUU	:	Illegal, Unreported and Unregulated
JSTU	:	Jashore Science and Technology University
KGF	:	Krishi Gobeshona Foundation
KU	:	Khulna University
LCMS	:	Liquid Chromatography Mass Spectrometer
MFA	:	Marine Fisheries Academy
MFA	:	Ministry of Foreign Affairs
MFTS	:	Marine Fisheries and Technology University
MoA	:	Ministry of Agriculture
MoC	:	Ministry of Commerce
MoE	:	Ministry of Education
MoEF	:	Ministry of Environment and Forest
MoFL	:	Ministry of Fisheries and Livestock
MoF	:	Ministry of Finance
MoL	:	Ministry of Land
MoLGRD	:	Ministry of Local Government and Rural Development
MoP	:	Ministry of Planning
MoST	:	Ministry of Science and Technology
MoWR	:	Ministry of Water Resources
MoYS	:	Ministry of Youth and Sports
MPA	:	Marine Protected Area
MSY	:	Maximum Sustainable Yield
NATA	:	National Agricultural Training Academi
NARS	:	National Agricultural Research System
NATP	:	National Agricultural Technology Program

NBSAP	:	National Biodiversity Strategy and Action Plan
NFP	:	National Fisheries Policy
NGO	:	Non-Government Organization
NM	:	Nautical Mile
NOPA	:	National Plan of Action
NRM	:	Natural Resources Management
NSTU	:	Noakhali Science and Technology University
PCR	:	Polymerase Chain Reaction
PIU	:	Project Implementation Unit
PP	:	Perspective Plan
PSTU	:	Patuakhali Science and Technology University
R and D	:	Research and Development
RNA	:	Ribonucleic Acid
RS	:	Riverine Station
RU	:	Rajshahi University
SAU	:	Sher-e-Bangla Agricultural University
SDG	:	Sustainable Development Goal
SRS	:	Shrimp Research Station
SylAU	:	Sylhet Agricultural University
UHPLC	:	Ultra High Performance Liquid Chromatography
UMIC	:	Upper Middle Income Countries
USDA	:	United State Department of Agriculture
WRPO	:	National Water Management Plan

Unit

µg	:	Microgram
gm	:	Gram
ha	:	Hectare
kg	:	Kilogram
kj	:	Kilojoules
mg	:	Milligram
t	:	Ton

Introduction

The world's marine and freshwater ecosystems, the Blue World, are the future of mankind for providing food and livelihoods, essential ecosystem services and biodiversity (FAO, 2020). Fish (all finfish and shellfish), fisheries (capture fisheries), and aquaculture have been increasingly recognized for their significant contribution to the aquatic food production, food security, nutrition, employment, and livelihoods of millions of people world-wide, especially, in the past two decades. Fish and fish products are valuable sources of protein, micronutrients, vitamins and minerals which are not only important for diversified and healthy diets but also to address some of the most severe and widespread nutritional deficiencies (Troll et al., 2019). According to FAO (2022), the total world fisheries and aquaculture production in 2020 reached 177.8 million tons (M t) of aquatic animals (excluding aquatic mammals, crocodiles, alligators, caimans, and algae), comprising 90.3 M t (51%) from capture fisheries and 87.5 M t (49%) from aquaculture (Table 1). Compared to the average of 1990s, the global production of capture fisheries has been slightly increased by 1.57% in 2020, while that of aquaculture has been increased enormously by301% particularly due to tremendous aquaculture growth in Asia. Annual per capita aquatic animal food consumption has been increased from 9.9 kg in 1960s and 14.3 kg in 1990s to 20.2 kg in 2020. An estimated 58.5 million people were employed in the primary sector and livelihoods of about 600 million people depended at least partially on fisheries and aquaculture. The international trade of fisheries and aquaculture products generated USD 150.5 billion in 2020, which was increased by 223% compared to USD 46.6 billion in 1990s.

Table 1 World fisheries and aquaculture production, utilization and trade 2020 (Source: FAO, 2022)

	1990	2020
Production (million tons)		
Capture		
Inland	7.1	11.5
Marine	81.9	78.8
Total capture	**88.9**	**90.3**
Aquaculture		
Inland	12.6	54.4
Marine	9.2	33.1
Total aquaculture	**21.8**	**87.5**
Total world capture and aquaculture	**110.7**	**177.8**
Utilization (million metric tons)		
Human consumption	81.6	157.4
Non-food uses	29.1	20.4
Per capita apparent consumption (kg)	14.3	20.2
Trade		
Exports in quantity (million metric tons)	39.6	59.8
Share of exports in total production	35.8%	33.7%
Exports in value (USD billion)	46.6	150.5

In the pace of global scenario, fisheries and aquaculture have been contributing significantly to nutrition sensitive food supply, national and household income, and

overall socio-economic development of Bangladesh. Fisheries sub-sector, engaging around 12% of the total population directly and indirectly for their livelihoods, has produced a total fish production of 4.62 million ton (M t) in 2020-21 with a share of 3.57% to national and 26.50% to agricultural GDP (BBS, 2021). The country has achieved self-sufficiency in fish production with per capita fish consumption of 62.58 g/day against the requirement of 60 g/day (DoF, 2022). According to the State of World Fisheries and Aquaculture (FAO, 2022), Bangladesh has been placed among the world fish producing countries with the rank of 3rd, 5th, and 1st in inland open water capture, aquaculture and hilsa production, respectively. The fisheries sub-sector has been earning a notable amount of foreign exchange. In 2020-21, the sector earned BDT 4,089 crore by exporting almost 76.59 thousand ton of fish and fisheries products. Over the period of 2001 to 2021, Bangladesh's production of total capture fisheries has been increased by 79.56%, while that of aquaculture has been increased by 235.43%, with an annual growth rate outstripping the crop sector.

The status of Bangladesh fisheries and aquaculture has come up with the key message that the country's fisheries and aquaculture production will continue to grow, as has been forecasted to an increase of 14% by 2030 in global perspective (FAO, 2022). While aquaculture will be holding great potential, sustainability of its growth must be ensured. Although aquaculture now provides around half of the fish for direct human consumption and is set to grow further, capture fisheries continues to make essential contributions to the food and nutrition security of poor people and is often the most important source of fish (Belton and Thirsted, 2014). Inland fisheries biodiversity is also important for maintaining the gene pool to support aquaculture.

Although the country has succeeded to maintain growth continuum in fisheries sub-sector during the last decade, the broad aqua-ecosystem along with the great diversity of fish and fisheries presents considerable challenges for further progression. Increasing pollution, over-exploitation, and Illegal, Unreported and Unregulated (IUU) fishing, climate change, disease outbreak, genetic erosion, poor quality and high cost of aquaculture inputs, etc. have become major threats to the aquatic eco-systems and aquaculture. These threats underpin the need for more resource efficient, integrated and socially inclusive concepts. FAO has come-up with the "Blue Growth Initiative (BGI)" model for sustainably developing fisheries and aquaculture for maximizing economic and social benefits while minimizing environmental degradation from these sectors (FAO, 2017).

Aligning with global initiatives, Bangladesh has greatly emphasized on fisheries sub-sector in its Perspective Plan 2041 and Delta Plan 2100 for increased production, consumption and trade. In the face of increased population growth and different natural and man-made threats and interactions related to culture and capture fisheries systems, the Government has set targets to sustain the current growth performance of fisheries sub-sector aligning with development plans and policies. The 8th Five-year Plan (FYP) of the Government has set a target of 4.99 M t fish production in 2024-25 with 22.44% increase from the baseline of the 7th FYP (GED, 2020a).

In this backdrop, there are rampant needs for increasing productivity and production from both culture and capture fisheries and transforming the subsistence fisheries to industry-based aquatic food system for domestic and global market. Fisheries and aquaculture represent dynamic systems characterized by a number of bio-ecological diversity and complexity. These diversity, complexity and dynamism are limited not only to the biological aspects along with current and forthcoming consequences of climate change of the system but also tow technological, economic, socio-cultural and political dimensions. To address these and meet the future demand of aqua-food production, there is no alternative of concerted efforts to generate multi-dimensional innovation-driven research knowledge for appropriately tuning our fisheries to highly productive, climate resilient and market-oriented resources over the long period. Climate and environment friendly policies and practices are also crucial.

Therefore, the approach to managing fisheries and aquaculture for achieving maximum outputs requires a holistic arrangement of systematic research focusing the target areas of national needs with changing socio-economic and natural environment. BARC prepared a vision document on "Research Priorities in Bangladesh Agriculture for 2030 and beyond" in 2012, where a few priority research areas for fisheries sub-sector were listed (BARC, 2012). However, this document has to be updated and a separate fisheries research priority document needs to be developed to align with the Bangladesh Perspective Plan (2021–2041), the Delta Plan 2100 and other relevant policy documents. This is highly required because of its adjustment with the contextual and temporal changes and to undertake demand-driven research for addressing the need of technology users in the present and coming decades.

The current document aims to analyze the fisheries sub-sector and its related plans and policies, and identify constraints, research needs and prioritize research areas for the next decades in participation with stakeholders. The research areas have been identified and prioritized for enhancement of fisheries productivity and production, improved efficiency in resource utilization and conservation, development of quality products, ensured fish and fishers' welfare, and enhanced sustainability. This document will play a key role in the research planning cycle of the concerned National Agricultural Research System (NARS) institute, i.e. Bangladesh Fisheries Research Institute (BFRI), universities and other organizations who are involved in fisheries research and development.

Methodology

Approach

Setting research priorities is a formal procedure for effectively targeting research agenda that have potential benefits for sustainable outcomes. In the process of research priority setting, considerations are taken into account the available fisheries resources, focus or scope of the research, identification of field-level problems and challenges, values of different levels of stakeholders, and political environment as well. Several methodological approaches were combined to a consensus framework model (Fig. 1) with an aim of acquiring comprehensive research priority setting for current and future fisheries research in the country.

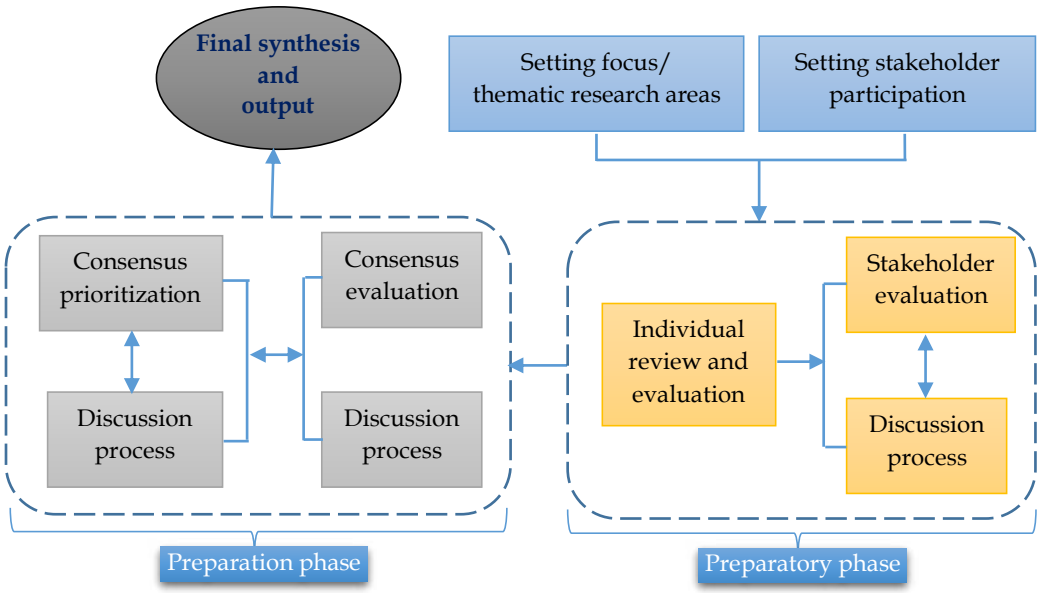

Fig. 1. Conceptual framework model for research priority consensus.

Priority setting process

Within the framework model, five major activities (Fig. 2) were identified and performed for setting the scope of entire research prioritization exercise under three different 'filters'. The ***first filter*** was applied during the regional fisheries sub-sectoral workshops, focusing on the identification of bottom level constraints through stakeholders' discussion (as mentioned earlier). Potential relevant stakeholders e.g. Public extension agencies, NARS institutes, university teachers, NGOs, fish entrepreneurs/farmers, private organizations, fisheries input suppliers, etc. were identified region-wise through online communication by the Project Implementation Unit of BARC (PIU-BARC), National Agricultural Technology Program Phase II Project (NATP-2). In the inception

meetings, preliminary ideas and process for research priority identification were shared. A group for each thematic area was formed for each of eight administrative divisions. Each group had a Lead and Co-lead person to prepare the PowerPoint presentation and papers in consultation with other members. Guidelines for preparation of presentations were prepared and provided ahead of scheduled workshop by PIU-BARC to the presenters. A total of eight day-long workshops (Table 2) on "Identification of Agricultural Research Priorities for Fisheries sub-sector" were organized by PIU-BARC, NATP-2.

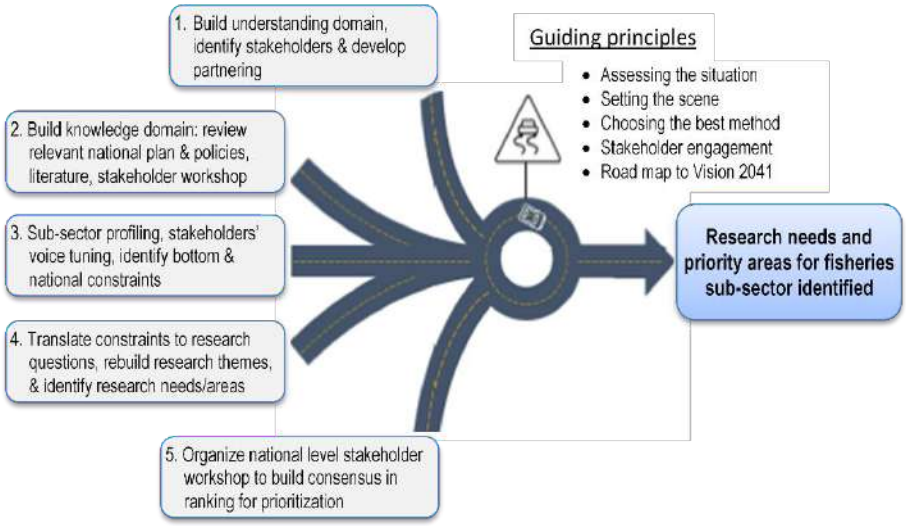

Fig. 2. Schematic diagram showing a roadmap illustrating how the five activities are linked to identify research priority areas

Along with fish farmers/entrepreneurs, representatives from different organizations, and officials and experts from PIU-BARC, Krishi Gobeshona Foundation, NGOs participated in the workshops. A total of 625 participants were participated in eight regional workshops (Table 2). Their organization-wise distribution of participants is shown in Fig. 3. The purpose of the workshops was to collate broader views of stakeholders for stock-taking of current status and problems by region, and to identify future research needs/areas for fisheries sub-sector.

Table 2. Details of regional workshops on "Identification of Research Priority Areas for Fisheries sub-sector"

Division/Region	Workshop venue	Date	No. of participants
Khulna	CSS Ava Centre, 82 Rupsha Strand Road, Khulna 9100	14.06.2022	65
Rajshahi	Ashrayan Centre, Paba, Rajshahi	20.06.2022	52
Barishal	BRAC Learning Centre (BLC), Barishal	02.07.2022	79
Chattogram	Chattogram Veterinary and Animal Sciences University (CVASU) Auditorium, Chattogram	08.07.2022	75
Rangpur	RDRS BangladeshConference Room, Dhap Road, Rangpur	05.09.2022	94
Sylhet	BRAC Learning Center (BLC), Khadimnagar, Sylhet	14.09.2022	80
Mymensingh	Bangladesh Institute of Nuclear Agriculture (BINA) Auditorium, Mymensingh- 2201	25.10.2022	80
Dhaka	National Agriculture Training Academy (NATA) Auditorium, Joydebpur, Gazipur- 1701	09.11.2022	100
Total			**625**

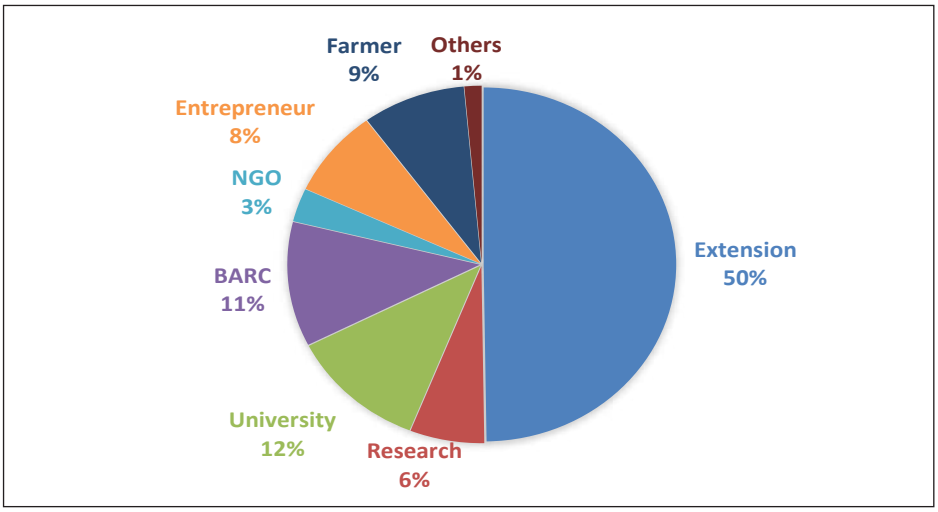

Fig. 3. Percentage of total participants from different organizations in eight regional workshops on research priority identification for fisheries sub-sector

The ***second filter*** concentrated on systematic individual review and analysis of fisheries sub-sector profile, relevant literatures, Government plans and policies, current research and research evidence gap, and previous priority setting exercises. The stakeholders' opinion and recommendations of regional workshops were also reviewed, synthesized, and evaluated. Besides, formal and/or informal in-person and organizational discussions/interviews were also conducted on particular issues that emerged during the process of research priority exercise. Based on the regional workshop outputs, the pre-set thematic areas were rebuilt for the current research priority setting process.

A clear focus or scope of specific thematic research areas to be addressed was defined relating to different aqua-ecosystems. Based on the broader views of stakeholders and specific recommendations of workshops, individual analysis and assessment of research constraints/problems were performed, and the constraints were translated into research questions and transformed into fisheries resource-specific research needs for each of the rebuilt thematic areas.

The ***third filter*** was applied during a final sectorial workshop, followed by the regional workshops and interim desk works emphasizing on narrowing the process for ranking of research priority areas through building a holistic consensus. In the workshop, a list of priority research areas that was prepared through the exercises of the first and second filters was presented to the workshop participants. A total of 92 persons from research (BFRI, BORI, BARC), extension (DoF), universities, MFA, World Fish, private entrepreneurs, BFDC, and others (KGF, PMU-NAPT-2, PIU-BARC, NAPT-2) participated in the workshop (Fig. 4).

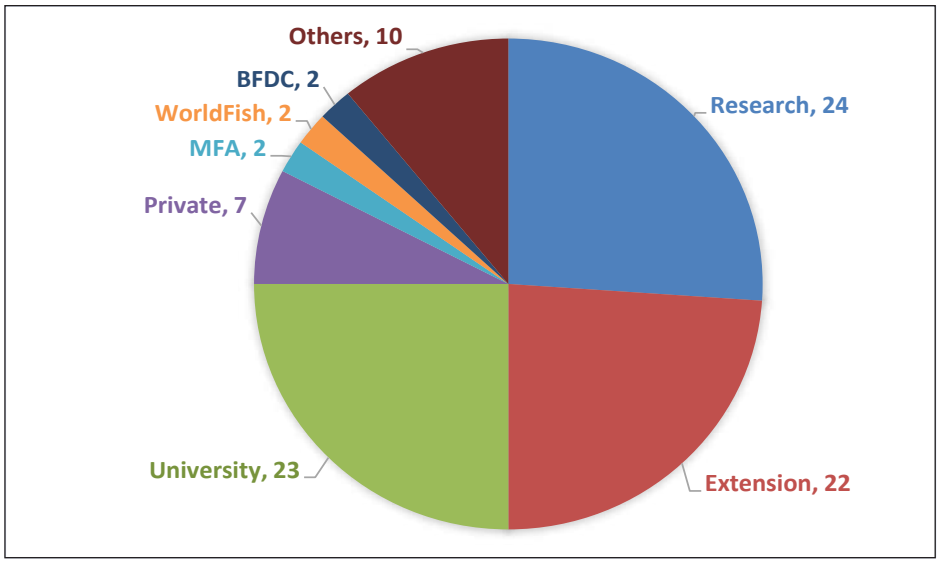

Fig. 4. Number of representatives from different stakeholders participated in priority ranking workshop by profession

Priority setting criteria and consensus building

Three most commonly sed categories in prioritization (Vestola 2010) were assigned as:

a) 'High': critical - to be addressed in immediate future,
b) 'Medium': potentially critical - to be addressed in near future, and
c) 'Low': not critical - to be addressed if resources permit but should not be discarded.

Simultaneously, the identified research areas were further prioritized using different time-scales as follows:

a) 'Short-term' - < 3 years,
b) 'Medium-term' - 3 to 5 years, and
c) 'Long-term" - 5+years (BARC, 2012).

During the ***third filter*** exercise, the priority of each research area was set both in category level and time-scale level considering the priority ranking by the workshop participants. In the workshop, ranking for the research areas was done in two ways. Firstly, the ranking score sheets were supplied to each participant for priority ranking individually. Secondly, another sets of ranking score sheets were supplied to groups that were formed for each thematic research areas. The criteria that were used by the workshop participants for ranking of research priority areas are given in Table 3. Relevant criteria were identified to facilitate the group discussion for setting priorities and building a common agreement and coverage as much as possible. In the workshop, priority marking exercise was done in two tiers. Firstly, the stakeholders marked both category and time-scale priority levels individually and then marked in a group for each thematic area.

Table 3. Criteria for ranking research priority areas

Criteria	Determinants
a) Appropriateness	• Potential utilization of the research area • Potential to generate innovative knowledge • Enhancing entrepreneurship • Culturally accepted
b) Relevance	• Equity focus and community concern/demand • The size of the problem • Contribution to the national and sectoral objectives
c) Feasibility	• Capacity of the system to support the research • Financial and human resources available • Cultural/political environment
d) Impact of research output and adoption	• Chance/opportunity to implement the research • Use of the research results • Link of the research to policy decisions • Overall reduction of the problem including cost

Numerical numbers of 1, 2 and 3 were assigned for high, medium and low and for short-, mid- and long-term ranking, respectively. The weighed values of score, along with suggestions and recommendations of participants were evaluated to build a consensus for ranking and finalizing the research priority document for fisheries sub-sector. However, the 8th Five Year Plan, Bangladesh Perspective Plan 2041 and Delta Plan 2100, which aim to transform Bangladesh into a middle-income country by 2030 and a prosperous country by 2041were further linked for producing the final list of research priorities.

A few of the photographs from different workshops are shown below:


(a) Khulna


(b) Rajshahi


(c) Barishal


(d) Chattogram


(e) Sylhet

(f) Rangpur

(g) Mymensingh

(h) Dhaka

Photos: Photographs of day-long expert panel discussion meeting for finalization of research priority areas for fisheries sub-sector

Photos: Photographs of final stakeholder workshops for building consensus on prioritization of research areas for fisheries sub-sector

Photos: Photographs of day-long expert panel discussion meeting for finalization of research priority areas for fisheries sub-sector

Fisheries Sub-Sector Profile

The fisheries sub-sector in Bangladesh is broadly divided into Inland fisheries and Marine fisheries, where Inland fisheries is further sub-divided into Inland open (capture) water and Inland closed (culture) water fisheries.

Physical Resources

According to the data of FRSS (Fisheries Resources Survey Systems) of the Department of Fisheries (DoF, 2022), the area of inland open water capture fisheries habitat has been decreased by13.65% from 2002-03 (4.47 million ha) to 2020-21 (3.86 million ha). In contrast, the area of inland closed water culture fisheries has been significantly increased by 94.1% from 4.37 million ha in 2002-03 to 8.48 million ha in 2020-21. Over the period of 2002-03 to 2020-21, the area of pond has been increased from 0.29 to 0.40 million ha and that of shrimp/prawn farm from 0.14 to 0.27 million ha. In addition, about 0.15 million ha of seasonal water areas including paddy field and borrow pit has been brought under culture.

Inland open water (capture) resources

The division-wise area distribution of inland water resources excluding rivers and estuaries in 2021-22 is given in Table 3.1 (DoF, 2022a). The inland open water has five types of habitats viz, rivers and estuaries, the Sundarbans, beels, the Kaptai lake, and floodplains. The pride of Bangladesh is its four major river systems, which are(i) the Brahmaputra-Jamuna, (ii) the Ganges-Padma, (iii) the Surma-Meghna, and (iv) the Chittagong Region river system. A total number of rivers is about 700 including tributaries with a total length of about 24,140 kilo meter (km) (https://en.banglapedia.org/index.php/River) and an area of 8.54 million ha (DoF, 2022a) is of fisheries importance. Of the inland open water area, floodplains account the major share (68.54%) dedicating to 2.32 million ha for subsistence fisheries, 0.08 million ha for fish fry release program and 0.25 million ha haors. The haors that are the marshy wetland ecosystem of a huge fishery-potential remain flooded for about 7-8 months a year, located in the north-eastern region of Bangladesh. According to FRSS (DoF, 2022a), there is a total of 0.25 million ha of haor located mainly in all districts of Sylhet division (0.14 million ha) and in other districts of Kishoreganj (0.06 million ha), Netrokona (0.04 million ha) and Brahmanbaria (0.008 million ha). The country has 0.114 million ha of low-lying depressions on a wetland or floodplain, which are sometimes either seasonal or perennial and called as 'Beel'. About 0.01million ha of beels are natural sources of fish production and about 0.02 million ha has been brought under the beel nursery program. There is only artificial man-made creek shaped lake of 0.068 million ha known as Kaptai Lake located in the Kaptai upazila under Rangamati district of Chattogram division.

Table 4. Division-wise inland open (capture) water area excluding river and estuaries in 2020-21

Division	Inland Open Water Area (ha)*						Total	%
	Sunder-bans	Beels		Kaptai lake	Floodplains			
		Natural source	Beel nursery		Fry released program	Haor		
Dhaka	-	12833	3469	-	28071	63956	108329	15.71
Mymensingh	-	21181	1388	-	2674	40240	65483	9.50
Rajshahi	-	21398	5507	-	16371	-	43276	6.28
Chattogram	-	788	479	68800	7027	8050	85144	12.35
Khulna	177700	6582	1017	-	6695	-	191994	27.85
Barishal	-	75	-	-	2716	-	2791	0.40
Rangpur	-	5507	1237	-	3690	-	10434	1.51
Sylhet	-	30534	2166	-	9806	139471	181977	26.40
Total	**177700**	**98898**	**15263**	**68800**	**77050**	**251717**	**689428**	**100**

Source: DoF, 2022a

**Excluding river, estuary and subsistence floodplains as no division-wise data are available*

Inland closed water (culture) resources

The inland closed water habitats include ponds, seasonal cultured water bodies and baors in freshwater ecosystem, and shrimp, prawn and crab farms in littoral low-lying intertidal coastal ecosystem in Bangladesh (Table 5).

Table 5. Division-wise inland closed (culture) water area in 2020-21

Division	Inland Closed Water Area (ha)								
	Pond	Seasonal cultured		Baor	Shrimp/ prawn farm	Crab farm	Pen culture	Total	%
		Floodplain & paddy field	Borrow pit						
Dhaka	45624	38010	1086	2361	1315	-	6165	94561	11.21
Mymensingh	45364	7098	314	-	1	-	334	53111	6.29
Rajshahi	71749	8425	2208	-	8	-	128	82518	9.78
Chattogram	90213	31988	3595	-	45767	135	436	172134	20.40
Khulna	58024	21216	4176	3310	212083	9425	7	308241	36.53
Barishal	32703	15365	973	-	3825	42	68	52976	6.28
Rangpur	42719	11667	1309	-	21	-	161	55877	6.62
Sylhet	21229	1801	1261	-	5	-	15	24311	2.88
Total	**407625**	**135570**	**14922**	**5671**	**263025**	**9602**	**7314**	**843729**	**100**

Source: DoF 2022a

The total pond area under fish culture is about 0.41 millionha (Table 5).The top 10 districts in terms of pond area coverage are presented in Fig. 5. There is highest pond area of about 0.029 million ha in Mymensingh district and the lowest of below 0.001 million ha in the hill tract districts of Bandarban (518 ha) and Rangamati (484 ha). Over the period of 18 years, the pond area has been increased by 71.32% and shifted from traditional extensive to semi-intensive (59%), intensive (29%) and highly intensive (4%) systems. The maximum areas of semi-intensive (0.06 million ha), intensive (0.05 million ha), and highly intensive (0.01 million ha) are located in Chattogram, Rajshahi, and Mymensingh division, respectively (Fig. 6).

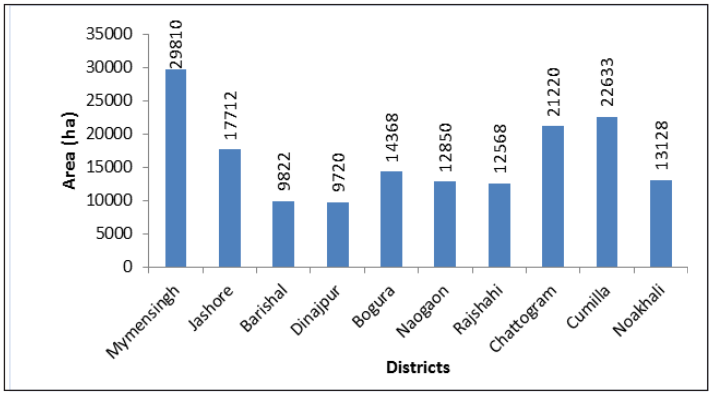

Fig. 5. Top ten districts of pond area coverage in 2020-21
Source: DoF 2022a)

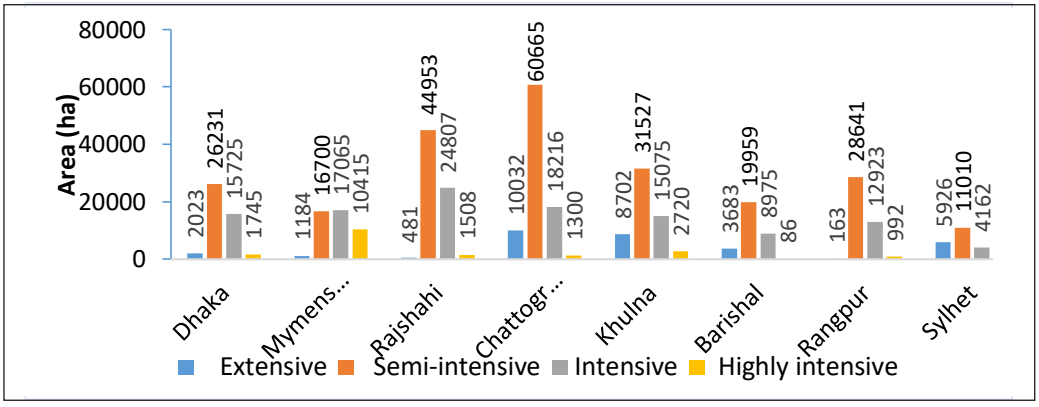

Fig. 6. Division-wise distribution of pond area by fish culture system in 2020-21
Source: DoF 2022a

About 0.136 million ha of seasonal flooded area with temporary boundary are utilized for fish culture in rice fields. Division-wise distribution of seasonal cultured waterbodies is presented in Fig. 7. The highest area of seasonal cultured waterbodies is located in Cumilla district (0.03million ha) followed by Barishal (0.012 million ha), Jashore (0.012 million ha) and Faridpur (0.011 million ha). The coverage of such waterbodies in other districts ranges from 28 ha to 6000 ha (DoF, 2022a). A total of 0.015 million ha borrow pits has been brought under aquaculture of which the highest area (0.02 million ha) is in Kushtia followed by 0.002 million ha in Chattogram and 0.001 million ha each in Pabna and Jhenidah districts. There are about six hundred baors or oxbow lakes (created by

changing or dying river course) in three greater districts with the highest area in Jashore (2473 ha) followed by Faridpur (2361 ha) and Kushtia (837 ha), which have a high potential of fish production.

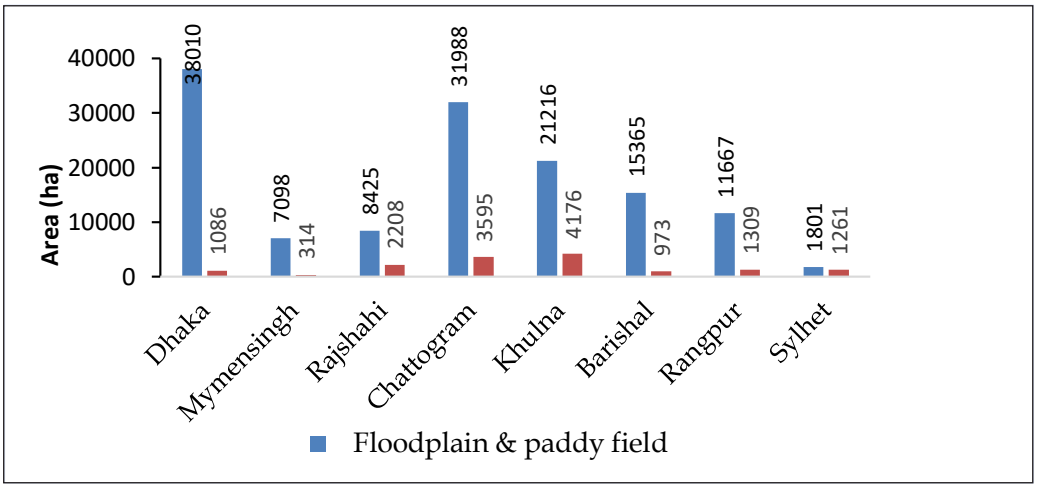

Fig. 7. Division-wise area (ha) distribution of seasonal cultured water
Source: DoF 2022a

The area distribution of shrimp, prawn and crab farms in 2020-21 is presented in Fig. 8. While shrimp (bagda) is cultured in coastal saline/brackish water ecosystem, prawn (golda) is cultured both in brackish water and freshwater ecosystems.

The total shrimp/prawn farms have been increased by 52% in the last 18 years with 0.19 million ha for shrimp, 0.071 million ha for prawn and 0.009 million ha for crab culture (DoF, 2022a). About 75% of shrimp culture area is concentrated in three southwest coastal districts of Khulna, Satkhira and Bagerhat and about 22% area exists in Cox's Bazar. Similarly, 97% of prawn and 98% of crab culture areasare located in Khulna region.

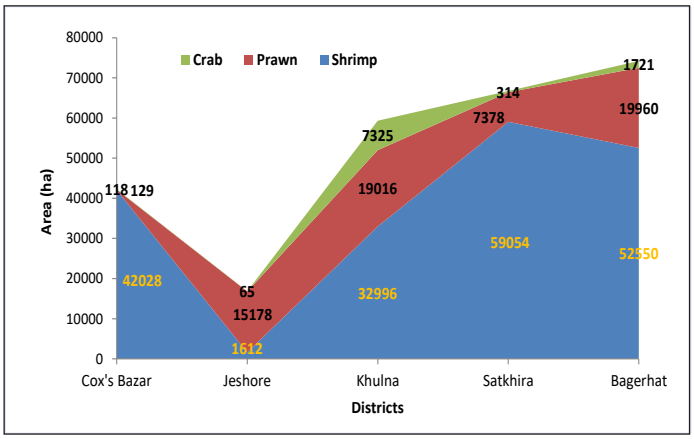

Fig. 8. Area distribution of shrimp/prawn farm in 2021-22 by species. *(Source: DoF 2022a)*

Marine water resources

There are recent declarations of the International Tribunal for Law of the Sea (ITLOS) regarding the Bangladesh-Myanmar maritime boundary (2012) and the Arbitral Tribunal of the UNCLOS on India-Bangladesh maritime boundary (2014). According to these declarations, Bangladesh has established sovereign rights on more than 118,813 km^2 area of territorial sea, 200 nautical miles (NM) of Exclusive Economic Zone (EEZ) and the continental shelf up to 354 nautical miles from the Chattogram coast. The main commercial fishing grounds (Fig. 9) in the exclusive economic zone (EEZ) in the Bay of Bengal are Swatch of no Ground, Middle Ground, South Patches and South of South Patches.

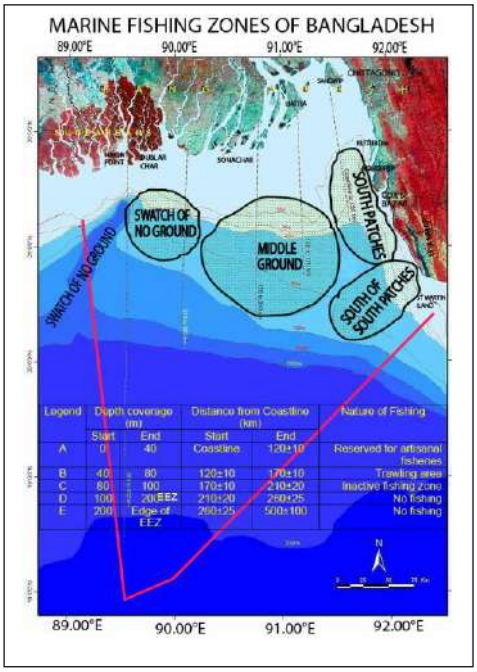

Fig. 9. Fishing grounds in the Bay of Bengal, Bangladesh

(Source: Sattelite Image Marine Fisheries Surveillance & Management Unit, Chittagong).

In Bangladeshi marine waters, fish resources are extracted in three tiers: (a) up to 40 m in depth from the coastline where normal fishing boats can operate; (b) from 40 m to 200 m in depth where mid-water trawlers can operate; and (3) from 200 m in depth to the end of the EEZ where long-liner trawlers can run (Islam et al., 2017). Currently, starting from the coastline to 40 m depth in the Bay, 32,440 km^2 are open to around 32,857 mechanized and 34,810 non-mechanized fishing boats. There are only 234 trawlers that are allowed for fishing in these regions by the government (DoF, 2022a). Among 188,707 gears operated in 2020-21, 62.72% were Gill net, 22.48% Set Bag net, 6.29% Long Line.

Biological resources

Freshwater fisheries biodiversity

A total of 260 finfish and 24 prawn species are known to inhabit in the freshwaters of Bangladesh with 12 exotic finfish species (IUCN, 2015). In addition, 4 species of crab, 16 species of gastropods, 6 species of bivalves,10 species of mussels, and 3 species of turtles are identified in Bangladesh territory (Begum, et al., 1989; Siddiqui et al., 2007). Some of the commercially important freshwater fish and shellfish species are listed in Table 6.

Table 6. Name of the commercially important freshwater finfish and shellfish (culture and capture) species

Sl #	Scientific name	Common name	Local name	Remarks
1.	*Labeorohita*	Indian major carp	Rui	Native
2.	*Gibelioncatla*	Indian major carp	Catla	Native
3.	*Cirrhinuscirrhosus*	Indian major carp	Mrigal	Native
4.	*Labeocalbasu*	Indian major carp	Kalibaus	Native
5.	*Labeobata*	Minor carp	Bata	Native
6.	*Labeoboga*	Minor carp	Bhangan	Native
7.	*L. gonius*	Minor carp	Ghonia	Native
8.	*Hypophthalmichthysmolitrix*	Chineese carp	Silver carp	Exotic
9.	*Ctenopharyngodonidella*	Chineese carp	Grass carp	Exotic
10.	*Arichtithysnobilis*	Chineese carp	Bighead carp	Exotic
11.	*Cyprinuscarpio*	Common carp	Common carp	Exotic
12.	*Anabas testudineus*	Climbing perch	Koi	Native
13.	*Anabas testudineus*	Climbing perch	Thai/Vietnam Koi	Exotic
14.	*Pangasiuspangasius*	Shark catfish	Pangas	Native
15.	*Pangasionodonhypophthalmus*	Shark catfish	Thai pangas	Exotic
16.	*Wallagoattu*	Helicopter catfish	Boal	Native
17.	*Speratаaor*	Long-whiskered catfish	Ayr	Native
18.	*S. seenghala*	Long-whiskered catfish	Guji	Native
19.	*Channastriatus*	Snake head fish	Shol	Native
20.	*C. marulius*	Snake head fish	Gojar	Native
21.	*C. punctatus*	Snake head fish	Taki	Native
22.	*Heteropneustesfossilis*	Asian stinging catfish	Shing	Native
23.	*Clariasbatrachus*	Walking catfish	Magur	Native
24.	*Oreochromisniloticus*	Nile tilapia	Tilapia	Exotic
25.	*Puntiussarana*	Olive barb	Sorpunti	Native
26.	*Mystuscavasius*	Gangetic catfish	Gulsha	Native
27.	*M. tengra*	Striped catfish	Tengra	Native
28.	*Barbodesgonionotus*	Silver barb	Thai sorpunti	Exotic
29.	*Ompokpabda*	Two stripe catfish	Pabda	Native
30.	*Macrobrachiumrosenbergi*	Giant river prawn	Golda chingri	Native
31.	*Macrobrachiummalcolmsonii*	Monsoon prawn	Chatkachingri	Native
32.	*Lamellidensmarginalis*	Freshwater Mussel	Jhinuk	Native
32.	*Lamellidensjenkinsianus*	Freshwater Mussel	Jhinuk	Native

Marine fisheries biodiversity

A total of 740 marine fish species of 389 genera and 145 families under 30 orders have been reported inhabiting in the coastal and marine water of Bangladesh (Habib and Islam, 2020).

Among these fishes, the authors reported 81 cartilaginous species (sharks, skates and rays) of 42 Genera and 659 bony fishes of 347 Genera. More than half of the total species (398) have been recorded from the Perciforms order. Marine water in Bangladesh also contains 32 species of shrimp, 3 species of lobsters, 12 species of crab, 282 species of gastropods and 142 species of bivalves. Hossain (2001) stated that seven species of edible oysters were found in the coastal areas of the country. Eight species of genus Pinctada and one species under Placuna belongs to pearl oysters are available in Bangladesh. Among them, *Pinctadafucata* is the best species for pearl production through induced technique. Some of the commercially important marine and brackish water finfish and shellfish species are listed in Table 7.

Table 7. Name of commercially important marine and brackish water finfish and shellfish species

Sl #	Scientific name	Common name	Local name
1.	*Rhizoprionodonacutus*	Requiem sharks	Hangor, Kamot
2.	*Eleutheronematetradactylum*	Four Thread Tassel fish	Tailla
3.	*Thunnus albacores*	Tuna	Tuna
4.	*Harpodonnehereus*	Bombay-duck	Loittya, Nehari
5.	*Protonibeadiacanthus*	Spotted Croaker	Kala Poa, Kala Datina
6.	*Euthynnusaffinis*	Tuna	BomMaitta
7.	*Dasyatiskuhlii*	Blue spotted rays	SaplaPata
8.	*Hilsailisha*	River shad	Ilish
9.	*Thryssasetirostris*	Long jaw thryrssa	Phasa
10.	*Hippocampus kuda*	Sea horse	SamudraGhora
11.	*Gymnurapoecilura*	Long tailed butterfly ray	Padmamoni, Kulta
12.	*Dasyatisbennetti*	Skates and Rays	Sankush, HaushPata
13.	*Sardinellafimbriata*	Fringe scale sardine	Khaira
14.	*Stolephorus tri*	Spined Anchovy	Kata Phasa
15.	*Argyrosomusamoyensis*	Amoy croaker	Poa, Poma
16.	*Liza subviridis*	Greenback mullet	Bata
17.	*Hilsakelee*	Klee shad	GutraIlish
18.	*Rhynchorhamphusgeorgii*	Long billed half beak	EkThute
19.	*Pampuschinensis*	Chinese Pomfret	Rup Chanda
20.	*Aetomylaeusnichofii*	Skates and Rays	Shankachil
21.	*Echeneisnaucrates*	Slender sucker fish	Hangor Chat
22.	*Osteogeneiosusmilitaris*	Marine Catfish	Apuia

Sl #	Scientific name	Common name	Local name
23.	*Strongyluraleiura*	Banded needlefish	Tuitta
24.	*Sphyrablochii*	Hammer-headed shark	HaturiHangor
25.	*Hamanturauarnak*	Sting rays	ChitraHaus
26.	*Rhizoprionodonacutus*	Requiem sharks	Hangor, Kamot
27.	*Eleutheronematetradactylum*	Four Thread Tassel fish	Tailla
28.	*Thunnus albacores*	Tuna	Tuna
29.	*Harpodonnehereus*	Bombay-duck	Loittya, Nehari
30.	*Protonibeadiacanthus*	Spotted Croaker	Kala Poa, Kala Datina
31.	*Euthynnusaffinis*	Tuna	BomMaitta
32.	*Latescalcarifer*	Asian sea bass	Bhetki
33.	*Mystusgulio*	Long whisker catfish	Lonatrengra
34.	*Lizaparsia*	Goldspot mullet	Parshe
35.	*Mugilcephalus*	Flathead grey mullet	Bhangan
36.	*Rhinomugilcorsula*	Grey mullet	Khosula
37.	*Penaeusmonodon*	Giant tiger shrimp	Bagdachingri
38.	*Penaeusindicus*	White shrimp	Chaka chingri
39.	*Metapenaeusmonoceros*	Speckled shrimp	Harinachingri
40.	*Panuliruspolyphagus/ornatus*	Lobster	ChhoaIcha
41.	*Scylla serrate/olivecea*	Giant mud srab	ShilaKankra
42.	*Portunuspelagicus*	Swimming crab	SataruKankra
43.	*Pinctadafucata/margaritifera/maxima*	Pearl oyster	Kostura
44.	*Pernaviridis/indicus*	Green mussel	Kala/badamijhinuk
45.	*Anadaragranosa*	Ark shell cockles	DaittaChilon

Present Status of Fisheries Production

The country's total fish production in 2020-21 has been reported to be 4.62 million ton, of which 1.30 million ton is from inland capture, 2.64 million ton from inland culture and 0.68 million ton from marine capture fisheries. Mari culture is so far not in practice, except some very recent research-scale initiatives of seaweed culture (Chowdhury et al., 2022). During the last fifteen years, the total fish production from all sources has been almost doubled (Fig. 10). The share of inland aquaculture has

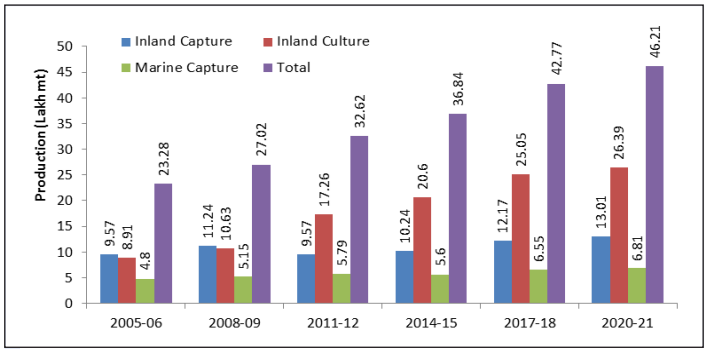

Fig. 10. Trends in fish production from all sources during 2005 – 2021 (DoF, 2022a). *1 lakh = 0.1 million*

been increased from 41% in 2005-06 to 57% in 2020-21 and that of the inland capture and marine fisheries decreased from 38 to 28% and 21 to 15%, respectively. However, the annual growth rate of overall fish production has been dropped from an average of 5.36% in 2016-17 to 2.62% in 2020-21 (Fig.11).

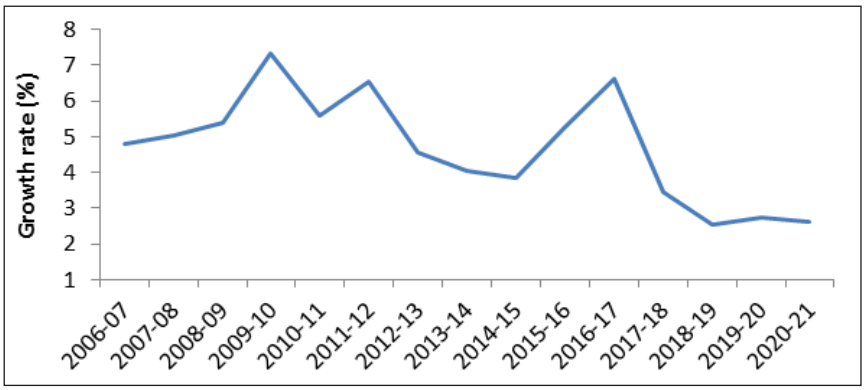

Fig. 11. Trends in annual growth rate of fish production (DoF, 2022a)

Inland open water capture fisheries

Fish production in 2020-21 from different inland capture sources is given in Table 8. Although the share of inland capture fisheries output has been declined over the period, it is still a major source of the total fish production with an average annual growth rate of 4.23% during the years of 1983-84 to 2020-21 (DoF 2022a). The top low and high fish catch producing districts are presented in Fig. 12 & 13, respectively.

Table. 8. Division-wise inland capture fisheries production in 2020-21.

Division	Type of inland fisheries ecosystem					Total	%
	River	Beel	Floodplain	Sunderbans	Kaptai lake		
Dhaka	29004	16723	157590	-	-	203317	*15.62*
Mymensingh	6703	19287	61262	-	-	87252	*6.71*
Rajshahi	16520	20128	91223	-	-	127871	*9.83*
Rangpur	7254	6103	45180	-	-	58537	*4.50*
Chattogram	82209	1245	169774	-	12345	265573	*20.41*
Khulna	15643	5918	95461	21544	-	138566	*10.65*
Barishal	176456	61	37939	-	-	214456	*16.48*
Sylhet	3262	35406	167004	-	-	205672	*15.81*
Total	**337051**	**104871**	**825433**	**21544**	**12345**	**1301244**	***100***
%	*25.90*	*8.06*	*63.43*	*1.66*	*0.95*	*100*	

Source: DoF 2022a

The lowest catch was recorded from hill districts of Khagrachori (280 t) and Bandarban (320 t) while the highest catch was from Bhola (0.98 lakh t) followed by Sunamgonj (0.95 lakh ton).

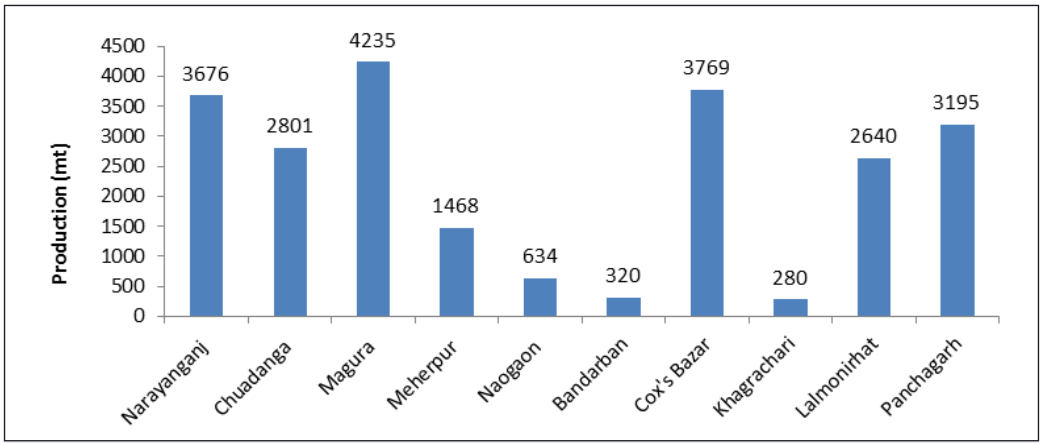

Fig 12. Top ten districts with the lowest fish catch (2020-21)
Source: DoF, 2022a

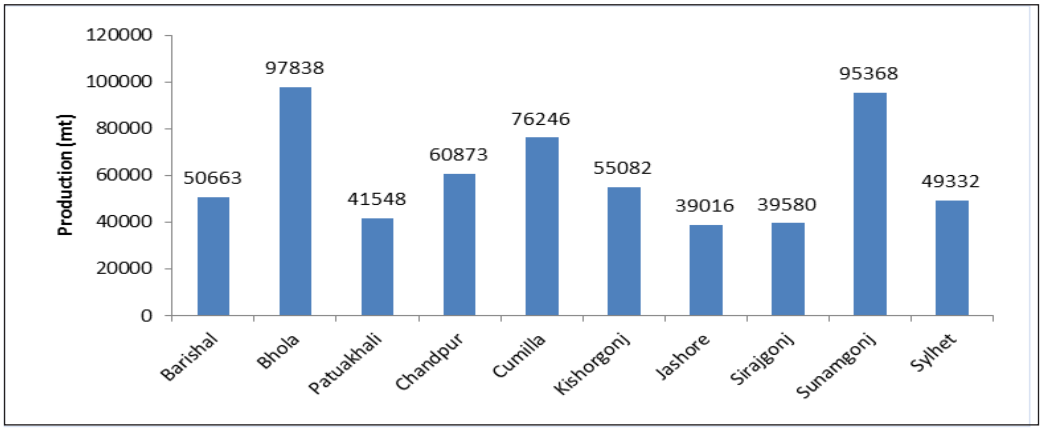

Fig. 13. Top ten districts with the highest fish catch (2020-21)
Source: DoF, 2022a

Floodplains are the major source of inland capture fish production contributing to about 63.43% of the total production (Table 8). Of the total fish catch from floodplain sources, the share of catch from subsistence fisheries was 81.40% followed by 13.94% from haors and 4.66% from fry released program. The catch from floodplain sources contributed to 17.86% of total inland open water fish production with a growth rate of 5.86% (Fig. 14). The production performance of different inland open water sources showed a moderate growth rate and that of the Kaptai lake showed a negative growth rate (Fig. 14) indicating an ineffective lake management intervention. Chattogram division contributed to 20.41% of total inland fish catch and Barishal division alone provided 52.35% of fish catch from the river ecosystem.

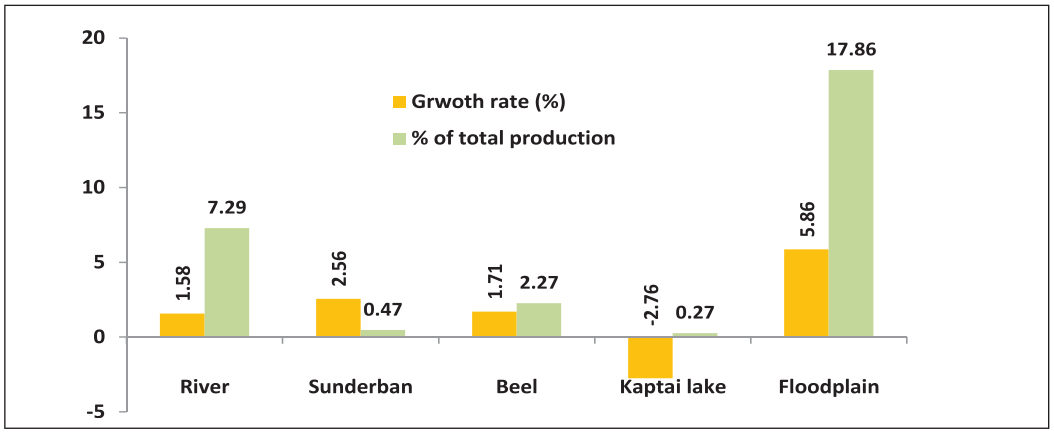

Fig. 14. Growth rate and contribution of inland open water fisheries to total production in 2020-21.

The haor ecosystem contributed significantly to inland fish catch of Sylhet, Dhaka, and Mymensingh divisions (Fig. 15). Fish production from haors has been reported from all districts of Sylhet division and from Kishrorgonj, Netrokona and Brahmanbaria districts of Dhaka, Mymensing and Chottagram division, respectively indicating the fisheries importance of haor ecosystems in Sylhet-Mymensingh basin. Of the total fish catch of 0.17 million ton from floodplains in Sylhet division, contribution of haors was 0.065 million ton.

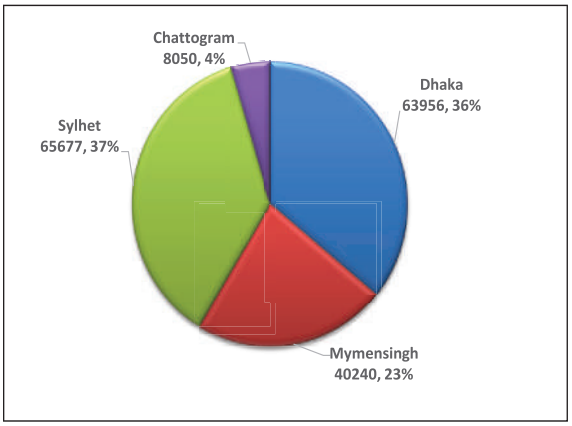

Fig. 15. Fish production (t and %) from haors in four divisions.

Inland closed water culture fisheries

In Bangladesh, fish is cultured in inland waters under freshwater and coastal/brackish water ecosystem. Freshwater aquaculture is comprised of pond, seasonal cultured waterbodies, baors, pen and cage culture, while coastal/brackish water aquaculture is comprised of shrimp, prawn, and crab farms. Division-wise fish production from different inland culture sources in 2020-21 (DoF, 2022a) is given in Table 9. Of the total aquaculture production, Khulna hadthe highest contribution (22.46%) followed by Chattogram (19.48%). The lowest contribution to aquaculture production was from Sylhet division (2.89%) followed by Barishal (5.46%) and Rangpur (8.31%). Freshwater ponds are the mainstay of inland aquaculture, accounting 79.23% of the total aquaculture production and 45.24% of total country fisheries production in 2020-21.

Table 9. Division-wise inland aquaculture production (t) in 2020-21

Division	Inland freshwater					Inland coastal		Total	%
	Pond	Seasonal cultured waterbody	Baor	Pen	Cage	Shrimp/ prawn farm	Crab farm		
Dhaka	238298	41593	3243	11852	1125	2307	0	298418	*11.31*
Mymensingh	400934	9894	0	858	38	3	0	411727	*15.60*
Rajshahi	367053	13337	0	243	1592	35	0	382260	*14.49*
Rangpur	201240	17428	0	284	207	75	0	219234	*8.31*
Chattogram	395761	90641	0	870	1581	22824	2453	514130	*19.48*
Khulna	292648	38669	8076	13	68	243525	9595	592594	*22.46*
Barishal	122844	10916	0	135	357	9627	289	144168	*5.46*
Sylhet	72009	4130	0	27	27	21	0	76214	*2.89*
Total	**2090787**	**226608**	**11319**	**14282**	**4995**	**278417**	**12337**	**2638745**	***100***
% Total	*79.23*	*8.58*	*0.43*	*0.54*	*0.19*	*10.55*	*0.47*	*100*	
Growth rate (%)	2.18	0.29	3.07	6.38	8.82	3.19	-1.79	2.12	

Source: DoF, 2022a

Mymensingh, Chattogram and Rajshahi are the lead divisions for pond aquaculture production. The unit area fish production of pond varies from the lowest (3.39 t/ha) in Sylhet division to the highest (8.84 t/ha) in Mymensingh division (Fig. 16). Other than ponds, seasonal cultured water bodies are contributing to the production of 0.23-million-ton fish with a major share of about 88% from floodplain and paddy fields, and 12% from borrowpits. The highest production is recorded from floodplain and paddy fields of Chattogram division (Fig. 17). Pen and cage culture are two novel approaches contributing to 0.54% and 0.19%, respectively, of the total aquaculture production in 2020-21 (Table 9). With a significant growth rate of 6 - 9%, these new methods have the potentiality to greatly increase fish production in the country. Presently, pen and cage culture are concentrated to Dhaka and Chattogram divisions (Fig. 17).

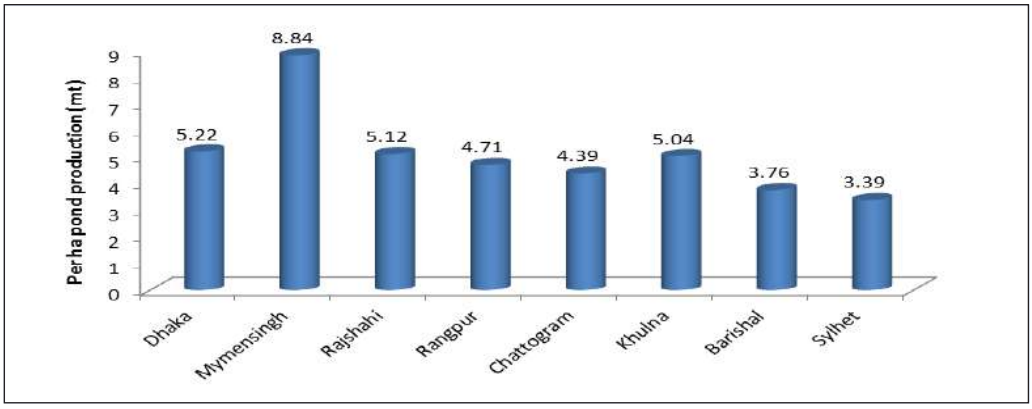

Fig. 16. Division-wise variations in pond aquaculture production per unit area.
Source: DoF, 2022a

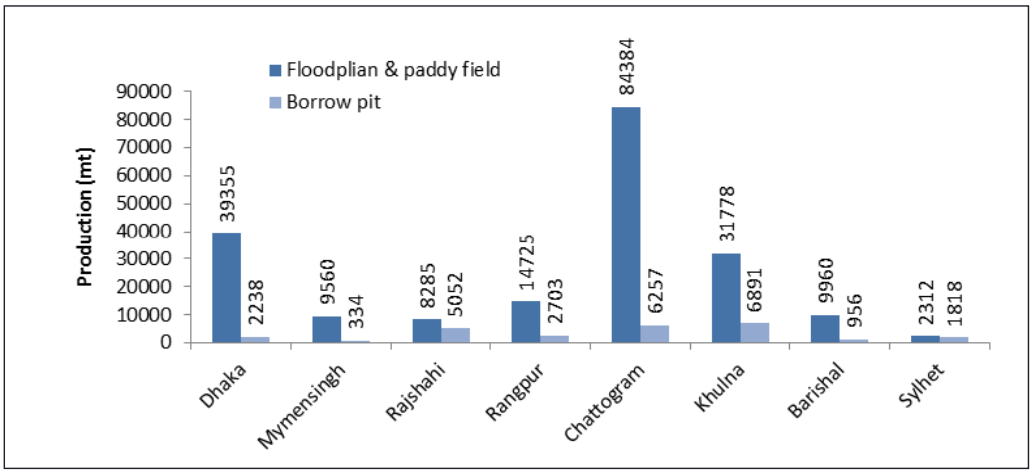

Fig. 17. Division-wise variations in aquaculture production from floodplains and borrow pit.
Source: DoF, 2022a

Currently, pond aquaculture production system is mainly semi-intensive (1.5 - 4 t/ha production range) with some intensive (4-10 t/ha production range) and in a very few cases highly intensive (above 10 t/ha production range) and extensive (below 1.5 t/ha) culture systems (Fig. 18). Semi-intensive culture system provided with 42.01% of total fish production from ponds, intensive systems resulted in 39.11%, highly intensive systems 16.80% and extensive systems only 2.09%. The unit area aquaculture production of pond (t/ha) is 1.35, 3.67, 6.99 and 18.59 from extensive, semi-intensive, intensive and highly intensive systems, respectively. Mymensingh division produced the highest share of fish production (about 54%) from highly intensive culture system while the contribution of Mymensingh district alone was 96% (207,842 ton).

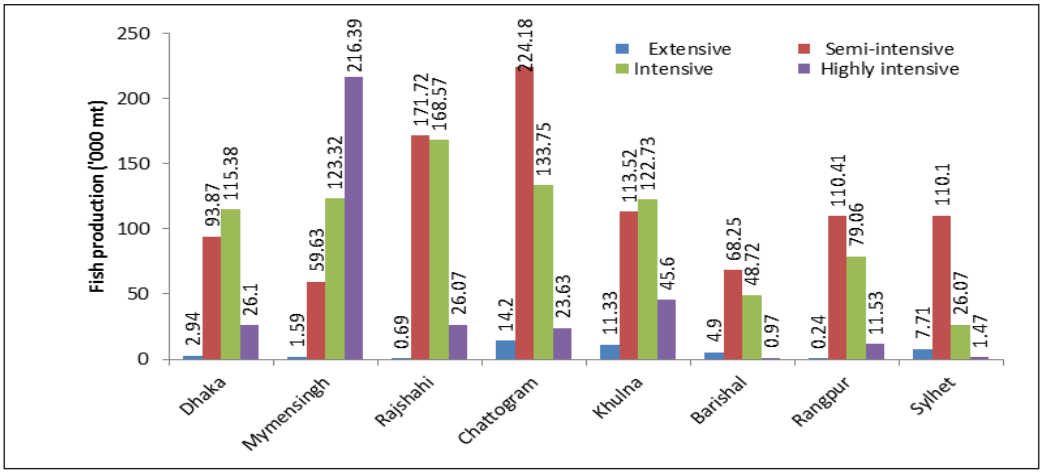

Fig 18. Division-wise fish production from different culture systems.
Source: DoF, 2022a

In contrast, aquaculture production from highly intensive system varied from 1 t to 46,000 t in other divisions, which constitutes 39% of highly intensive pond aquaculture production. The aquaculture production from Chattogram division (224,184 t) was the highest from semi-intensive system in comparison with the production from semi-intensive (171,722 t) and intensive (168,572 t) systems in Rajshahi division. Aquaculture has been transforming largely to highly intensive in Mymensing division. However, it is of great concern that despite increased pond aquaculture production during the last decades the highest annual growth rate (10.05%) occurred in 2011-12 has drastically declined to 2.18% in 2020-21(Fig. 19).

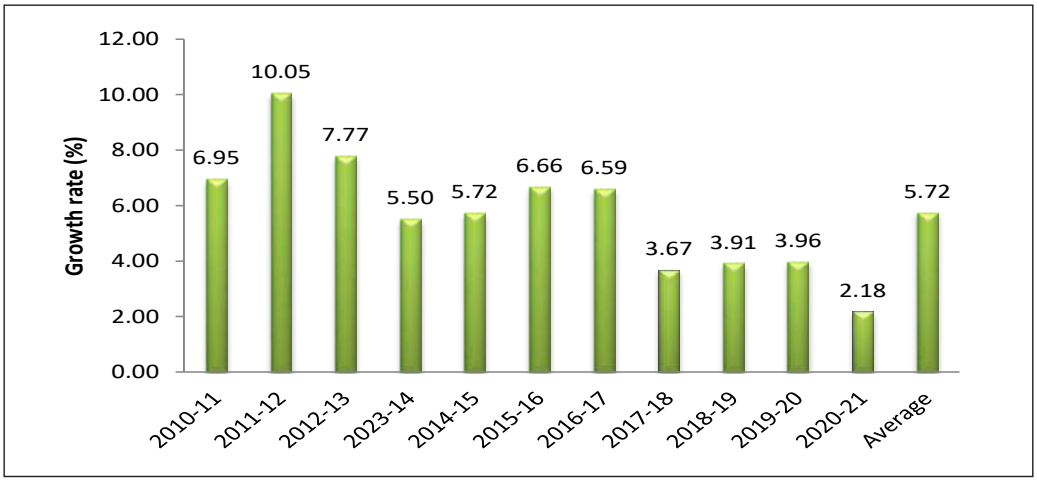

Fig. 19. Year-wise variation in pond aquaculture growth rate.
Source: DoF 2022a

In 2020-21, inland coastal/brackish water aquaculture contributed to about 11% of total aquaculture production of which about 87% was produced in Khulna divisions (Table 9). Besides targeting shrimp (*P. monodon*) and prawn (*M. rosenbergii*) as major species in shrimp/prawn farms, about 53% of production consisted of finfishes (Fig. 20). Crab (*S. serrate/olivecia*) farm production has been included in DoF's statistics separately since 2015-16. The per unit production of shrimp (347 kg/ha) has increased a little bit since 2019-20 by a growth rate of 6.21%while that of prawn (713 kg/ha) decreased by -0.68% annually.

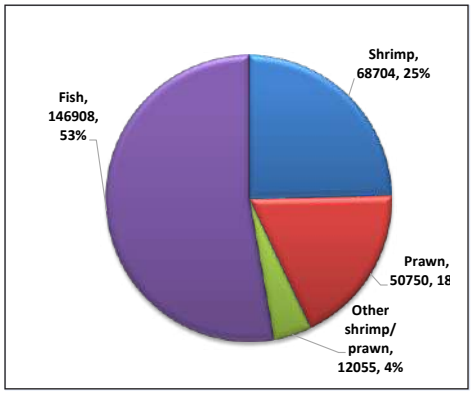

Fig. 20. Contribution (kg and %) of different species to inland brachish water aquaculture *(Source: DoF, 2022a)*

By species, inland capture and culture fisheries are mainly comprised of carps, hilsa, snakehead fish, catfish, tilapia, perch, silver barb, and several other fishes, though in a lesser scale (Table 10). Hilsa is the main captured fish species contributing to about 35% of total capture followed by major carps (20%) and snake head fish (11%). In case of aquaculture production, major carps' share was the highest (35.5%) followed by exotic pangas (16%) tilapia (15%), and silver carp (11%). Of the major carps, rui (*L. rohita*) production is the highest (0.45millionton) which has contributed to 14% of total inland capture and culture production.

Table. 10. Species-wise production from inland fisheries and aquaculture in 2020-21

Species	Inland capture		Inland culture		Inland capture & culture	
	Qty (t)	%	Qty (t)	%	Qty (t)	%
1. Rui (*Labeorohita*)	63239	8.93	382814	15.29	446053	13.89
2. Catla (*Gibelioncatla*)	30720	4.34	234135	9.35	264855	8.25
3. Mrigal (*Cirrhinuscirrohosus*)	36051	5.09	228482	9.13	264533	8.24
4. Kalbaus (*Labeocalbasu*)	5532	0.78	37382	1.49	42914	1.34
5. Bata (*L. bata*)	4523	0.64	60124	2.40	64647	2.01
6. Ghania (*L. gonius*)	3056	0.43	18620	0.74	21676	0.68
7. Silver carp (*Hypophthamichthysmolitrix*)	7311	1.03	269575	10.77	276886	8.62
8.						
9. Grass carp (Ctenopharyngodonidella)	9155	1.29	64990	2.60	74145	2.31

Species	Inland capture		Inland culture		Inland capture & culture	
	Qty (t)	%	Qty (t)	%	Qty (t)	%
10. Common carp (*Cyprinus* spp.)	24006	3.39	107547	4.30	131553	4.10
11. Pangas (*Pangasionodonhypophthalmus*)	10489	1.48	391809	15.65	402298	12.53
12. Boal (*Wallagoattu*)/ Air/Guzi (*Sperataaor/seenghela*)	72196	10.20	984	0.04	73180	2.28
13. Shol (*Channastriata*) / Gozar (*C. marulius*)/ Taki (*C. punctatus*)	75548	10.67	2920	0.12	78468	2.44
14. Koi (*Anabas testudineus*)	12481	1.76	59299	2.37	71780.02	2.24
15. Tilapia (Oreochromes spp.)	60602	8.56	385548	15.40	446150	13.89
16. Shingi (*Heteropneustesfossilis*)/ Magur (*Clariasbatrachus*)	2104	0.30	38265	1.53	40369	1.26
17. Sarputi (*Barbodesgonionotus/ Puntiussorna*)	24856	3.51	77076	3.08	101932	3.17
18. Cuchia (*Monopteruscuchia*)	8318	1.18	877	0.04	9195	0.29
19. Hilsa (*Tenualosa* sp.)	250847	35.54	0	0.00	250847	7.84
20. Galda (*Macrobrachiumrosenbergii*)	2988	0.42	54005	2.16	56993	1.77
21. Bagda (*Penaeusmonodon*)	33	0.00	68704	2.74	68737	2.14
22. Harina (*Metapenaeus28onoceros*)	3034	0.43	5079	0.20	8113	0.25
23. Chaka (*Penaeusindicus*)	18	0.00	2595	0.10	2613	0.08
24. Crab (*S. serrata/olivacea*)	-	-	12337	0.49	12337	0.38
Total	**707850**	100.00	**2503167**	100.00	**3211017**	100.00

Source: DoF, 2022a

Marine fisheries

Contribution of marine fisheries is only 0.68 million tons (14.47%) to the national fish production (Table 11). The artisanal fishing is done up to 40 m depth in the near shore coastal areas of Bangladesh. A total of about 230 industrial trawlers and 67,903 artisanal vessels engaged in marine fishing in 2020-21 (Table. 11). Compared to 2010-11, the total number of crafts has increased, while that of gears/nets has decreased in 2020-21 except in case of gill net fishing that has increased both by the number of vessels and gears (Table 11).

Table 11. Comparative production of marine fisheries in Bangladesh between FY 2010-11 and FY 2020-21

Type of Fishing	FY 2010-11			FY 2020-21			Difference		
	Trawler/ Boat (no.)	Gear/ Net (no.)	Catch (t)	Trawler/ Boat	Gear/ Net	Catch (t)	Trawler/ Boat	Gear/ Net	Catch (t)
A. **Industrial** (trawl fishing)	158	-	41665	234	60	119121	76	60	77456
B) **Artisanal**									
i. Gill Net Fishing	26084	108040	321114	37190	118353	383857	11106	10313	62743
ii. Set Bag Net Fishing	13094	51522	148718	20750	42425	156352	7656	-9097	7634
iii. Long Line Fishing	2794	25538	14928	3225	11863	15939	431	-13675	1011
iv. Trammel Net Fishing (NMB)	1123	7122	10956	131	422	3062	-992	-6700	-7894
v. Other Gears Fishing (NMB)	2282	31636	8952	6373	15640	2908	4091	-15996	-6044
Total Artisanal	45377	223858	504668	67669	188707	562118	22292	-35151	57450
Grand Total	**45535**	**223858**	**546333**	**67903**	**189367**	**681239**	**22368**	**-34491**	**134906**

Source: DoF, 2022a

However, the catch from marine fisheries has increased by about 0.134 million ton over this period. The major species and their catch in the marine waters of Bangladesh in 2020-21 are presented in Fig. 21. Hilsa is the major species, which contributed to the highest (46.09%) of marine catch followed by bombay duck (10.55%), jew fish (7.15%), shrimp (6.8%) and sardine (5.06%).

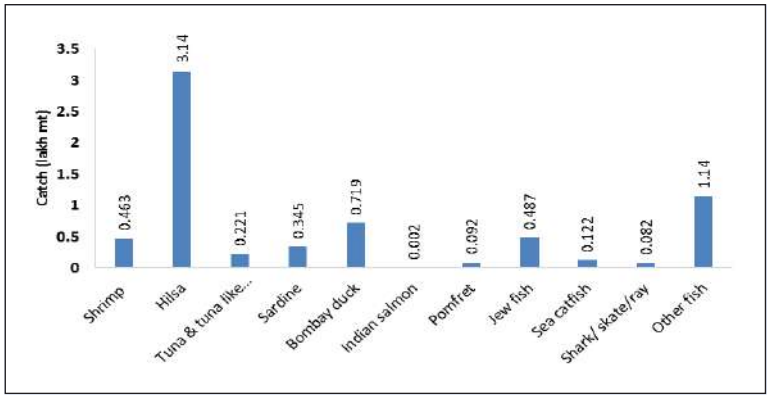

Fig. 21. Species-wise catch from marine fisheries in 2020-21.
Source: DoF 2022a

Among the captured fish species in Bangladesh, hilsa is the biggest single-species in inland and marine waters, contributing to about 12.23% of the total fish production in 2020-21 and 1% to the county's GDP (DoF, 2022a). During the last decade, there has been an increasing trend in hilsa catch particularly in case of inland waters from 0.39 million tons in 2014-15 to 0.56 million ton in 2020-21(Fig. 22). Table 12

shows that landing of hilsa from both inland and marine waters was the highest in Barishal division (65.34%) followed by Chattogram division (32%).

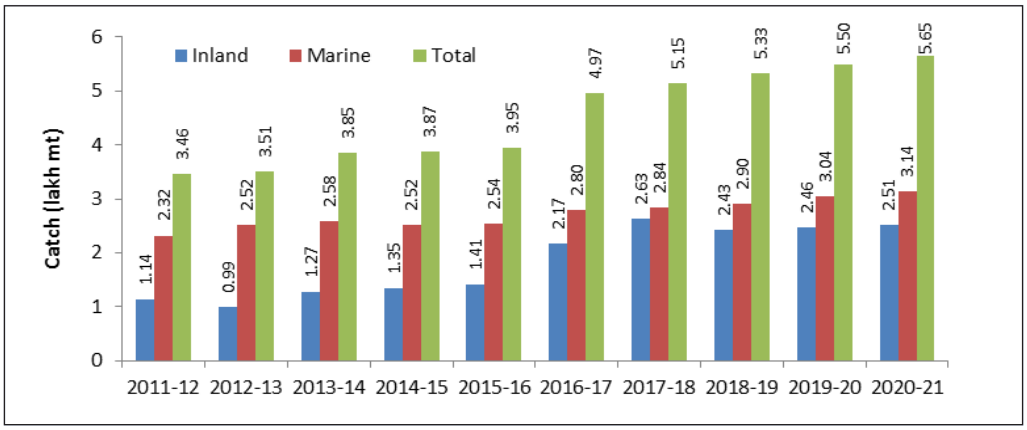

Fig. 22. Hilsa production trend from inland and marine waters from 2011-12 to 2020-21. *Source: DoF 2022a.*

Table 12. Division-wise catch of hilsa from inland and marine capture fisheries in 2020-21.

Division	Inland catch (t)		Marine catch (t)		Total	%
	River	Sundarban	Industrial	Artisanal		
Dhaka	8951	0	0	0	8951	1.58
Mymensingh	85	0	0	0	85	0.02
Rajshahi	741	0	0	0	741	0.13
Rangpur	322	0	0	0	322	0.06
Chattogram	73506	0	6631	102537	181274	32.07
Khulna	1938	743	0	1816	4497	0.80
Barishal	165292	0	1150	201459	369301	65.34
Sylhet	12	0	0	0	12	0.00
Total	250847	743	7781	305812	565183	100.00
Growth rate (%)	*2.40*	*-16.52*	*-19.80*	*3.68*	*2.68*	

Source: DoF 2022a

Fish and shrimp/ prawn seed production

The country has a total of 1,056 (103 public and 953 private) fish hatcheries in operation of which 339 hatcheries are in Mymensingh, 175 in Rajshahi, 139 in Chattogram, and 93 in Khulna division in 2020-21 (Fig. 23). In 2020-21, the total production of fish hatchlings (4-5 days old) was 668,031 kg (98 % from private) from hatcheries (Table 13). Besides artificial production, 2152 kg of fish hatchlings were produced from different natural sources of which the highest hatchlings were produced from Jamuna river (970 kg) followed by Padma (822 kg) as shown in Fig. 24.

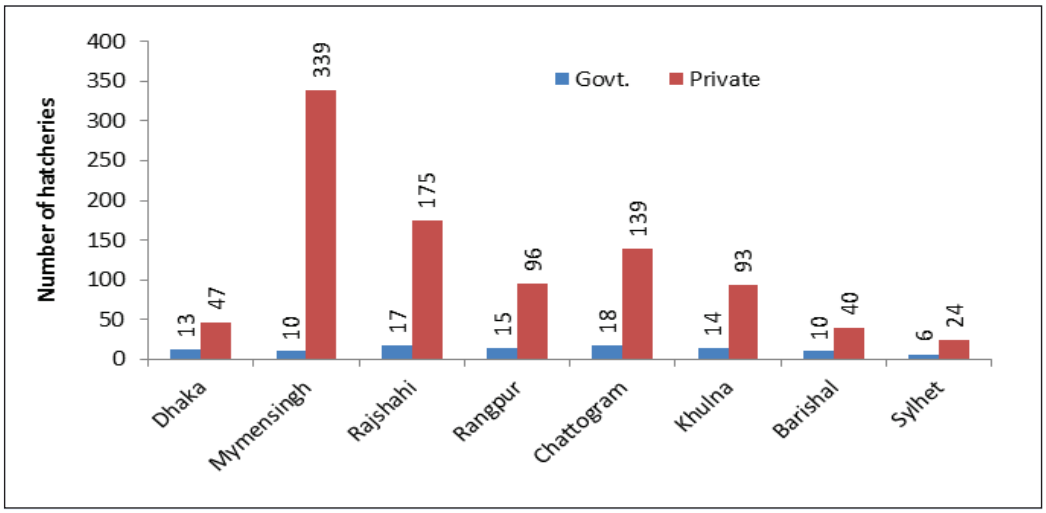

Fig. 23. Division-wise distribution of fish hatcheries in 2020-21 (*Source: DoF, 2022a)*

Table 13. Division-wise fish hatchlings production from government and private hatcheries in 2020-21

Division	Govt. Hatchery		Private Hatchery		Total Hatchery	Total Production	%
	No.	Production (kg hatchlings)	No.	Production (kg hatchlings)			
Dhaka	13	1026	47	21047	60	22073	3.30
Mymensingh	10	2048	339	191733	349	193781	28.97
Rajshahi	17	2199	175	190017	192	192216	28.74
Rangpur	15	1899	96	73658	111	75557	11.30
Chattogram	18	2126	139	61627	157	63753	9.54
Khulna	14	1662	93	87984	107	89646	13.40
Barishal	10	425	40	21735	50	22160	3.31
Sylhet	6	808	24	8807	30	9615	1.44
Total	**103**	**12193**	**953**	**656608**	**1056**	**668801**	100
BFRI, Mymensingh	1	459	-	-	1	459	

Source: DoF, 2022a

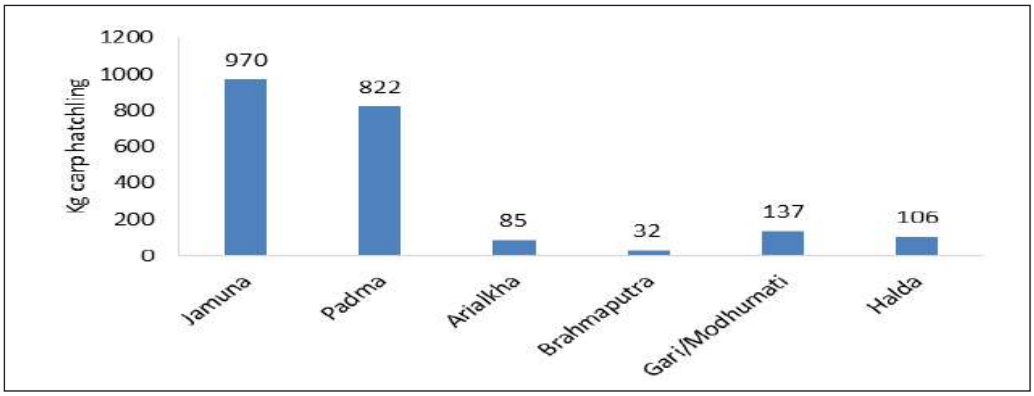

Fig. 24. Carp hatchling production from natural sources in 2020-21 (*Source: DoF, 2022a).*

Table 14 shows the species-wise hatchlings production from hatcheries in different divisions in 2020-21 (DoF, 2022a). Mymensingh, Rajshahi and Khulna are the lead divisions producing about 72% of the total fish hatchlings, while lower hatchling production ranged from 1.34% in Sylhet to 3.30% each in Dhaka and Barishal divisions. Native major and exotic carps accounted for about 68% of the total fish hatchling production. Besides carps, all divisions are producing hatchlings of Thai punti, bata, shingh/magur, Thai/Vietnam koi and other fishes like pabda, gulsha, gonia, chital etc. The seed production of shing/magur (66%), koi (53%), and Thai punti (47%) is concentrated in Mymensingh division. Most of the pangas hatchlings are produced in

Table 14. Species-wise fish seed production from hatcheries in different divisions in 2020-21.

Division/ BFRI	Fish hatchling production (kg)								Total	%
	Major carp	Exotic carp	Pangas	Thai punti	Bata	Koi	Shing/ Magur	Other		
Dhaka	11548	4466	0	1772	2500	560	360	867	22073	*3.30*
Mymensingh	64003	56221	5980	14522	3238	6247	26197	16922	193330	*28.94*
Khulna	43567	34253	2961	1995	2280	1542	1294	1754	89646	*13.42*
Barishal	10899	4870	346	3003	266	261	487	1939	22071	*3.30*
Rangpur	28417	25128	0	5857	12702	412	1973	1082	75571	*11.31*
Rajshahi	57432	50748	12663	1879	13624	2354	9073	44433	192206	*28.77*
Chattogram	45901	7259	6486	1702	910	314	282	878	63732	*9.54*
Sylhet	4983	3286	30	146	353	25	0	120	8943	*1.34*
BFRI, Mymensingh	321	47	3	88	0	0	0	0	459	*0.07*
Total	**267071**	**186278**	**28469**	**30964**	**35873**	**11715**	**39666**	**67995**	**668031**	***100***
%	*39.98*	*27.88*	*4.26*	*4.64*	*5.37*	*1.75*	*5.94*	*10.18*	*100*	

Source: DoF, 2022a.

Rajshahi (44%), Chattogram (23%) and Mymensingh (21%) divisions. The Rajshahi and Rangpur division are producing the highest amount of bata hatchlings accounting for about 38% and 35%, respectively.

In 2020-21, a total of 5419.6 million tilapia juveniles were produced from the government and private hatcheries. The Government (DoF managed) hatcheries produced only 0.4 million tilapia juveniles, while BFRI produced 469.5 million (Fig. 25). The share of private hatcheries in tilapia juvenile production was 91.33%. Rajshahi and Chattogram divisions are producing the lion share of tilapia juveniles (35.16% and 32.42% respectively) followed by Mymensingh and Khulna.

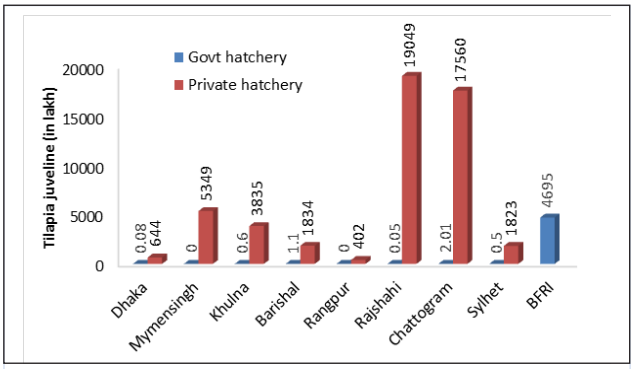

Fig. 25. Division-wise tilapia juvenile production in 2022-21. *Source: DoF, 2022a.*

There were 33 (27 publics and 6 private) galda and 44 private bagda hatcheries in operation in 2020-21. A total of 237 million of galda post-larvae were produced, out of which 27 public hatcheries produced only 37 million against the requirement of 150-200 million PL for stocking in 65,000 ha of galda cultivable waterbodies (DoF, 2022b). Bagda hatcheries produced a total of 72,100 million post-larvae, which is also less than the requirement.

Fish processing and trade

Usually, the deep-sea fishing trawlers and mechanized fish boats are equipped with the basic fish processing machineries and cold storage facilities to manage the fish on board. But the small-scale (mechanized and non-mechanized) fishing boats operating in inland and marine waters have no fish processing machineries. The caught fish and shrimps are stored with ice, and then they are delivered to market, fish processing plants or distributors for further processing. Before 1971, there were 9 fish processing plants in Bangladesh which was expanded to 40 between 1972-1984 and then 72 in 1985-1998 (https://www.meat-machinery.com/) and at present 107 plants are in operation for processing and exporting shrimp and fish products. The fish processing plants are operated by the private sector and only 77 are EU approved plants (DoF, 2022a). With the development of the fishery industry, the need of modern machinery and technology for appropriate fish and fishery products is obvious.

Fisheries sub-sector has been earning a notable amount of foreign exchange emerging as a significant contributor to national export earnings. Different categories of fish (live and frozen), shrimp and fishery products are exported from Bangladesh (Table 15). In 2020–21, the country earned BDT 4088.97 crore by exporting 66,592t of fish, shrimp and other fishery products (DoF, 2022a) which contributed to 1.24% of the national export earnings.

Table 15. Annual export of fish and fishery products in 2020-21

Export commodity	Volume		Value	
	Ton	%	Crore BDT	%
1. Frozen shrimp/prawn	30615.14	45.97	2730.56	66.78
2. Frozen fish	3022.82	4.54	419.48	10.26
3. Chilled fish	16567.76	24.88	522.86	12.79
4. Dry fish	4691.47	7.05	62.58	1.53
5. Salted/dehydrated fish	79.43	0.12	7.68	0.19
6. Live fish (Cuchia)	3151.13	4.73	63.59	1.56
7. Crab	6288.21	9.44	264.06	6.46
8. Shark fin/fish maws	2175.73	3.27	18.16	0.44
Total	**66591.69**		**4088.97**	

Source: DoF, 2022a.

The shrimp export destinations are highly concentrated in the European Union (EU), the US and Japan. More than 85% of fishery exports (by quantity) are exported to these three markets and remainder are exported to Southeast Asian countries and Middle East countries.

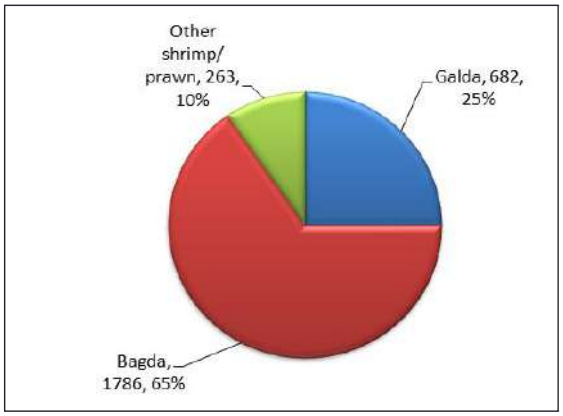

Fig. 26. Share of export value (crore Tk) in frozen shrimp/prawn category.
Source: DoF, 2022a.

Frozen shrimp and prawn is the most exported commodity in Bangladesh and share about 30,615 t (45.97%) in volume and 2,731 crore BDT (66.78%) in value of total export earnings from fisheries sub-sector (Table 15). Bagda, galda and other shrimps (mainly harina and chaca) are included in the frozen shrimp/prawn category and their contribution to export value is shown in Fig. 3.22. Bagda contributed highest share (65%) compared to Galda and other srimp/prawn. A substantial quantity of frozen and chilled fish has been exported which earned about 942 crore BDT (23%). The export volume and value of crab has increased from 589.50 t and 57.85 crore BDT in 2019-20 to 6,288 t and 264.06 crore BDT in 2020-21 (DoF, 2022a).

Fisheries Governance and Legal Arrangement

Fisheries governance structure

Several cross-sectional organizations and institutions are involved in the development and management of fisheries sub-sector in Bangladesh, where the Ministry of Fisheries and Livestock (MoFL), Government of the People's Republic of Bangladesh is the main and lead administrative agency responsible for drafting, formulating and implementing the fisheries rulesand regulations (Fig. 27). Under the lead ministry (MoFL), five government organizations are largely involved for the overall development and governance of fisheries sectors with specific mandates as stated below:

a) ***Department of Fisheries (DoF)***

- To disseminate improved aquaculture technologies through training and demonstration and to provide extension advisory services to the focal stakeholders.
- To protect and enhance fisheries resources through enacting conservation and management of measures.
- To assist the administrative ministry to formulate policies, acts etc.
- To enforce quality control measures and ensure issuance of health certificates for exportable fish and fish products.
- To conduct fisheries resource survey and assessment of stock to develop fisheries database for proper planning.

b) ***Bangladesh Agricultural Research Council***

- BARC is the body in-charge at the National Agricultural Research System.
- It is the apex body of the National Agricultural Research system.
- It has the responsibility to strengthen the National Agricultural Research capacity through planning and integration of resources.
- It is the umbrella under when the entire Bangladesh Agricultural Research is coordinated.

c) ***Bangladesh Fisheries Research Institute (BFRI)***

- To carry out basic and adaptive research for development and optimum utilization of all living aquatic resources and coordinate fisheries research activities in Bangladesh;
- To conduct experiment and standardize techniques for maximizing productions and better management of living aquatic resources;
- To identify new production opportunities and develop them to usable levels;
- To develop skilled research manpower through training and higher studies (MS and PhD);
- To transfer developed technologies to the end users through training of extension workers, planners, fish farmers and other stakeholders and
- To advise the Government in all matters relating to research and management of living aquatic resources.

d) ***Bangladesh Fisheries Development Corporation (BFDC)***

- To establish fish landing, preservation, processing and marketing centers with modern facilities to reduce post-harvest loss of fish harvested from marine, coast, haors and Kaptai lake.
- To assist marketing, preservation, processing and export of fish and fishery products, and create employment opportunities.
- To provide slipway, marine workshop, birthing, and basin facilities for repairing marine trawlers including docking.

e) ***Fisheries and Livestock Information Department (FLID)***

- To collect modern information, preserve, evaluate, and analyze modern technologies.
- To provide mass media with improved techniques and modern technologies for wider dissemination.
- To prepare and circulate extension materials to make people aware and motivated on modern technologies.

f) ***Marine Fisheries Academy (MFA)***

- To offer graduate academic program and pre-sea training for creating skilled workforce in the fields of sea navigation, marine engineer and fish processing technology.
- To provide ancillary training to navy officer and sailors on basic security measures in seas.
- To conduct refresher, course for officers of sea-going fishing ships/trawlers and commercial ships prior to sitting for Certificate of Competency Examination.

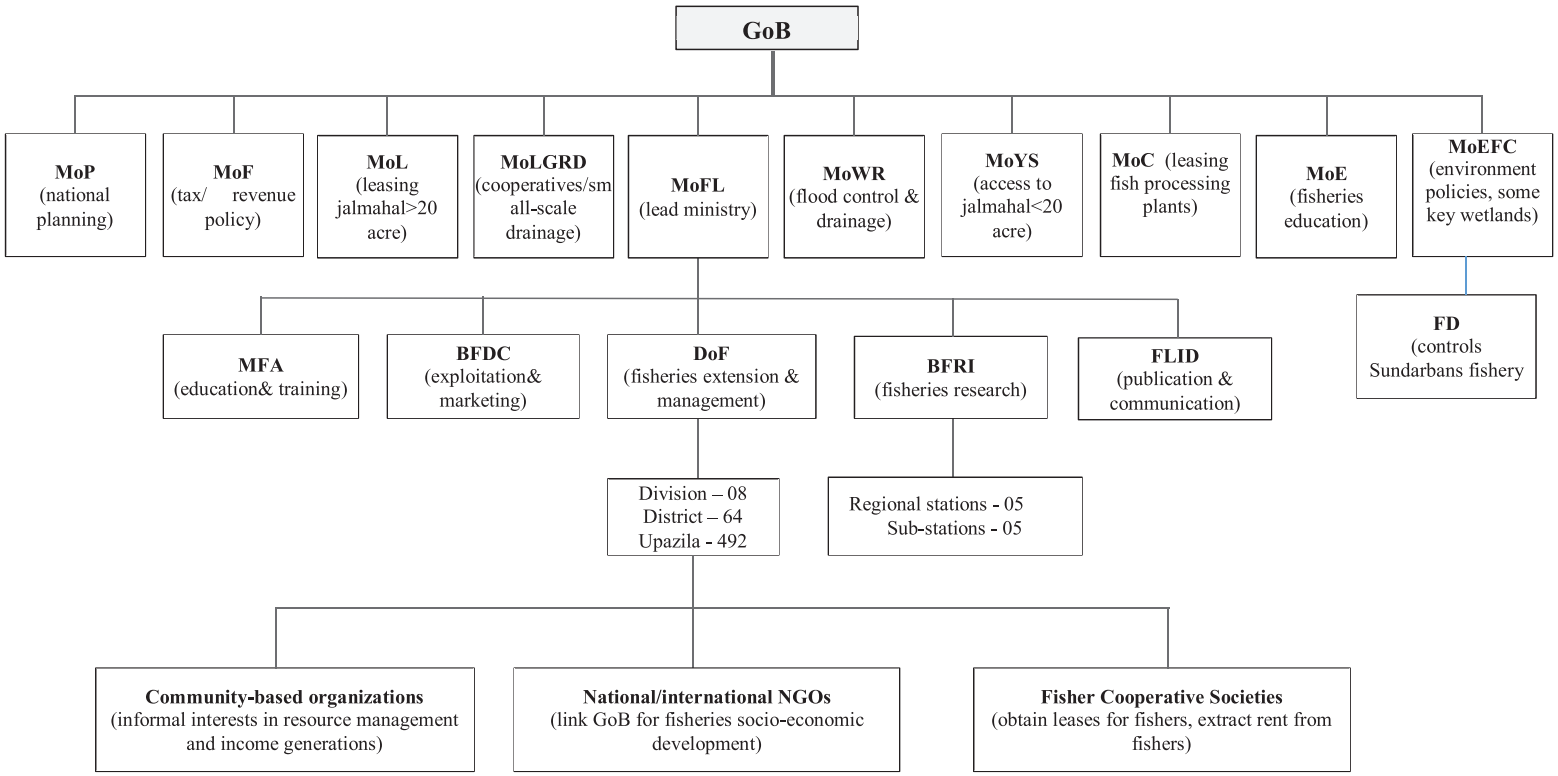

Fig. 27. Flow-diagram showing the organizational setting of fisheries sub-sector in Bangladesh (modified from Rahman et al., 2018)

Legal arrangement

There are different legal arrangements for fisheries sub-sector based on which the responsible organizations carry out and manage their functions for fisheries governance and resource management. The list of different acts, rules, ordinance of fisheries sub-sector and their main purpose are given in Table 16.

Table 16. Legal arrangements for fisheries sub-sector of Bangladesh (Shamsuzzaman, et al., 2017; Rahman, et al., 2018)

Acts/Rules/Ordinance	Main Purpose/ Objective
1) The Tanks Improvement Act 1939	Irrigation and pisciculture
2) The Protection and Conservation of Fish Act 1950	Conservation of fisheries resources as a whole.
3) Territorial Waters and Maritime Zones Rules 1977	Conservation, management and development of marine fisheries
4) Marine Fisheries Rules & Ordinance 1983	Marine fisheries conservation and management
5) The Fish and Fish Product (Inspection and quality control) Ordinance 1983	Quality control, fish and shrimp, mainly targeting export
6) The Protection and Conservation of Fish Rules 1985	Regulations on protection and conservation of fish.
7) The Private Fisheries Protection Act 1889	Protection of private rights for fishing
8) National Fisheries Policy 1998	Conservation, management, exploitation, marketing, quality control and institutional development
9) National Fisheries Strategy 2006	Emphasizes collaboration, linkages and partnerships, reflects current government concerns for poverty alleviation through more targeted activities
10) The Fish Hatchery Act 2010 and Rules 2011	Mitigate the inbreeding and crossbreeding problems, encourage the hatchery and nursery owners in producing quality fish seeds in hatcheries
11) Fish Feed and Animal Feed Act 2010and rules 2011	Maintain the quality of the feed and feed ingredients
12) National Shrimp Policy 2014	Flourish the shrimp industry, raise employment opportunity, alleviate poverty, export earnings and meet up the nutritional demand of the people
13) Fish Quarantine Act 2018	Prevention of the infiltration and spread of pathogens within Bangladesh and to monitor the regulation of fisheries, import controls and related anomalies for the protection of fisheries.
14) Marine Fisheries Act 2020	Provides substantive rules concerning fishing activities carried out by local and foreign fishing vessels within Bangladesh's maritime area.
15) The Bangladesh Fisheries Research Institute Act 2018	Establishment of Bangladesh Fisheries Research Institute (suspending Fisheries Research Institute Ordinance 1984)
16) Bangladesh Fisheries Development Corporation Act 1973	Establishment of the Bangladesh Fisheries Development Corporation.

Fisheries Research System in Bangladesh

Bangladesh Agricultural Research Council (BARC), as the apex body of agricultural research, has the responsibility of planning, coordinating, monitoring and evaluating research across the Agricultural Research Institutes (ARIs) under the National Agricultural Research System (NARS). It mainly coordinates planning, prioritization of research, human resource development and approval of agricultural research programs. Bangladesh Fisheries Research Institute (BFRI) is a NARS institute under the Ministry of Fisheries and Livestock (MoFL), which is responsible to conduct research for the development of need-based technology on aquaculture and fisheries resource management of the country. The institutional arrangement of fisheries research system is shown in Fig. 28. Besides BFRI, a total of 17 public universities under the Ministry of Education (MoE) and the Bangladesh Oceanographic Research Institute (BORI) under the Ministry of Science and Technology (MoST) are also involved in fisheries research.

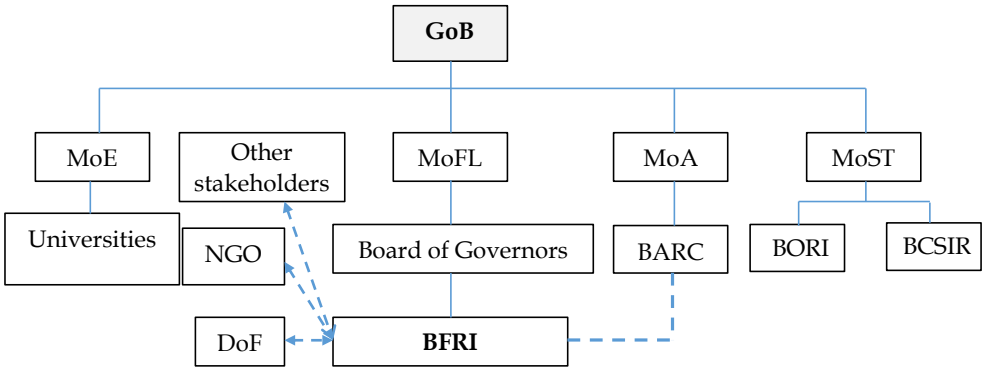

Fig. 28. Institutional arrangement of fisheries research in Bangladesh

Bangladesh Fisheries Research Institute (BFRI)

BFRI is an autonomous national research organization, which is linked administratively with the Ministry of Fisheries and Livestock, Government of the Peoples' Republic of Bangladesh. The general direction, administration and supervision of the affairs of the institute are vested in the Board of Governors consisting of 13 members under the Chairmanship of Hon'ble Minister, MoFL. Complying with the mandates of the institute, BFRI functions through its Headquarter located in Mymensingh, 5 location- and resource-specific Research Stations and 5 Sub-stations. The organogram of the institute is shown in Fig. 29. The Headquarter of BFRI functions through its various divisions in respect of overall administration, planning, development and coordination, and operation of its research programs in different stations and sub-stations.

Research Stations and Sub-stations

1) Freshwater Station (FS), Mymensingh

The Freshwater Station (FS) is located in Mymensingh attached to BFRI Headquarter, which concentrates its research activities to inland closed freshwater environment under six research divisions as follows:

(i) Reproductive Physiology and Genetics,
(ii) Aquaculture and Farming System,
(iii) Nutrition, Food and Feed Technology,
(iv) Fish Disease Diagnosis and Health Management,
(v) Soil, Water and Productivity Management, and
(vi) Fisheries Socio-economics.

Three research sub-stations are attached to the FS. These are:

a) ***Floodplain Sub-Station, Santahar***: It supports the floodplain fisheries development program taken up by the Government, and conducts studies on the ecology, limnology and gear selectivity of floodplains.
b) ***Freshwater Sub-Station, Jashore***: It supports freshwater aquaculture farmers and hatchery operators of greater Jashore region and conducts research on breeding and culture of different freshwater fish species, carp disease diagnosis and prevention, and also farming system research and development.
c) ***Freshwater Sub-Station, Saidpur***: It supports the fisheries development program in northern region of Bangladesh, conducts need-based research to suit with the ecosystem of northern Bangladesh and transfers technology to the farmers through effective training and demonstration.

2) Riverine Station (RS), Chandpur

The Riverine Station (RS) located in Chandpur is concentrating its research activities to inland open water fisheries and aquaculture. The RS consists of five research divisions viz, (i) Stock Assessment and Resource Dynamics, (ii) Fisheries Resource Management and Conservation, (iii) Culture-based Fisheries Management, (iv) Reproductive Biology of Riverine Species, and (v) Environment and Aquatic Pollution. Two research Sub-stations are attached to the RS.

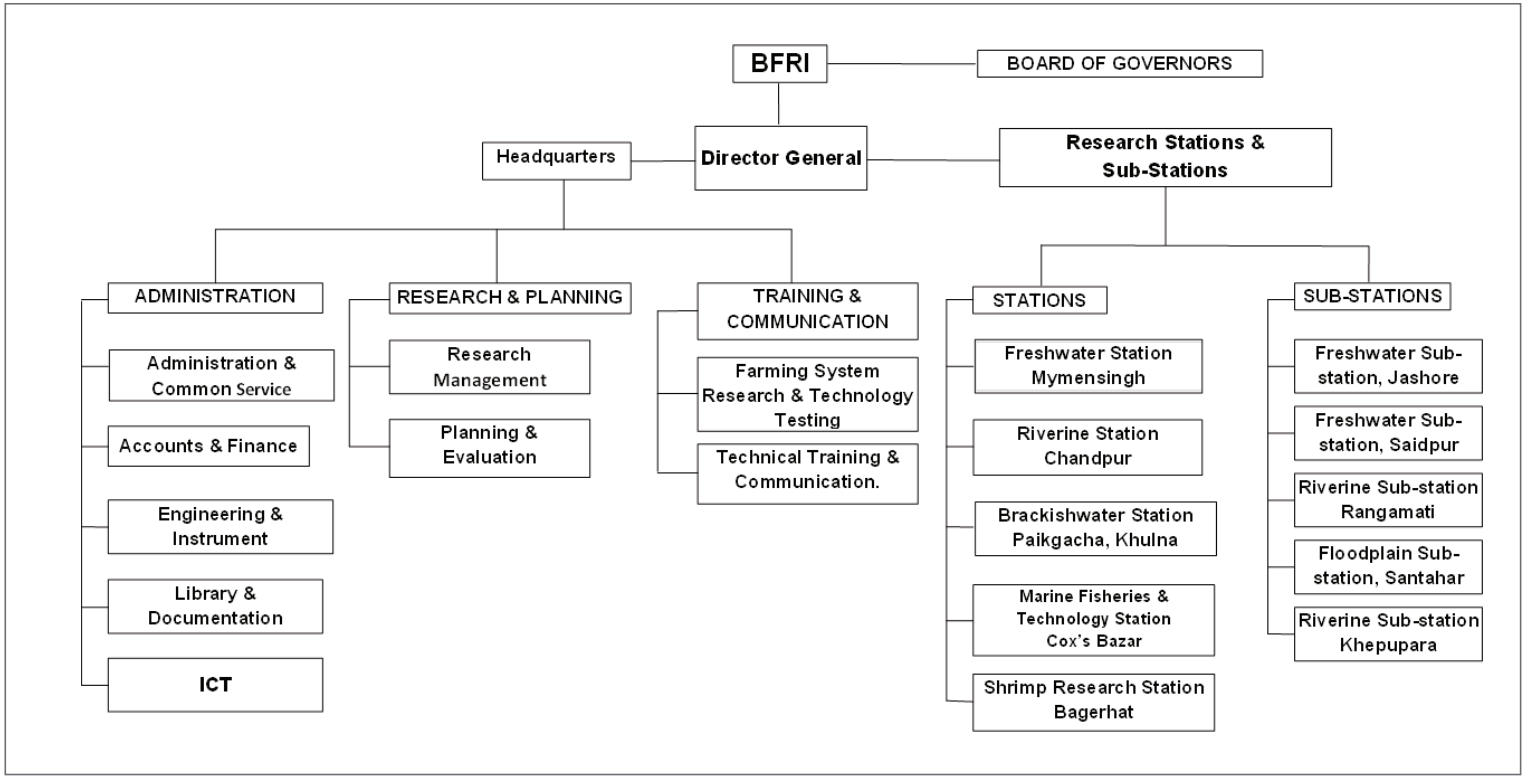

Fig. 29 Organogram of the Bangladesh Fisheries Research Institute
(Source: BFRI Annual Report 2019-20)

a) ***Riverine Sub-Station, Rangamati***: It conducts research activities for sustainable management and development strategies for the Kaptai lake fishery.
b) ***Riverine Sub-Station, Khepupara, Patuakhali***: It carries out research mainly on hilsa fishery coastal aquaculture.

3) Brackishwater Station (BS), Paikgacha, Khulna

The Brackishwater Station (BS) located at Paikgacha Upazilla under Khulna district is concentrating its research activities to inland brackishwater environment. The station conducts research under five research divisions viz, (i) Nutrition and Feed Technology, (ii) Disease Diagnosis and Health Management, (iii) Brackishwater Aquaculture, (iv) Estuarine Ecology and Environment, and (v) Soil, Water and Productivity Management.

4) Marine Fisheries & Technology Station (MFTS), Cox's bazar

The station is located in Cox's Bazar concentrating its research activities to marine fisheries. The station is involved in research on marine ecology, seaweeds culture, environmental studies, stock assessment and population dynamics of commercially important species, diseases diagnosis and control, development of processing and preservation technologies, socio-economic studies of marine and coastal fishers, and quality control of marine products.

5) Shrimp Research Station (SRS), Bagerhat

The station is located in Bagerhat district having an area of 8.0 ha. SRS is involved in research mainly on enhancement of shrimp production, shrimp health management, shrimp feed and nutrition, post- harvest handling and quality control of shrimp and shrimp products.

Research facilities of BFRI

a) ***Field facilities***

Research Station	Facilities
Freshwater Station, Mymensingh	• 118 drainable ponds consisting of 20 mini ponds, • 52 nursery ponds (0.1 ha each), • 47 rearing ponds (0.25 ha each) • 16 grow-out/brood stock ponds (1.6-2.6 ha each) • Two carp and one prawn hatchery • One four-storied training dormitory
Riverine Station, Chandpur	• Thirty six non-drainable ponds of 8.6 ha water area with an individual size ranging from 0.12 to 0.37 ha. • One carp, one catfish and one prawn hatchery • Water supply system • One well-equipped research vessel, one mechanized wooden and three speed boats
Marine Fisheries and Technology Station, Cox's Bazar	• Outdoor complex with 39 cisterns (200 m^2 each) • One crab breeding hatchery
Brackishwater Station, Paikgacha, Khulna	• Fifty three drainable experimental ponds of different sizes ranging from 0.05 to 1.0 ha

Research Station	Facilities
	• Eight non-drainable freshwater ponds • One hatchery for complex prawn and brackishwater finfish
Shrimp Research Station, Bagerhat	• Nine experimental ponds of varied sizes • One four-storied training dormitory

b) ***Laboratory facilities***

Name of laboratory	Major equipment	Major analytical capacity
Freshwater Station, Mymensingh		
Water quality and pond dynamics laboratory	DO meter (HACH), Spectrophotometer, HI 98194 PH/EC/DO multiparameter, Microscope, HI2211 PH/ORP meter (Hanna instrument)	Estimation of DO, CO_2, temperature, NH_3, NO_2, NO_3, iron, copper, dissolved phosphorus, sulfide, etc.
Fish disease and health management	Thermocycler (PCR machine) laminar air flow cabinet, Gel documentation system nanodrop, Maxwell -96, Trinocular microscope, Refrigerator centrifuge, Autoclave, Block incubator, RT-lamp, Tissue processor, CO_2 incubator, Spectrophotometer (ELISA reader)	Identification of bacteria and viruses, imaging and documentation of PCR products and proteins, DNA, RNA and proteins extractions and concentration quantification, fish vaccine preparation, antibody (IgM, IgG) titers and lysozyme measure, etc.
Fish nutrition and feed technology	Kjeldahl apparatus, Soxhlet apparatus, Muffle furnace	Crude protein, lipid, and ash content estimation
Pearl culture	Hot air oven, Microscope, Pressure Stream Sterilizer, Incubator (CO_2 microcomputer control), etc.	Pearl production, harvesting, polishing and related works
Fish genetics	qPCR, Thermal cycler, UV documentation chamber, Laminar air flow, Distilled water plant	DNA amplification and visualization, chemical mixing
Riverine Station, Chandpur		
Hilsa laboratory	Digital microscope, Microtome, Vacuum tissue processor, Digital colony counter	Fish reproductive biological aspects
Fish disease	GCMS (Gas Chromatograph Mass Spectrometer), GCMS (Gas Chromatograph Mass Spectrometer), Inverted binocular microscope,	Fish disease diagnosis

Name of laboratory	Major equipment	Major analytical capacity
	Thermostat cabinet, Autoclave, Incubator	
Limnology	Microscope, Retsch, Distilled water maker, Autoclave	Aquatic ecological parameters
Marine Fisheries and Technology Station, Cox's Bazar		
Seaweed tissue culture	Tissue processing and growth materials	Seaweed production
Live feed culture	Microscope, laminar air flow, autoclave and culture material	Algae and zooplankton culture
Histology	Microtone, inverted microscope and histological materials	Fish biological parameters
Larvae culture unit	Larval rearing tank, water treatment unit, live feed culture unit	Breeding and larviculture of shellfish and finfish
Brackishwater Station, Paikgacha, Khulna		
Water quality	Spectrophotometer, Water purifier, Microscope, HACH Kits	pH, Salinity, TDS, Alkalinity, DO, NH_3, Turbidity
Fish disease	Autoclave machine, Incubator, Microscope	Identification of Bacteria through classical microbiology
Fish nutrition	Ultra High Performance Liquid Chromatography (UHPLC)	Bio active compounds extraction, identification, phytochemical screening, bioactivity test, pesticides and antibiotic residue determination.
Shrimp Research Station, Bagerhat		
Shrimp health management	rt-PCR, Microtome, Incubator, Autoclave, Gel Documentation	Gene expression, histological analysis, nucleic acid and protein
Shrimp/fish quality control	Ultra High Performance Liquid Chromatography (UHPLC), Gas Chromatography Mass Spectrometer (GC-MS), Liquid Chromatography Mass Spectrometer (LC-MS)	Bio active compounds extraction, identification, phytochemical screening, bioactivity test, pesticides and antibiotic residue determination.
Fish/shrimp feed and nutrition	Kjeldahl apparatus, Soxhlet apparatus, Fiber test apparatus Oven, Muffle furnace	Proximate composition (macro nutrient element) of feed
Water & soil Quality Laboratory	Spectrophotometer, Water quality related titration equipment	Limnological parameters of water and soil such as pH, DO, free Co_2, alkalinity, BOD, COD, primary productivity, conductivity etc.

Name of laboratory	Major equipment	Major analytical capacity
Riverine sub-station, Khepupara, Patuakhali		
Seaweed Laboratory	Kjeldahl apparatus, Soxhlet extraction apparatus, Electric dryer/Drying oven, FT-NIR, Mincer, Rotary evaporator, UV-visible Spectrophotometer, HPLC, Freeze dryer, Ultrapure water purification, Ultrasonic bath, Shaking Incubator	Seaweed bio-active analysis, by-products development
Riverine Sub-station, Rangamati		
Water Quality laboratory	Binocular light microscope, Multiparameter water analyzer, etc.	Physical, chemical and biological water quality analysis
Freshwater Sub-station, Saidpur, Nilphamari		
Water Quality Laboratory	Spectrophotometer, Steam distiller, Biological compound microscope, Digital multiparameter (Hanna), Electric centrifuge	Water quality parameters i.e., pH, Temperature, DO, conductivity etc. (12 parameters), and others
Freshwater Sub-Station, Jashore		
Water Quality laboratory	Autoclave, Spectrophotometer, Digital multiparameter (HACH) analyzer, Water quality testing kit, Microscope	Analysis of water quality parameters in all aspects

Human resource (scientific)

Presently, BFRI has a total of 116 positions (16 in headquarters and 100 in regional research stations and sub-stations), who are involved in research and research management (Table 17). Among these positions, 88 (76%) are male and 28 (24%) are female with a male: female ratio of 3.14:1.0. Out of 116 scientists, BFRI has a total 25 PhDs including 6 female PhDs indicating a poor share of Ph.D. (21.5%) compared to the average PhD degree holders (41.2%) of NARS institutes (BARC, 2023). The scientists and scientific managers of all tiers have different scales of expertise/specialization. The highest number of 41 officers has expertise in aquaculture (35%) followed by 21 in genetics and fish breeding (18%) and 18 in open water fisheries management (16%). Although there are diversifications in the scale of research expertise, the number of scientists with specialization and research interest on fish disease, fish feed and nutrition, post-harvest and quality control, and fish population dynamics is not sufficient (Fig. 30). There is only one scientist who has specialization to address fisheries socio-economics. The manpower capacity for conducting mariculture and marine fisheries research is quite inadequate. BFRI has to develop balanced manpower capacity in each research station to handle the multidisciplinary research on fisheries and aquaculture. Moreover, BFRI has to increase its PhD degree holders from 21.5% to 70% by 2041 in line with the HRD plan for the NARS institutes 2023-2041 (BARC, 2023).

Table 17. Existing status of scientific manpower in Bangladesh Fisheries Research Institute

Positions	Total	Male		Female	
		PhD	MS	PhD	MS
Headquarters					
Director General	01	01	-	-	-
Director	02	02	-	-	-
Chief Scientific Officer (CSO)	01	-	-	01	-
Principal Scientific Officer (PSO)	01	-	01	-	-
Senior Scientific Officer (SSO)	04	01	02	-	01
Scientific Officer (SO)	07	-	04	-	03
	Research stations and Sub-stations				
Chief Scientific Officer (CSO)	01	-	-	01	-
Principal Scientific Officer (PSO)	10	08	01	01	-
Senior Scientific Officer (SSO)	45	07	27	03	8
Scientific Officer (SO)	44	-	34	-	10
Total	**116**	**19**	**69**	**6**	**22**

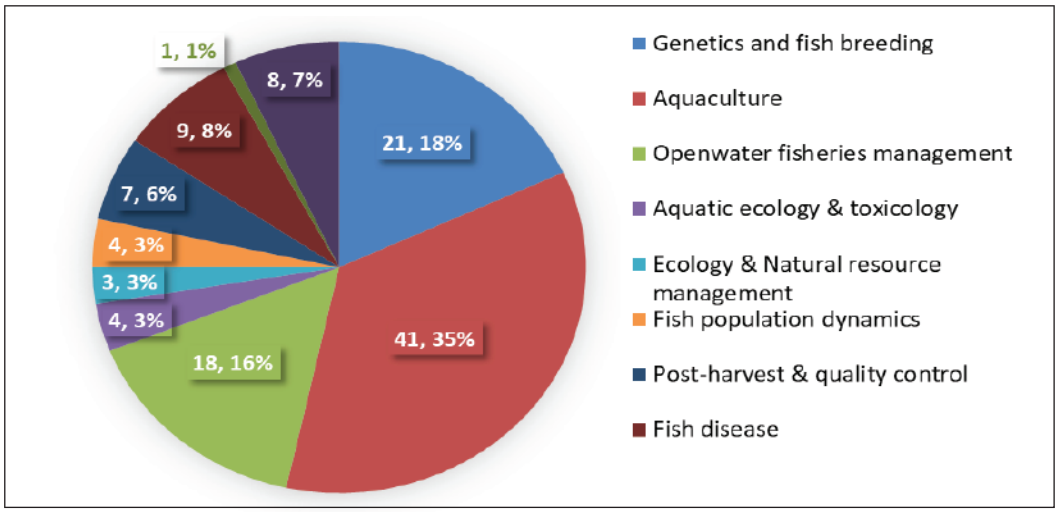

Fig. 30. Percent expertise of existing BFRI scientists

Major research achievement and current research

Since the inception of BFRI, it has been conducting research programs reflecting the national developmental needs and aligning with the government policies. BFRI has so far innovated 73 improved aquaculture and management technologies through demand driven research. About 22 technologies are widely disseminated while 26 are relatively less disseminated in the field in various degrees and the reminders are transferred to DoF for dissemination (BFRI, Per. Comm.). The salient research achievements of BFRI are:

- Development of breeding and culture technology of 24 endangered fish species.
- Identification of the 6th sanctuary of hilsa.
- Development of the 4th, 12th, 7th, and 4th generation of 20%, 62%, 35% and 12% high yielding rui (*L. rohita*), tilapia (*O. niloticus*), silver barb (*B. gonionotus*) and koi (*A. testudineous*), respectively.
- Pearl production in freshwater mussels.
- Development of breeding and culture technology of brackishwater tengra (*M. gulio*) and parshe (*L. parsia*) fish.
- Development of vaccine (*Koi-Vec*) for koi fish disease control.
- Conservation management of natural breeding ground in the Halda river.
- Production of mud crab (*S. serrata/olivecia*) in hatcheries.
- Diagnosis of shrimp disease.
- Seaweed culture in coastal areas.
- Development of seed production and culture technology of oyster.
- Development of BFRI mechanical fish dryer.

In 2022-23, BFRI has approved and is implementing a total of 54 research projects through its research stations and sub-stations. The major number of projects are on the broad areas of Genetic and Fish Breeding, Freshwater Aquaculture and Open water Fisheries

Management (Fig. 31). Despite limited capacity, a good number of research projects have been undertaken on various aspects of mariculture.

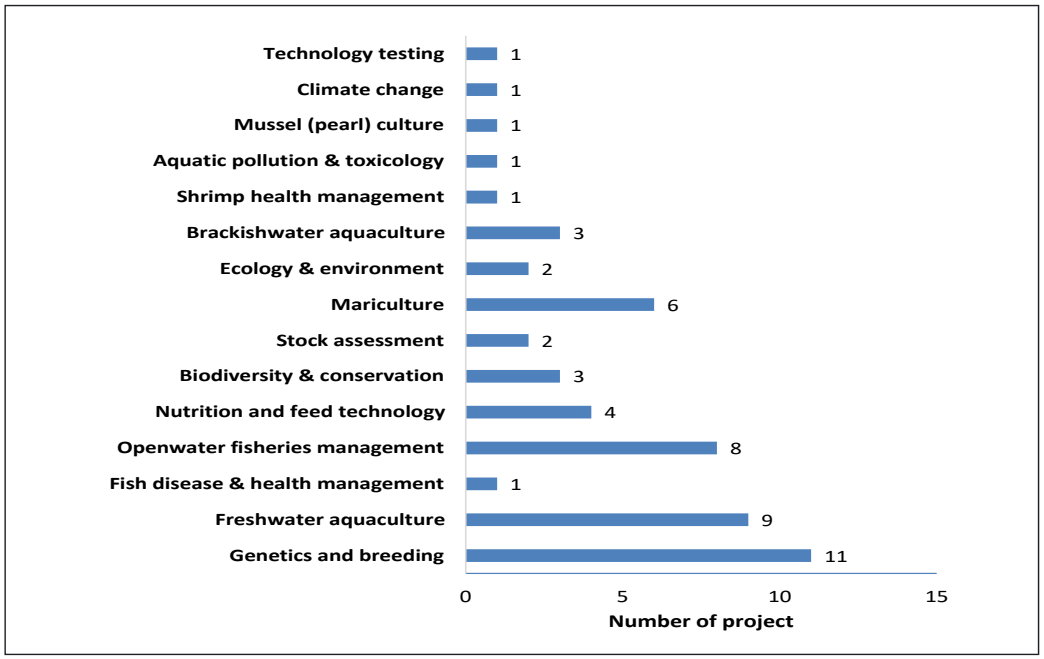

Fig. 31. Number of research projects under implementation by BFRI in 2022-2023.

Fisheries education and research

The formal higher education and research in fisheries was started in the country after the establishment of Faculty of Fisheries in the Bangladesh Agriculture University (BAU) in 1967. The rationale for setting up the faculty was to produce high quality fisheries graduates equipped with up-to-date knowledge in different fields of fisheries science and to develop the country's fisheries sector by conducting research and applying advanced modern technologies. Over the period, a total of 17 public universities (Table 18) are offering fisheries undergraduate and graduate program and conducting research on different areas of fisheries and aquaculture

Table 18. List of public universities offering fisheries higher education and research development.

Sl #	Name of university	Name of Faculty/Discipline/Department
1	Bangladesh Agricultural University (BAU)	Faculty of Fisheries
2	Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU)	Faculty of Fisheries
3	Shere-e-Bangla Agricultural University (SAU)	Faculty of Fisheries
4	Sylhet Agricultural University (SylAU)	Faculty of Fisheries
5	Hajee Mohammad Danesh Science and Technology University (HSTU)	Faculty of Fisheries
6	Noakhali Science and Technology University (NSTU)	Department of Fisheries and Marine Science
7	Patuakhali Science and Technology University (PSTU)	Faculty of Fisheries
8	Jashore Science and Technology University (JSTU)	Department of Fisheries and Marine Bioscience
9	Dhaka University (DU)	Department of Fisheries
10	Chattogram University (CU)	Faculty of Marine Sciences and Fisheries
11	Khulna University (KU)	Fisheries and Marine Resource Technology Discipline
12	Rajshahi University (RU)	Department of Fisheries
13	Chattogram Veterinary and Animal Sciences University (CVASU)	Faculty of Fisheries
14	Khulna Agricultural University (KU)	Department of Fisheries
15	Bangabandhu Sheikh Mijubur Rahman Science and Technology University (BSMRSTU)	Department of Fisheries and Marine Bioscience
16	Bangamata Sheikh Fojilatunnesa Mujib Science & Technology University (BMFSTU)	Department of Fisheries
17	Habigonj Agricultural University (HAU)	Faculty of Fisheries

The universities are conducting research on fish fauna, reproductive biology, conservation and management of brood stock, fish breeding, chromosome and gene manipulation, fish culture, nutrition and fish pathology, population dynamics, economics and marketing, fish health, processing and preservation, pre- and post-harvest technology, fish microbiology, quality of fish products, etc.

Other institutions involved in fisheries research

Bangladesh Oceanographic Research Institute (BORI), which was established in Cox's Bazar by the Bangladesh Ocean Research Institute Act-2015 under the Ministry of Science and Technology (MoST), has mandate of conducting research on different topics of oceanography, namely:

a. Physical Oceanography;
b. Geological Oceanography;
c. Chemical Oceanography;
d. Biological Oceanography;
e. Climate Change and the Ocean; and
f. Anything else about the sea.

The institute so far managed and financed for 8 R&D projects in FY 2021-22, 8 in FY 2019-20, 6 in FY 2018-19 and 5 projects in FY 2017-18 (http://www.bori.gov.bd) on different aspects of oceanography. The institute conducts all the activities as a focal point of Bangladesh at national and international levels in the field of oceanography and Blue Economy in the context of research and development. BORI has developed future Blue Economy-based research projects for short, medium and long term up to the year 2030 (BORI, 2021).

The Institute of Food Science and Technology of the Bangladesh Council of Scientific and Industrial Research (BCSIR) deals with nutrition and processing technologies of food and fisheries products. Along with education, similar research has also been conducted by the Institute of Nutrition and Food Science of the University of Dhaka. There are a few international non-government organizations, notably the WorldFish and Winrock International are implementing fisheries research and development program in the country.

Availability and utilization of research funds

Bangladesh Fisheries Research Institute has been receiving funds from the revenue of the Government and budget of the development projects for conducting research (Fig. 32). BFRI is also offering research funds to universities. The research budget from revenue increased enormously from Tk. 11.9 million in 2008 to 33.9 million in 2021-22. In the last five years (2017-18 to 2021-22), the institute utilized a total of Tk. 302 million (both from revenue and development budget) for research. It is noteworthy that, the research fund allocation from revenue budget has been increasing and the average is Tk. 32 million each year (BFRI, pers. comm.).

Several other national sources eg, Ministry of Education (MoE) through Bangladesh Bureau of Educational Information and Statistics (BANBEIS), Bangladesh Academy of Science (BAS), Ministry of Science and Technology (MoST), Krishi Gobeshona Foundation (KGF) etc., are also funding for research on different disciplines including fisheries.

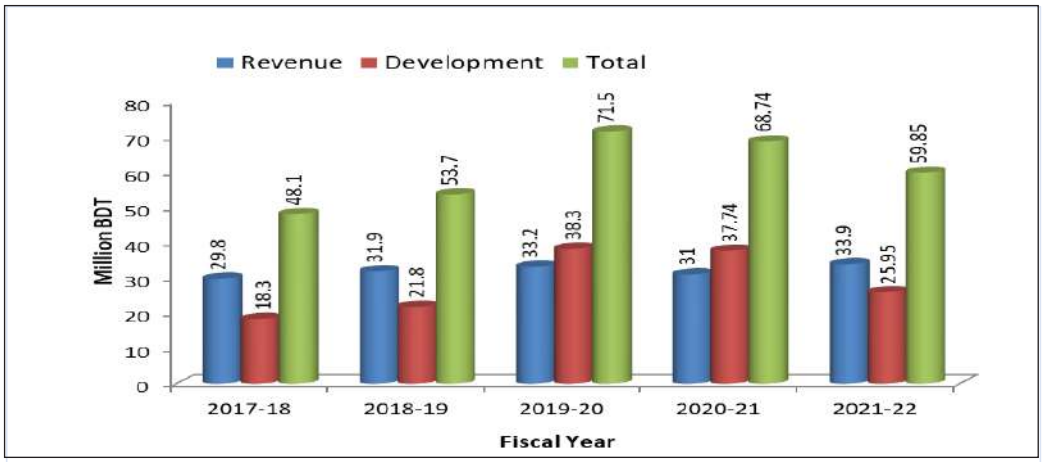

Fig. 32. Research fund allocation in BFRI for the period of 2017-18 to 2021-22

(source: BFRI, pers. comm.)

All these organizations support competent researchers for conducting scientifically sound and nationally important projects on competitive basis. In 2020-21, MoST allocated a total of Tk. 221.9 million (MoST, 2022) and in 2021-22, MoE allocated Tk. 160.0 million (http://www.banbeis.gov.bd) for research including agricultural sciences. The research fund allocation of MoST and MoE for the last five years is shown in Table 19. The research grants are open and there is opportunity for hunting funds for fisheries research.

Table 19. Competitive research fund allocation from 2017-18 to 2021-22

Financial Year	Funding source (in million taka)	
	MoST	MoE (BANBEIS)
2017-18	173.6	110
2018-19	162.7	144
2019-20	156.2	150
2020-21	221.9	160
2021-21	N/A	160
Total	**714.4**	**724**

The funding support by KGF to different disciplines of agriculture and fisheries during the FY 2016-17 through 2020-21 is shown in Fig. 33, which clearly demonstrates a poor representation of fisheries discipline (KGF, pers. comm.). During the last five years, the share of fisheries research was only 5% of the total KGF's research expenditure (Fig. 34). However, in the 4th phase for the period of 2020-2023, BAS-USDA allocated a total of Tk 166.41 million of which fisheries related projects received Tk. 34.87 million (21%), competing with all other disciplines (Fig. 35). (https://www.bas.org.bd/project-lists).

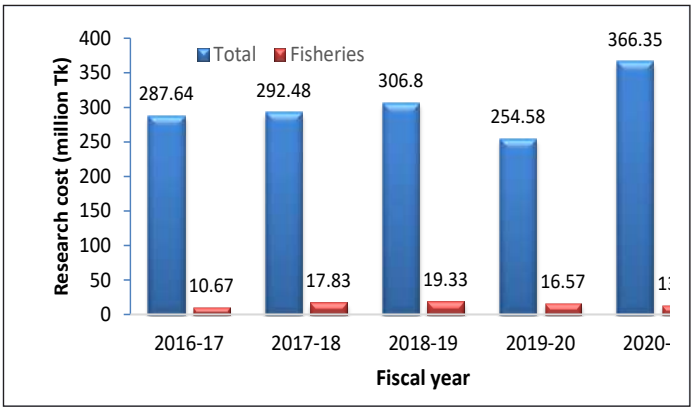

Fig. 33. Research expenditure of KGF during the FY 2016-17 through 2020-21.

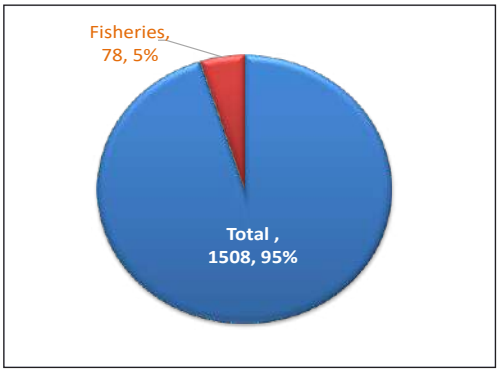

Fig. 34. Share of KGF competitive research fund (million Tk. & %) for fisheries discipline in the last five years.

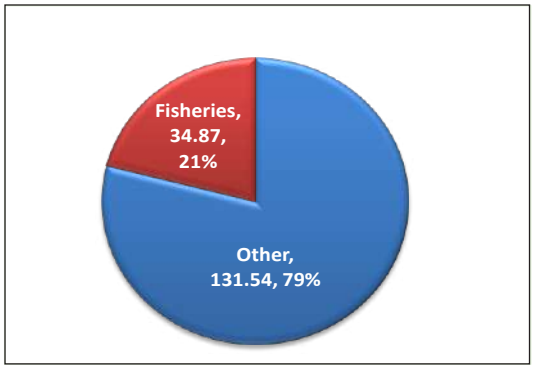

Fig. 35. Share of BAS-USDA competitive research fund (million Tk. & %) for fisheries discipline in 2020-23.

Fisheries Policies and Strategic Plans

Since fishery is a productive growth sector in Bangladesh, it has high potential to contribute to meeting the future demand of nutrition-sensitive food from fish, strengthening national economy and improving livelihoods of millions of people despite various human and climate induced challenges. To meet the compelling demand and fulfilling the current and future requirement of fish, Bangladesh has formulated a number of fisheries laws, rules, guidelines, policies, plans, ordinances and acts to ensure that fisheries and aquaculture are productive and sustainable ecologically, economically and socially. It is also concerned for ensuring access to common-pool fisheries resources maintaining employment and the sector's economic viability. In this chapter, policies and plans relevant to fisheries sub-sector are reviewed with a view mainly to mapping out the research needs.

National Fisheries Policy 1998

In the backdrop of multidimensional threats and constraints to fisheries, the Ministry of Fisheries and Livestock (MoFL) has formulated the "National Fisheries Policy1998" with the following objectives:

a) to conserve fisheries resources and enhance fish production from inland and marine sources for poverty alleviation, and
b) to enhance economic growth, employment generation and nutrition maintaining ecological balance and biodiversity conservation.

The policy intends to transform the fisheries and aquaculture sub-sector from subsistence to highly productive sector through required investments, improved governance and use of appropriate research-based technologies (NEF, 1998). The policy includes by its legal status all the Government organizations, NGOs, multi-national institutions, voluntary organizations, and persons who are working for the production, harvesting, preservation, export-import or other businesses related to the fisheries sector. The policy encompasses (a) inland open water fisheries resources conservation policy; (b) inland closed water aquaculture and management policy; (c) coastal shrimp and aquaculture policy; (d) marine fisheries resources conservation, management and exploitation policy; (e) fisheries related subsidiary policies; and (f) other aspects related to fisheries (NFP, 1998).

The NFP 1998 delineated a number of actions under each policy and envisaged to implement these actions in an integrated way through institutional arrangements that deal with multi-sectorial issues at all levels of the value chain. The actions under each policy framework that lead to research questions are given in Table. 20.

Table 20. Fisheries policies and actions therein leading to research questions/ intervention

Sl. No.	Name of policy and stated actions	Research questions/intervention
1	***Policy for inland open water fisheries resources conservation, management and exploitation***	
1.1	Protection of fish habitat during implementation of development activities.	• How can the need for dams and associated infrastructure be balanced with connectivity, health and flow requirements of inland aquatic ecosystems and biodiversity?
1.2	Establishment of fish sanctuaries in Jalmohal for increased production and to conserve biodiversity.	• How can conservation and restoration measures be developed that most effectively and efficiently address synergistic threats to freshwater biodiversity?
1.3	Conservation of breeding grounds of fish and freshwater giant prawn.	• Where and why have past efforts on identification of fish and prawn breeding grounds been done and what have been learned from the outcomes?
1.4	Fish/ shrimp cum HYV rice culture in the beels, haors and other flood affected areas.	• At what spatial and temporal scales have the technology and management interventions been applied to benefit fish/shrimp/prawn culture in the specified water areas?
1.5	Fish culture in low lying lands, which remain inundated under 50 cm of water for a period of more than 3 months.	
1.6	Prohibits/minimizes discharge of harmful municipal and industrial wastes and use of insecticides in crop fields.	• What approaches to pollution reduction and remediation efforts will most benefit inland fisheries biodiversity?
1.7	Appropriate measures to culture fish in waterlogged areas, haors, baors and beels.	• What research innovations are needed to benefit the ecologically challenged water areas introducing fish culture?

Sl. No.	Name of policy and stated actions	Research questions/intervention
1.8	Arrangements to conserve the threatened and endangered fish species and ensure mass production.	• What type of research and investments in ex situ conservation (e.g. captive breeding, reintroduction, managed relocation) are most effective for imperiled and threatened fish species?
1.9	Demonstration of fish culture in cage and pen.	• Where and how can fish culture in cages and pens be the best minimizing potential challenges and maximizing carrying capacity?
2	Inland closed water aquaculture and management policy	
2.1	Encourages fish culture in all ponds (mini and large). Proper observation on impact of exotic species prior to introduction.	• What are the appropriate technologies and how can these be adopted in wider aqua-ecological areas? • What are the best ways to manage freshwater invasive species and diseases to ensure proactive and meaningful improvement in inland aquaculture production?
2.2	Develops low-cost aquaculture feed by using local ingredients and encourage private entrepreneurs in feed industry.	• What are the potential local sources of low-cost fish feed ingredients and their usage in fish feed industries? • How are available fish feeds cost and yield-effective?
2.3	Develops soil maps in all potential aquaculture areas suggesting lime and fertilizer requirement.	• How do soil-water quality and dynamics in aquatic ecosystem vary from region to region and how can the location-specific nutrients based optimum primary productivity be maintained.
2.4	Encourages integrated prawn-fish-rice farming in brackish water.	• It is already in practice (Nesar 2010). However, how can the system benefit to the full extent both at the "farmer level" and at a "landscape level"?
2.5	Mono and polyculture of freshwater giant prawn.	

Sl. No.	Name of policy and stated actions	Research questions/intervention
2.6	Encourages commercial fish seed production by private sector.	• Private sector has been supplying 98% of total fish seed production from commercial hatcheries (Table. 3.10). However, what are the determinants of accessibility and frequency of fish seed production of target species in quality and quantity?
2.7	Develops different fish culture and management technology packages for entrepreneurs.	• A number of aquaculture technology packages are available. What, where and how can organizational mechanisms accelerate technology adoption and feedback for fine-tuning of technologies in changing environment.
3.	Coastal shrimp and fish culture policy	
3.1	Maintains ecological balance by introducing integrated rice-fish or shrimp-rice system.	• Research results on shrimp-rice-prawn/fish system in intertidal coastal areas have been reported (Alam et al., 2010). However, there are a number of further research questions: • How does fish in a shrimp-rice production system provide profitability, food and nutrition security, and the ecosystem services? • Is the increase in resilience of systems affected by different levels of salinity through synchrony in cropping season and fresh water availability and use of targeted varieties of rice and species of fish for different landscapes?
3.2	Encourages private sector for establishment of commercial shrimp and prawn hatchery.	• Although a large number of hatcheries of shrimp (P. monodon) in the country (44) are entirely owned by private sectors, only a few hatcheries (6) of prawn (M. rosenbergii) are in the private sectors. The major concerns are: • How are produced and supplied shrimp/prawn post-larvae pathogen/disease free?

Sl. No.	Name of policy and stated actions	Research questions/intervention
		• How are inconsistent set of symptoms which usually lead to mass mortalities during the larval rearing cycle minimized?
3.3	Improvement of shrimp farming using appropriate technology, feeding and post-harvest management.	• How is the shrimp farms' yield rate improved sustainably and what is the aquaculture system best suited for intensification of shrimp culture? • Are there any alternative sources of low-cost but nutrient efficient shrimp feed ingredients? • When, where and what amount is to feed the shrimp? • How do pond conditions and farming protocols influence feeding activity?
4	Marine fisheries resources conservation, management and exploitation policy	
4.1	Undertakes research for the development of marine fisheries resources.	• To what degree must foraging needs of top predators and other animal species be considered in exploitation of fish stocks to ensure healthy ecosystems? • How much is marine biomass lost to ghost fishing and what is the most effective way to reduce this source of mortality? • How can fishing gear and techniques be improved to minimize habitat damage?
4.2	Application of appropriate technology for marine fisheries conservation and increased production.	• How is the provision of ecosystem services (known and unknown, quantitative and qualitative) incorporated into marine conservation? • How can the impacts of by-catch from Illegal, Unreported, and Unregulated (IUU) fisheries be reduced to a level that will allow the reversal of declining trends of affected species?
4.3	Conducts research and survey under regional and international program to develop skills of using modern fishing techniques and technologies.	• What can strategies be used to promote long-term integrated multi-national and multi-disciplinary collaborations?

Sl. No.	Name of policy and stated actions	Research questions/intervention
	Fisheries related subsidiary policies	
5.1	Improvement of traditional fish processing and preservation, and value addition	• What are the novel fish processing and preservation technologies that may result in economical and improved quality products? • How will the innovations go in parallel with consumer demand for healthy food and safer while improving the quality and shelf life of fishery products.
5.2	Coordination among all organizations involved in fisheries	• How is to integrate and link the organizations together for joint planning, implementation and evaluation of fisheries research and development program?
5.3	Prioritizes research areas considering productivity potentials and economic benefit.	• How do research organizations prioritize research needs when everything appears to be a priority?
5.5	Prohibits untreated industrial waste disposal to aquatic environment.	• Where does water pollution come from and what are the types of pollutants there? • What are the properties and dangers of industrial pollutants? • What are the specific ways of bio-accumulation and bio-magnification and remedial measures?
5.6	Development of fisheries sectorial data base.	• Does a digital fisheries data hub in the internet age serve as a tool for research and monitoring using online data for fisheries planning and development?

Marine Fisheries Act 2020

The Marine Fisheries Act 2020 (MFA, 2020) replaced the Marine Fisheries Ordinance 1983 with a view to upgrading the regulation of fisheries resources in Bangladesh's marine waters. The Act introduces a few novel provisions on:

a) distinction between artisanal and industrial fishing;
b) Illegal, Unreported, and Unregulated (IUU) fishing stating that the Government reserves the right to issue any necessary orders to prevent IUU fishing within Bangladesh's marine waters';
c) declaration relating to the establishment of mariculture zones within the marine areas of Bangladesh to expand the growth of blue economy; and
d) compulsion of industrial fishing trawlers either imported or locally built to specifications fixed by the government.

The 2020 Act does not cover recreational fishing in the Bangladesh's marine waters, which is still relatively uncommon, primarily due to the reason behind the absence of any provision on such fishing. To deter and combat IUU, it is necessary to conduct regular research on stock assessments (either overall or for specific species), conservation measures, and determination of allowable catches in Bangladesh's maritime area. The new law gives wide power to the authorities to declare zones for mariculture, which requires research to identify suitable areas, select suitable species and develop appropriate mariculture methods. The provision of mariculture activities also requires a proper environmental impact assessment.

National plan of action to prevent, deter and eliminate Illegal, Unreported and Unregulated (IUU) fishing- 2019

Illegal, Unreported and Unregulated (IUU) fishing is a global phenomenon occurring across all fishery types, sectors and geographies (Temple et al. 2022). National Plan of Action to prevent, deter and eliminate IUU Fishing (NPOA−IUU) of Bangladesh has been developed in accordance with the FAO developed International Plan of Action to prevent, deter and eliminate IUU fishing (IPOA−IUU). The NPOA-IUU demonstrates Bangladesh's commitment to achieving the 2030 Agenda for Sustainable Development commensurate with the Sustainable Development Goals (SDGs) particularly SDG 14-Life Below Water through implementation of international instruments aiming to combat IUU fishing.

The NPOA-IUU applied several general and special measures such as fishing vessel registration, record of fishing vessels, authorization to fish, control transport and vessels re-supply, evidence indicating IUU fishing, trade, catch documentation and markets, and innovative marine fisheries management. Some priority actions for preventing, controlling and eliminating IUU fishing from the maritime boundary through enhancing organizational and professional capacity have also been indicated. However, in the National Plan of Action, integration of the interest and ownership of the small-scale fishers of the territorial water is some-how missing, which should be considered to ensure inclusiveness. Apart from NPOA-IUU, fighting against IUU fishing requires more focus in marine fisheries management, maritime zone related policies, and strategies as well as national policy documents (Latif et al., 2022).

To garner the benefits of blue economy, ensuring ocean governance is prerequisite for Bangladesh. However, IUU fishing is veering into an obstacle to garner such benefits. To successfully address IUU fishing, a contemporary and more granular understanding is required that must be supported by an appropriate research evidence base at relevant spatial and temporal scales. To improve the understanding of IUU at relevant national spatial-temporal scales and from which to make effective evidence-based actions, a four-step research agenda has been suggested (Temple et al., 2022) as: (a) defining intent and goal-setting, (b) risk assessment and prioritization, (c) estimation of volume, costs and impacts, and (d) economic appraisal of policy and regulatory reform.

The 8th Five Year Plan (July 2020 – June 2025)

The 8th Five Year Plan (8th FYP) has six core themes, of which two themes viz, (a) GDP growth acceleration, employment generation, productivity acceleration and rapid poverty reduction, and (b) a sustainable development pathway that is resilient to disaster and climate change and entails sustainable use of natural resources are directly correlated to fisheries sub-sector (GED, 2020). The plan envisaged further increase in diversification of agriculture including fisheries while maintaining food security through improvements in farm productivity, supply of inputs, price policy support, water supply, farm credit and marketing support. Fisheries sub-sector has been recognized for its pivotal role in increasing farm income and employment through promotion of exports of fish and fishery products. The main objective of the fisheries sub-sector in the 8FYP is to support sustainable growth of fish and shrimp production with other aquatic resources for domestic consumption and exports by managing open water fisheries resources. It also supports for exploring blue economy through community participation leading to equitable distribution of the benefits for optimal economic and social growth, and reducing post-harvest loss (GED, 2020a).

Despite the significant contribution of fisheries sub-sector to food security and national income discussed in Chapter 3 of this document, the 8th FYP has outlined a set of strategies against the challenges that may hinder the future growth. The strategies particularly those needs research intervention against the challenges are summarized in the Table 21.

Table 21. Summary of challenges and strategies of the 8th FYP for fisheries sub-sector

Challenges	Strategies need research intervention
Supply chain disruptions due to COVID-19.	The consequence of the COVID-19 induced disruption in the fisheries supply chain is likely to be not clear at this stage.
Inland capture fisheries	
Degradation, conservation and sustainable management of natural resources.	• Inland unused open water resources will be conserved and developed for fish production. • Effective fish conservation strategies will be developed and implemented. • Natural breeding, spawning, nursery and grow-out areas will be conserved to complete the whole lifecycle and natural reproduction process to ensure pure brood and fingerlings. • Pollution control and replenishment of fish stocks involving local communities.

Challenges	Strategies need research intervention
	• Fish and wetland sanctuaries will be established with complete ban on fishing in certain eco-sensitive areas. • Maximum Sustainable Yield (MSY) of hilsa will be determined.
Increased waterlogging, blocking of fish migratory routes, loss of biodiversity, and social conflicts in case of floodplain aquaculture.	• Further deterioration of water logging, blockade of water-flows and shrinkage of waterbodies will be prevented following environmental rules and regulations and consulting with MoFL • Projects and program will be implemented to construct and maintain fish-passes and fish-friendly regulators.
Inland culture fisheries	
Poor brood stock management, inadequacy of the supply of quality fish, shrimp and prawn seeds, low availability of reliable and quality fish feed at a reasonable cost, and spread of infectious diseases of both fish and shrimp	• Aquaculture intensification, and species diversification and farm mechanization will be promoted avoiding water pollution. • Adaptive aquaculture technologies and fisheries management system will be introduced. • Fish health management strategy and aquaculture policy will be adopted and implemented. • Supply of quality fingerlings and fish feeds through private sectors will remain an important strategy for culture fisheries. • Promoting small indigenous species in conjunction with pond carp culture will be given importance. • Community-based market-driven innovative floodplain aquaculture will be expanded and combined with maintaining sanctuaries and restocking of indigenous species. • Cage culture in the flood plains with private ownership will be encouraged, which can certainly contribute to productivity. • Increasing fish production by introducing different fish culture methods and conserving natural environment including rice-cum-/alternate fish culture under the community enterprise approach in suitable habitats. • Introduction of biofloc system of fish production for landless and marginal farmers and also in the urban areas.

Challenges	Strategies need research intervention
Low productivity of shrimp and prawn, lack of good quality feed and post-larvae, quality assurance, traceability and inadequacy in social compliance for export market.	• Community organizations of shrimp farmers and other primary stakeholders will be supported with technology, input, financing and market linkage by contract growing system run by the processing plants and monitored by the DoF and partner NGOs. • To ensure supply of virus-free shrimp PL, all hatcheries will ensure PCR testing of both mother shrimps and shrimp PL. • Development of tractability system to identify the sources of contaminants/banned antibiotics and other chemicals used for fish farming and fish processing so that the Government can take lawful and corrective measures to improve/ratify them.
Marine fisheries	
Overcapacity of fishing effort, long gap exploratory survey on stock assessment, deployment of destructive and illegal gears, IUU, pollution, climate change paradigm, degradation of highly productive coastal and near-shore marine habitat and breeding grounds, infringement of rules and regulations, etc. in case of marine fisheries	• Stock and maximum sustainable yield/total allowable catch (quota) must be determined thorough assessments on a regular basis. • Identify conservation needs and methods that can be effectively administered and regularly monitored. • Harness the potential of blue economy, stock assessment of marine fisheries and promote sustainable exploitation of marine fishes, especially tuna and tuna like other pelagic fishing. • Development of Digital Marine Fisheries Resource Mapping (DMFRM) for the marine waters using digital cartography of the marine fisheries resources. • Establishment of MPAs (Marine Protected Areas) as fish spawning and nursery grounds.
Others	
Adverse impacts of climate change	• No specific strategy to address impacts of climate change on fisheries.
Inadequate human resources, logistic support and knowledge gap of the producers.	• Extension supports and research extension linkages will be strengthened. • Application of Information and Communication Technology (ICT) will be promoted to disseminate

Challenges	Strategies need research intervention
	fisheries information and modern technology in the remote areas of the country for facilitating fisheries activities particularly the aquaculture. • Regular and long-term study/research on change of biodiversity, impact of sanctuary, habitat restoration, physical, chemical & biological changes of haor basin, fish production, fish migration and socio-economic condition of fisher folk will be implemented.
Inadequate/limited institutional capacity for research and extension services.	• Institutional capacity for research, development and extension services will be strengthened.

Bangladesh Perspective Plan 2021-2041

The Government of Bangladesh has introduced the Bangladesh Perspective Plan 2021-2041 (GED, 2020b), which is a national plan with multi-sectorial approach. The key aim of BPP 2041 is to eradicate extreme poverty, achieve the upper middle class by 2030 and make Bangladesh a developed country by 2041. The key priority areas of BPP2041 related to fisheries research and development will be discussed here:

The perspective plan 2021-2041 has been introduced when Bangladesh has made a substantial production and economic growth in fisheries sub-sector. Besides Government's technical, investment and policy supports, there are increased private investment in backward and forward supply chain in production, consumption and trading of fish and fishery products that have led to this growth during the last decade. BPP 2021-41 has listed a number of similar challenges, as has been stated in the 8FYP (Section 4.4) that the country has to achieve the future progress for ensuring sustainable fisheries. Among these, the most critical challenges related to fisheries sub-sector and approaches to combat these challenges as delineated in BPP 2021-41 are stated in Table 22.

Table 22. Delineated challenges and approaches in BPP 2021-2041 for fisheries sub-sectorial development

Critical challenges	PP 2021-2041 approaches
Degradation of natural resources and depleting land available for agriculture	Optimum use of land so that more agricultural products can be produced on limited available land.
Scarcity of water	Proper scheduling water requirement of crops and non-crops, particularly of aquaculture, to increase water use efficiency and decrease the loss of precious water resources in future.
Market access and value chain constraints	Production, processing, packaging, scientifically warehousing, transportation and marketing of the high-valued fish and fishery products.
Inadequate investments in agro-processing value chains	Increase investments in different segments of the value chain, including supply of knowledge on new fisheries technology to help farmers produce according to market needs maintaining the quality and safety abiding national and international standards/norms.
Weak market infrastructure and poor transportation facilities	• Rules and regulations will be enacted to ensure that farmers are getting real benefits for their sweat-toiling agricultural products including fishes. • Price of agricultural products at the farm level will be maintained in such a way that the farmers get fair prices. • The Road Users Cost (RUC) will be maintained at minimum as possible by maintaining the rural roads and road infrastructures. • Support expansion of M4P/M4C (Market for Char) approach to national private business networks in chars and other hard to reach areas. • Support innovation for the growth of local enterprise and integration/inclusion of these local enterprises with regional and national value chains. • Facilitate public investment in related infrastructure through capitalization, anchoring and influencing.
Lack of easy credit to small farmers and other market intermediaries	Extend timely and hassle-free credits to the poor farmers and small traders in the supply chain.
Climate change impact	• Adapt to the impacts of climate change to improve the resilience of food production systems

Critical challenges	PP 2021-2041 approaches
	• Management of water resources and addressing the vagaries of climate change will have to be integrated into the national strategies.
Addressing food security	• Bringing unfavorable aqua-ecosystems eg, haor, char, coastal, barind tracts, hill tracts etc, under productive sustainable fish production practices. • Intensification of fish cultivation maintaining sustainability of aquatic ecosystem health. • Sustainably intensifying fisheries production systems without bringing new land under cultivation. • Increasing resilience of fisheries production systems despite pernicious impacts of climate change. • Diversification in agricultural output and livelihoods involving more fish and shellfish species. • Coping with uncertainty in developing responses about the scale and eventual nature of adaptation needed to address climate change.
Development and scaling up of innovative demand-led innovative technology and information.	• Research organization(s) will be strengthened and adequately funded to address the problem areas (like hills, coastal, char, haor, hill and barind areas) that are more prone to weather vagaries and that have proportionately higher population of poor and vulnerable people. • Research in private firms will be encouraged.

To this end, the BPP 2021-41 has emphasized on generation of appropriate and sustainable technology for enhancing safe fish production, controlling pollution and maintaining aquatic health, conservation of aquatic resources and biodiversity, and biotechnological intervention. The BPP 2021-41 has also stressed for the development of intensive, diversified and climate resilient/smart fish production systems. The increasing trend in production of giant tiger shrimp (bagda) and giant freshwater prawn (golda), which are the major fisheries export commodities, could be further enhanced through the use of improved extensive and intensive culture technology. Besides strengthening of monitoring and evaluation from production to processing and marketing, effective research-based techniques will be developed on the safety of fish and fishery products and nutrition value for enhancing export. In addition, the challenge for striving to upper middle income country (UMIC) status by 2031 will be to exploit international markets with investment in areas like packaging, sanitary and phytosanitary standards (SPS), and Good Aquaculture Practices (GAPs).

Overall, BPP 2021-41 has identified following priority strategies for aquaculture development (GED, 2020b).

- Fish health management strategy, aquaculture policy, and marine fisheries policy need to be adopted and implemented for sustaining food security and nutrition.
- Aquaculture intensification and species diversification will be promoted.
- Farm mechanization and vertical expansion of aquaculture should be the major priority for sustaining and diversifying aquaculture production.
- Collaborative efforts need to be taken for exploring blue economy-related activities concerning the fisheries sector.
- Besides subsistence level mono aquaculture and fisheries interventions, aquaculture-based farming activities (integrated with crops, livestock etc.) will be expanded to uphold the household's nutritional status.
- Private sector investment will be enhanced for increasing value chain of fish and fisheries product.
- Motivational activities for farmers/entrepreneurs will be undertaken to adopt advanced farming technologies.
- Skilled/trained manpower will be developed to operate modern laboratory and processing plants.
- Introduction of adaptive aquaculture technologies and fisheries management system through training and farm demonstration for the poor fish farmers/fishers of coastal region.
- As the fishers dependent on aquatic environment are highly vulnerable to the effect of climate change, special importance/consideration should be given to their livelihoods.
- Collaboration and coordination among ministries, department and agencies will be strengthened.

The Bangladesh Delta Plan 2100

The Bangladesh Delta Plan 2100 (BDP 2100) has been formulated aligning with national goals of the "Perspective Plan 2041" viz, (a) eliminate extreme poverty by 2030; (b) achieve UMIC status by 2030; and (c) being prosperous country beyond 2041. The plan has six specific goals for ensuring long term water and food security, economic growth and environmental sustainability while effectively reducing vulnerability to natural disasters and building resilience to climate change and other delta challenges through robust, adaptive and integrated strategies, and equitable water governance (GED, 2018). The BDP 2100 has identified six "hotspots" and other cross-cutting areas (Fig. 36) on the basis of previously identified eight hydrological regions in the National Water Management Plan 2001 (WRPO, 2001). In BDP 2100, the hotspots are a broad grouping of districts and areas facing similar risks evolved by hydrology, climate change and natural hazards. The identified six hotspots are: (1) Coastal Zone (27,738 sq. km); (2) Barind and Drought Prone Areas (22,848 sq. km); (3) Haor and Flash Flood Areas (16,574 sq. km); (4) Chattogram Hill Tracts (13,295 sq. km); (5) River System and Estuaries (35,204 sq. km); and (6) Urban Areas (19,823 sq. km).

Fig. 36. Mapping of districts to hotspots in Delta Plan 2100.

The remaining areas are identified as "Cross cutting" areas characterized by a combination of issues and challenges e.g. floods, river bank erosion, sedimentation, groundwater depletion, water pollution and water supply and sanitation.

Depending on the geographical locations and hydrological systems, the hotspots are characterized with different types of inland and marine fisheries resources, which have ample scopes of development for enhanced fisheries production and socio-economic development of the country. It is to be noted that the fisheries has emerged as a potential sub-sector with increasing value-added and employment shares compared to the crop sub-sector in recent years. The BDP 2100 has set out a number of strategies, which have direct or indirect benefits to the development of fisheries and aquaculture. These strategies are summarized in the Table 23.

Table 23. Strategies and targets of Delta Plan 2100 related to fisheries and aquaculture development (italics are the indirect benefits of the strategies)

Sl. #	Strategies	Set targets having fisheries potentials
	National Strategy	
A	**Flood Risk Management**	
A.1	Equipping the FCD Schemes for the Future	• Restoration of water bodies and connectivity *– Fisheries-friendly fish bypass should be considered*
		• River management, excavation and smart dredging *– Natural fish breeding and spawning ground will be restored*
A.2	Safeguarding livelihoods of vulnerable communities	• Strengthening of the social safety net including rapid economic recovery though vital inputs and financial services for alternative income activities. - *Social security opportunities may be created for fishers during non-fishing period.*
B	**Freshwater**	
B.1	Ensures water availability by balancing supply and demand for sustainable and inclusive growth	• Excavation of local water reservoirs (canals, ponds and baors) for restoration of water and explore rain water harvesting - *Aquaculture will be expanded*
		• Enhancement of freshwater flows in urban and regional rivers - *Salinity intrusion problems for inland freshwater fisheries and aquaculture will be reduced*
B.2	Maintains water quality for health, livelihoods and ecosystems	• Monitoring, control and mitigation of water pollution. - *Healthy and safe fish production will be ensured* • Action research for improved water resource planning and ecosystem services - *Research knowledge on fisheries biodiversity and ecosystem services may be integrated for sustainable resource use*
		• Introduction of green production technologies.

Sl. #	Strategies	Set targets having fisheries potentials
		- *Aquaculture is itself a green production technology*
	Hotspot specific strategies	
A	**Coastal zone**	
A.1	Increase drainage capacity and reduce flood risk at coastal zone	• Restoration of rural rivers/canals and livelihood improvement in exposed and interior coastal districts - *Increased water flow enhance fish culture and abundance*
A.2	Balancing water supply and demand for sustainable growth	• Demand management and efficient water use - *May reduce water use conflicts between crop production and aquaculture*
		• Resource planning and protection of environment - *Fish habitat loss and habitat fragmentation will be minimized*
A.3	a) Reclaims new land in the coastal zone	• Protects and develops zoning of the reclaimed land - *Aquaculture may be expanded in newly reclaimed areas*
	b) Conservation of Sundarbans	• The "engine" of succession, the cause of ecosystem change, is the impact of established species upon their own environments. - *Surdarbans fisheries resources will be protected and conserved*
	c) Restoration of dead/low flowing rivers and basin wide management of trans-boundary rivers for increasing supply of fresh water	• Reduces salinity intrusion to protect freshwater aquatic biodiversity and increases fish productivity
B	**Barind and Drought Prone areas**	
	Balancing supply and demand for sustainable and inclusive growth	• Preserves and enhances valuable wetlands and ecosystem
		• Demand management and efficient water use - fish production consuming less water
		• Encouraging excavation of ponds and digging well to retain rain water

Sl. #	Strategies	Set targets having fisheries potentials
C	**Haor and Flash Flood Areas**	
	Sustainable Haor Ecosystem and Biodiversity Management	• Identification of important breeding, spawning, nursery and grazing distribution of fish and other aquatic fauna
		• \Restoration and maintenance of the connectivity between the rivers and haors will ensure the environmental improvement to make haors more potential for sustainable fish production
		• Development and conservation of the mother fisheries in Tanguar haor, Hakaluki haor, Kawadighi haor, etc
		• Fish passes should be introduced in existing FCD/I projects
D	**Chattogram Hill Tracts**	
	a) Maintains ecological balance and values (assets)	• *The values of Halda river ecosystem and fisheries will be ascertained and protected*
	b) Strengthens resilience of livelihoods and sustainable food production	• Creates markets, marketing and value chain for income diversification (e.g. processing of fisheries, value chain etc). • Explores potentials for rehabilitation of the Kaptai lake for management of fishing, hydropower, and agriculture.
E	**River Systems and Estuaries**	
	a) Maintains ecological balance and values (assets) of the rivers	• Pollution free freshwater • Designated (protected) fish sanctuaries for safe reproduction • Connectivity between river branches and floodplains
	b) Development of strategy for sediment management including a strong capital dredging and maintenance program	• Enabling environmental restoration, and providing flora and fauna habitat
F	**Urban Areas**	
	a) Integrated and sustainable use of urban land and water resources	• Introduction of aquaponics farming system to culture fish and plants together

Sl. #	Strategies	Set targets having fisheries potentials
	b) Conserves and preserves urban wetlands and ecosystems and promote their wise-use	• Feasibility study and piloting to develop the wetlands in a sustainable way in which the ecological and hydrological values remain
	c) Control and monitoring of water pollution caused by industry and other sources	• Industrial waste treatments in current industrial zones
	Cross-cutting Strategies	
A	Sustainable land use and spatial planning	• Sustainable coastal land management for enhancing agriculture and non-agriculture land • Zoning for coastal shrimp, prawn, shrimp-prawn -rice farming system will be developed
B	Agriculture, food security, nutrition and livelihoods	• Climate resilience and diversified fish production systems • Encourages establishing commercial fish farming • Introduces precision aquaculture model • Preservation of ecosystems for fishes • Maintaining biodiversity to ensure long term fish availability • Improves wetland management in haor areas • Sustainable marine fisheries resources management

Sl. #	Strategies	Set targets having fisheries potentials
C	Advancing the Blue Economy	• Quick completion of multidimensional survey of marine resources • Technology based fishing in areas beyond EEZ and international waters • Increases both shallow and deep sea fishing • Marine aquaculture & permaculture • Maintains biodiversity to ensure long-term fish availability • Keeping the coasts and sea pollution free • Developing a strong human resources base for domestic utilization and export to foreign job markets • Building a solid science, research and education base • Establishes 'home' to coordinate developments in blue economy
D	Creating a Delta knowledge bank	• Collates all relevant delta related knowledge globally and nationally into a digitized knowledge library • Establishes a delta data bank • Develops and implements a comprehensive delta knowledge and data updating effort

No sectorial policy is independent, rather it is an interdependent document associated with other policy papers. Fisheries and other related policies in Bangladesh are fractional documents, which have certain relationships with other allied sectorial policies of Bangladesh. For example, the National Environment Policy 1992 (MoEF, 1992) in one of its subsection advocated preserving the coastal and marine ecosystem. In Bangladesh Environment Conservation Act, 1995 (MoEF, 1995), the Government declared a region under environmentally critical situation as "Ecologically Critical Area (ECA)". The Environment Conservation Rules 1997 (MoEF, 1997) updated policy related issues concerning coastal and marine ecosystem. The Bangladesh Coastal Zone Policy 2005 (MoWR, 2005) mentioned about Integrated Coastal Zone Management (ICZM) focusing mainly towards water resources and natural calamities. The oldest wildlife conservation act in the country was Bangladesh Wildlife (Preservation) Order 1973 and it was subsequently amended in 1974 to differentiate between ordinary animals (including domestic) and wild animals (Shamsuzzaman et al., 2017). This law is the root of biodiversity conservation in the country. The Government has developed the National Biodiversity Strategy and Action Plan (NBSAP) 2016-2021 (DoE, 2016) with detailed conservation strategies to protect terrestrial and aquatic biodiversity of Bangladesh.

Fish Production Target, Constraints and Research Questions

Fish production target

The population of Bangladesh has been projected to increase as many as 208 million in 2041, with an annual addition of about 2 million (BBS, 2015), which translates increasing demand for food and more pressure on land and water. Given the increased fishing pressure and depletion of wild aquatic resources and ecosystems, production and consumption of wild-capture fisheries are already high in recent years. Over the last two decades, Bangladesh has made a profound development in fish production driven by the proliferation of aquaculture and capture fisheries. Growth of aquaculture has made a significant contribution mitigating fish output reduction from capture fisheries to meet increasing demand for fish. Therefore, the present and future demand for fish and fisheries as food and nutrition, livelihoods of millions of people, and national economic growth as well is growing. Knowing the importance of fisheries and aquaculture, The Government has developed national policies and plans for the sustainable development of fisheries sub-sector with multi-faceted strategies for increased fish production.

In the 8th FYP, a fish production target has been set to 5.83 million ton in 2025 (GED, 2020a). To achieve this target, the fisheries production from all inland sources is expected to increase, particularly from ponds, cages, pens and seasonally cultured water bodies in a relatively higher rate (Fig. 37).

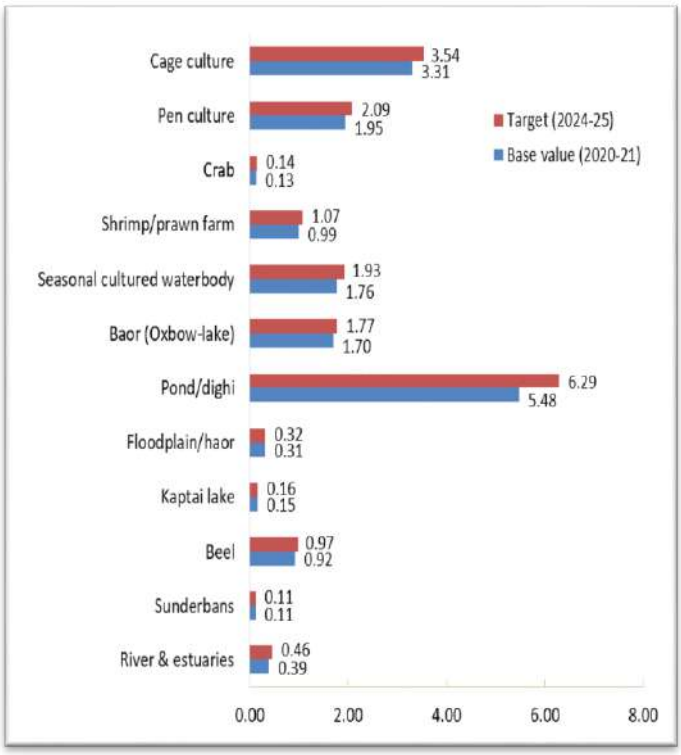

Fig. 37. Fisheries production from inland water sources

Beyond 2025, the country has set a target of 6.5 million ton fish production in 2031 and 8.5 million ton in 2041 against the corresponding demand of 6.37 million ton and 8.33 million ton, respectively, commensurate with the increasing population in the BPP 2041 (GED, 2020b).

Besides the national target, different studies have projected the fish production potential of the country. Applying the Asia Fish Model, Tran et al. (2022) projected a fish production of 5.83 million ton in 2030 and 8.01 million ton in 2041 in a business-as-usual (BAU) scenario (Fig. 38), which is close to the target of BPP 2041. In another study, Saifuddin et al. (2022) has projected, using ARIMA (1,2,1) and ARIMA (1,1,0) models, a fish production of 7.2 million ton (4.7 million ton from culture and 2.5 million ton from capture) by 2028, which is higher than the target of BPP 2041. With the increased production, fish will remain as a main contributor to the food and nutrition security during the coming decades (Table 24). Under the BAU scenario, the key nutrient supply from fish including protein, vitamin A, iron, iodine, zinc, calcium, and energy in 2040 are projected to increase by a range of 1.01 - 1.99 times and protein shows the highest increase (1.99 times) followed by energy (1.87 times) and zinc (1.69 times).

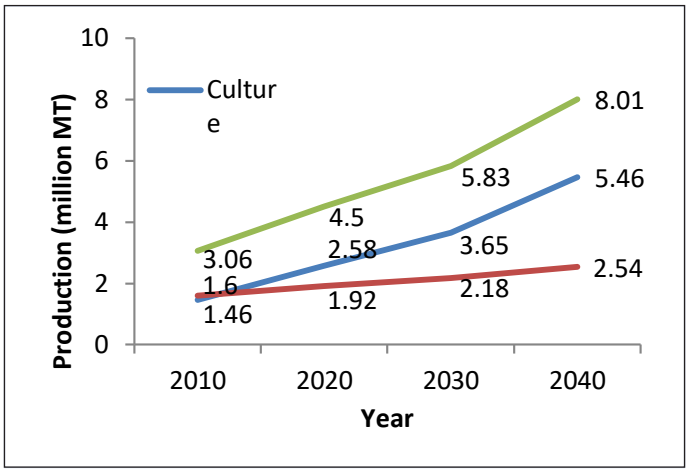

Fig. 38. Projection of aquaculture and capture fisheries production for 2030 and 2040 under the BAU scenario.

In the study of Tran et al. (2022), growth rate of capture fisheries and aquaculture between 2020 and 2040 has been projected at 1.4% and 3.8% per year, respectively. Similarly, production of native and exotic carps, shrimps and prawns, and other fish species are projected to increase by a range of 2.50 - 3.0 times from aquaculture and 0.04-1.6 times form capture between 2020 and 2040. There is potential for a higher growth rate of pagasius (5.1%) and tilapia (6.1%) between 2020 and 2040. Growth rate of the single highest hilsa fishery is expected to be 1% in this period.

Table 24. Supply of potential nutrient from fish per person per day during 2010 – 2040 (*source*, Tran et al., 2022)

Nutrients	2010	2020	2030	2040	Growth rate (%)
Protein (g)	6.66	9.55	11.3	14.16	1.99
Vit A (µg)	13.84	17.5	19.47	22.92	1.36
Iron (mg)	0.66	0.92	1.05	1.27	1.65
Iodine (mg)	8.76	12.22	13.66	16.24	1.47
Zinc (mg)	0.55	0.76	0.88	1.07	1.69
Calcium (mg)	148.89	185.35	200.25	226.62	1.01
Energy (kj)	173.18	256.54	299.57	371.67	1.87

Fish exports and imports (fish trade) are also expected to increase annually by 4.43% and 4.65%, respectively, over the projection period (Tran et al., 2022). Growth rate of total fish production has been projected at 2.9%, which is expected to fulfill the gradual increase in per capita annual fish consumption rate at the national level from 25.16 kg in 2020 to about 37.1 kg in 2040. Aquaculture is likely to be the major contributor to the total consumption. However, to achieve the fish production target and meet the future demand of food and nutrition security in the country, concerted R & D efforts are needed to harness sustainably the full potentials of country's fisheries and aquaculture.

Constraints for fisheries development

In the global context of Sustainable Development Goal (SDG) and fish industry (Golden et al., 2021), fisheries and aquaculture in Bangladesh have potentials to contribute directly to the following:

i. poverty alleviation (SDG 1)
ii. help enhance food and nutrition security (SDG 2) by improving dietary diversity,
iii. play a key role in achieving healthy lives (SDG 3),
iv. sustainable diets globally (SDG 12),
v. provide several million jobs across the country (SDG 8),
vi. help empower women (SDG 5) involving them across aquaculture value chains and food systems and
vii. help proper utilization of aquatic biodiversity and ecosystems (SDG 14).

However, the fisheries industry in Bangladesh is confronted with a range of technological, economic, institutional and environmental concerns. Besides policy level (top-down), it is very important to identify the field level problems (bottom-up) for the development and the benefits of demand-led technologies. A system innovation can never be 'organized from the top' only as the top down approaches explicitly seek to change the system at large. It needs to make use of the 'problem-backed innovative ideas' within the existing production sector, *i.e.* lessons learned in the bottom-up process (Bos, 2009).

Both the top-down and bottom-up approaches were co-designed to identify the constraints/ problems and meet the challenges in future fisheries and aquaculture production sectors. The relevant national plans and visions of fisheries sub-sector and research-led information were analyzed following top-down process. An extensive consultation with stakeholders covering field-level fisheries extension workers, NGOs, farmers, academia and scientific experts was conducted in eight administrative divisions (Table 25). Both approaches were combined while the sustainability claim of national plans/visions varies from expert analysis only. A broad variety of bottom up initiatives is taken by farmers and filed level extension workers and those who develop and try out new approaches to meet the challenges as they see them. Major constraints identified under each thematic area of fisheries and aquaculture in the stakeholder workshops are synthesized in the Tables 25 to 29.

Table 25. Enhancement of fish productivity and production

Major constraints/problems	Divisions							
	Dhaka	Mymensingh	Khulna	Barishal	Rajshahi	Chattogram	Rangpur	Sylhet
Inland open waters (capture)								
• Over-fishing caused by population pressure	*	*	*	*		*	*	*
• Indiscriminate killing of juveniles and destruction of spawning grounds	*	*	*	*	*	*	*	*
• Obstruction of the migratory routes due to increased silt deposit on the river channels	*		*	*	*	*		*
• Reduced availability of wild fish through increased use of agro-chemicals	*	*	*	*	*	*	*	*
• Climate change impacts on fisheries	*	*	*	*	*	*	*	*
• Gradual depletion fisheries resource	*		*	*	*	*		*
• Deterioration of brood stock of potential species	*	*	*	*	*	*	*	*
• Flash flood in haor areas								*
• Unplanned embankment in coastal and haor areas			*	*				*
• Gradual siltation in river courses and haors			*	*	*	*		*

Major constraints/problems	Divisions							
	Dhaka	Mymensingh	Khulna	Barishal	Rajshahi	Chattogram	Rangpur	Sylhet
Inland closed waters (culture)								
• Unpredictable supply of quality fish/shrimp/ prawn seeds	*	*	*	*	*	*	*	*
• High production cost due to commercial fish feed and ingredients	*	*	*	*	*	*	*	*
• Sub-standard quality of fish/shrimp/prawn feed	*	*	*		*	*	*	
• Lack of good aquaculture practices (GAPs) for ensuring food safety	*	*	*	*	*	*	*	*
• A limited number of species in aquaculture	*	*	*		*		*	
• Climate change impacts on aquaculture	*	*	*	*	*	*	*	*
• Risks of water-logging, loss of biodiversity and social conflicts due to floodplain aquaculture	*	*	*	*	*			*
• Deterioration brood stock of potential species	*	*	*	*	*	*		
• Inbreeding depression in cultured indigenous small species (SIS)	*	*						
• Lack of zoning for appropriate species-specific production intensive aquaculture	*	*			*	*		
• Fish disease outbreak and mass mortality	*	*	*	*	*	*	*	*
• Unregulated use of aqua-drugs in fish farms	*	*	*		*	*	*	
• Seasonal water scarcity for fish culture			*	*	*	*	*	
• Less interest in high investment for aquaculture								*
• Poor investment for coastal aquaculture (shrimp, finfish, crab, etc.)			*	*				

Major constraints/problems	Divisions							
	Dhaka	Mymensingh	Khulna	Barishal	Rajshahi	Chattogram	Rangpur	Sylhet
• Poor farm infrastructure and water management in and around the coastal polder system			*					
• Drought and tidal surge			*		*			*
Marine Fisheries								
• Heavy overfishing in inshore waters and use of illegal/destructive gears				*		*		
• Inadequate information about the standing stock of fish, fish habitats, fish behavior and fishing effort				*		*		
• Lack of technology for appropriate vessels and gears for offshore fisheries to exploit under-utilized resources.				*		*		
• Highly capital intensive				*		*		
• On-board post-harvest loss of fish				*		*		
• Lack of technological know-how on marine water resources potential						*		
• Knock-on effects of by-catch on environment and biodiversity				*		*		
• Improper by-catch management						*		
• No marine aquaculture yet						*		
• Lack of captive breeding and seed production of marine fish species			*			*		
• Loss of fish and shrimp biodiversity			*			*		
• Marine pollution (microplastics, oil spill, etc.)				*		*		

Table 26. Fisheries protection and conservation

Major constraints/problems	Divisions							
	Dhaka	Mymensingh	Khulna	Barishal	Rajshahi	Chattogram	Rangpur	Sylhet
• Fish habitat loss, fragmentation and degradation	*	*	*	*	*	*	*	*
• Aquatic pollution from different sources	*	*	*	*	*	*	*	*
• Indiscriminate fishing and over exploitation	*	*	*	*	*	*	*	*
• Climate change impacts	*	*	*	*	*	*	*	*
• Loss of natural breeding ground and biodiversity	*	*	*	*	*	*	*	*
• Invasive species	*	*			*			
• Illegal and arbitrary fishing	*	*	*	*		*		
• Weak enforcement of Fisheries Conservation Act and other rules and regulations	*	*	*	*	*	*	*	*
• Indiscriminate killing of fish and other aquatic lives during shrimp/prawn PL collection			*	*				
• Inappropriate site selection and management of fish sanctuary	*	*	*	*	*	*	*	*
• Lack of effective ecosystem-based fisheries management and conservation tools	*	*				*		*
• Inadequate institutional strength	*	*			*		*	

Table 27. Fish germplasm collection, characterization, conservation and improvement

Major constraints/problems	Divisions							
	Dhaka	Mymensingh	Khulna	Barishal	Rajshahi	Chattogram	Rangpur	Sylhet
• Increase of threatened fish species	*	*		*		*		*
• Stock deterioration of cultured species	*	*			*	*		*
• Loss of biodiversity due to anthropogenic and natural interventions	*	*	*	*	*	*	*	*
• Lack of *ex-situ* conservation	*	*	*	*	*	*	*	*
• Inadequate and proper management of *in-situ* conservation	*	*	*	*	*	*	*	*
• Unplanned hybridization	*	*	*		*			*
• Inbreeding depression	*	*	*				*	
• Invasive species	*	*			*		*	
• Inferior quality of brood fish and inbreeding	*	*	*			*		*
• Poor capacity in aquatic genetic resource management	*	*						*
• Irresponsible exchange of germplasm		*						*
• Lack of genetically improved aquaculture species	*	*			*	*		

Table 28. Fish harvesting, post-harvest and processing management

Major constraints/problems	Divisions							
	Dhaka	Mymensingh	Khulna	Barishal	Rajshahi	Chattogram	Rangpur	Sylhet
• Use of destructive fishing gear	*	*	*	*	*	*	*	*
• Natural and physical hazards	*	*		*		*		
• Covid-19 impact	*	*		*	*	*		
• Weak enforcement of fishing regulation	*	*	*	*	*	*	*	*
• Illegal, Unreported and Unregulated (IUU) fishing	*			*		*		
• Inadequate Vessel Monitoring System (VMS)				*		*		
• Poor handling on board and landing center				*		*	*	*
• Improper processing, preservation and transportation	*	*	*	*	*	*	*	*
• Lack of locally fish preservation facilities	*	*	*	*	*	*	*	*
• Use of no or low quality and contaminated ice		*		*	*		*	*
• Post-harvest loss (physical, chemical, market) from farm to consumer	*	*	*	*	*	*	*	*
• Microbial and chemical contamination in fish during handling, transportation and processing			*	*	*	*		*
• Either no or inadequate surveillance and monitoring from farm to consumer	*	*		*	*	*		
• Inefficient fish value chain	*	*	*	*	*	*	*	*
• Lack of value addition for fish and fishery products development	*	*	*	*	*	*	*	*

Table 29. Technology validation and adoption

Major constraints/problems	Divisions							
	Dhaka	Mymensingh	Khulna	Barishal	Rajshahi	Chattogram	Rangpur	Sylhet
• Gender discrimination, old age and poor educational status	*	*			*	*		*
• Lack of technological know-how	*	*	*	*	*	*	*	*
• Inadequate credit facilities	*	*				*	*	*
• Farmers' hesitation on reliability of technology	*	*				*	*	*
• Lack of research-extension-farmer participatory technology transfer program	*	*	*	*	*	*	*	*
• Incompatibility with socio-cultural condition	*	*				*		*
• Inadequate fisheries extension support	*	*	*			*		*
• Lack of farmers' support group (cooperative)	*	*				*		*
• Low price and inadequate market support	*	*	*	*	*	*	*	*
• Socio-demographic factors affecting GAP adoption	*		*	*	*	*	*	*
• Weak research and extension coordination	*	*	*	*	*	*	*	*

Mapping top-down and bottom-up identified constraints

In the era of transformation from subsistence to industrial fisheries, there is renewed concern about enhancing the links between research-based knowledge and policy-making. From the view point of evidence-based policy-making, an ideal nexus ensures that relevant knowledge is produced and made available to policy-makers in forms they can understand and use. A major obstacle, however, is that research commonly deals with questions that have no policy interest while researchers do not recognize policy maker's questions as valid. In the Table 30, an attempt has been made for mapping of challenges/constraints those were identified in policy level with the lessons from bottom to minimize this generalized gap and to create synergy between policy interests and research priorities. This entails that there exists a synergy of some field level problems identified with those identified in the policy documents (Table 30) and all constraints identified in the stakeholder's workshop and policy documents require research to address them.

Table 30. Synergies of constraints/challenges identified in policy level (8th FYP) with those identified under thematic areas in stakeholder's workshop

Constraints/challenges identified in policy level (8th FYP)	Constraints/challenges identified under thematic areas in stakeholder workshop
Inland capture fisheries	
• Degradation, conservation and sustainable management of natural resources	Thematic area 26.
• Increased waterlogging • Blocking of fish migratory routes • Loss of biodiversity • Social conflicts in case of floodplain aquaculture	Thematic area 25
Inland culture fisheries	
• Poor brood stock management • Inadequacy of the supply of quality fish, shrimp and prawn seeds • Low availability of reliable and quality fish feed at a reasonable cost • Spread of infectious diseases of both fish and shrimp • Scarcity of good quality feed and post-larvae	Thematic area 25
• Low productivity of shrimp and prawn	Not identified as such
• Quality assurance • Traceability and inadequacy in social compliance for export market	Thematic area 28
Marine fisheries	
• Overcapacity of fishing effort • Long gap of exploratory survey on stocks assessment • Deployment of destructive and illegal gears • Pollution • Degradation of highly productive coastal and near-shore marine habitat and breeding grounds	Thematic area 25
• IUU fishing	Thematic area 26 and 28
• Disastrous impacts of climate change	Almost all thematic areas
• Infringement of rules and regulations, etc. in case of marine fisheries	Thematic area 26

Constraints/challenges identified in policy level (8th FYP)	Constraints/challenges identified under thematic areas in stakeholder workshop
Others	
• Adverse impacts of climate change	Almost all thematic areas
• Inadequate human resources and logistic support, and knowledge gap of the producers. • Inadequate/limited institutional capacity for research and extension services.	Thematic area 29

Among the total of 625 participants in eight regional workshops, the percentage of respondents to major problem areas are presented in Fig. 39. The increase in production cost due to the rising price of fish feed (69% of respondents) and unpredictability in adequate supply of fish seeds timely in quality and quantity (64% of the respondents) have been identified as the major problems by the participants. The outbreak of disease in cultured fish and shrimps, post-harvest loss from farm to market, climate change impacts, loss of natural fish habitats and lack of producer-friendly marketing system were also identified as the major concerns among other constraints.

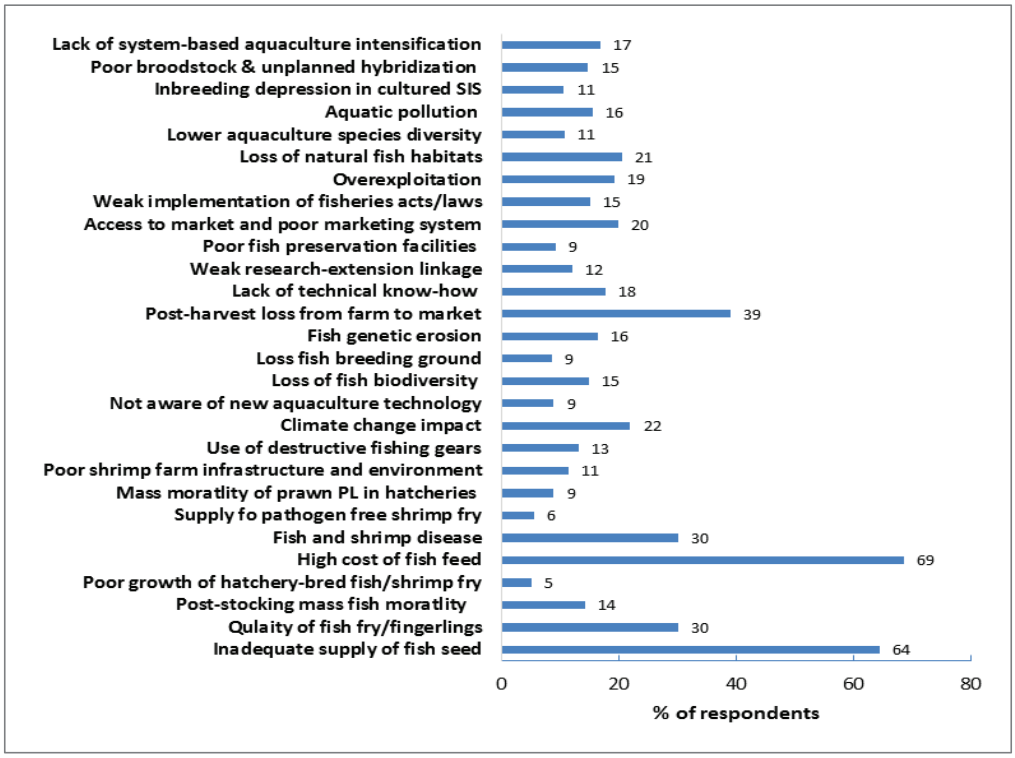

Fig. 39. Regional workshop participants' response to constraints that need research intervention.

Translating problems into research questions

Research organizations and researchers as well usually plan, prioritize research areas, design and implement research projects, and transform the research findings into practice and policy. For the research priority setting program identification of research problems involving researchers and research output users and then translation of these problems into research questions are needed for setting the research priority areas to be planned and executed. Here in this case, research problems were identified following both top-down and bottom-up approaches as delineated in the previous section. Taking all identified critical problems for fisheries and aquaculture development into account, this section deals with formulation of important broad research questions which will be the basis of selecting fisheries research needs and priorities for the next decades.

Enhancement of fish productivity and production

A. ***Inland open water (capture) fisheries***

Sl. No.	Constraints/Problems	Broad Research Questions
A.1	Loss and degradation of fish habitats due to development activities and natural calamities.	• How can the need for dams and associated infrastructure be balanced with connectivity, health and flow requirements of inland aquatic ecosystems and biodiversity? • To what extent does habitat loss and degradation affect the productivity of inland freshwater fisheries? • How can management and restoration of inland freshwater and coastal wetlands be improved to support fisheries production? • Can recruitment of native freshwater fish species be improved through habitat restoration? • How effective is habitat restoration including dam removal and fish way installation, and how can the costs and benefits be accurately evaluated to make better decisions?
A.2	Loss of fish biodiversity and increased number of threatened fish species.	• To what extent does habitat loss and degradation affect the productivity of fisheries? • How can conservation and restoration measures be developed that most effectively and efficiently address synergistic threats to freshwater biodiversity?

Sl. No.	Constraints/Problems	Broad Research Questions
		• What are the type of research and investments in *ex situ* conservation (e.g. captive breeding, reintroduction, managed relocation etc.) most effective for imperiled threatened fish species? • How is the methods developed to empirically measure the impact of aquatic invasive animals in freshwater ecosystems? • What are the research innovations needed to help restore freshwater biodiversity? • What are the key biodiversity areas that need to be prioritized for conservation of freshwater biodiversity?
A.3	Loss of breeding/spawning ground of fish/prawn.	• Where and how will the efforts on identification of fish and prawn breeding grounds be done and what will be the measures to conserve those areas?
A.4	Under-utilization and low fish productivity in rivers, floodplains and seasonal waterbodies including rice fields.	• At what spatial and temporal scales are technology and management interventions best applied to benefit fish/shrimp/prawn culture in the specified water areas minimizing ecosystem and social conflicts?
A.5	Increased water pollution from different points and sources.	• What are the approaches to pollution reduction and remediation efforts that will most benefit inland fish productivity and fisheries biodiversity? • What are the approaches to pollution reduction and remediation efforts that will most benefit freshwater biodiversity?
A.6	Adverse impacts of climate change	• How does climate change affect fish stock, reproductive biology, pathogen dynamics, and migration in open water fisheries? • What are the strategies to conserve and manage inland fisheries resilience to climate change?

Sl. No.	Constraints/Problems	Broad Research Questions
A.7	Lack of data base on fish population dynamics.	• What is the process of more timely stock assessment information for advancement of stock assessment capacity? • What are the individual and cumulative effects of anthropogenic stressors on physiology and ecology of migratory species and how can these threats be mitigated? • Can model(s) (location and species-specific) benefit to develop data-base on how mortality, growth, and recruitment interact to affect fish abundance?

B. ***Inland closed water (culture) fisheries***

Sl. No.	Constraints/Problems	Broad Research Questions
B.1	Lack of system-based intensive aquaculture	• What are the types of environmentally responsible and cost-effective aquaculture methods that could be used to enhance fish productivity and production? • What are the types of low-impact and low energy intensive fish production systems that could be used to improve the sustainability? • How is to increase the production volume and diversity of aquaculture species.
B.2	Inadequate supply of good quality seeds of cultured fish species	• What are the factors and how is to address these factors for production of adequate number of quality seeds of cultured fish/shrimp/prawn species? • How is to manage climate-related risks in fish/shrimp/prawn hatchery and nursery management operations?
B.3	Incurring high production cost due to rising price of feeds.	• Can alternate conventional and non-conventional food sources and feeding strategies reduce the high cost of traditional fishmeal-based fish feeds? • How is to increase the feed conversion efficiency of cultured fish species?

Sl. No.	Constraints/Problems	Broad Research Questions
		• How is to optimize fish feeding strategy and fish nutrition in different types of production systems? • How is to improve the palpability, nutrient digestibility, fish immunity, water stability, and fish quality?
B.4	Lack of good aquaculture practices (GAqP) for ensuring food safety	• What are the factors influencing the level of GAqP practices for safe fish production? • How does GAqP influence the fish production and income from aquaculture farms. • How is to design procedures and protocols to foster efficient and responsible aquaculture production? • How can the best performance of fish be ensured in all life stages and optimal combinations (and timing) of production systems
B.5	Adverse impacts of climate change on aquaculture	• How does climate change affect fish growth, reproduction, fish health and aquatic environment? • How can lessons from individual, household, enterprise and community adaptive responses around the world be effectively shared and applied to build resilience to climate change? • What are the policy processes nationally, regionally and globally needed to engage aquaculture agencies to enhance and implement adaptation? • How can climate change adaptation be effectively incorporated into aquaculture development and management planning?
B.6	Risk of increasing water-logging, disturbing biodiversity and creating social conflicts in case of floodplain aquaculture.	• What would be the most effective management strategy(s) for floodplain aquaculture development to reduce environmental, biological, and social conflicts?

Sl. No.	Constraints/Problems	Broad Research Questions
B.7	Deterioration of brood stock of potential fish species	• What are the causes of deteriorating quality of brood stock? • How can genetic improvement of stocks having fast growth, resistance to disease and efficient reproduction capacity be done over generations to produce more desirable fish.
B.8	Fish disease outbreak and mass mortality	• What are the approaches to prevention and control strategies of infectious disease in aquaculture? • How do pathogens affect fish survival and growth and are the effects more pronounced under regimes of acute or chronic environmental change? • How can health of fish and shellfish species be improved and maintained?
B.9	Unregulated use of aqua-drugs in aquaculture farm	• Does the use of commercial aqua drugs and chemicals have impact on fish health management?
B.10	Socio-demographic factors in GAqP adoption	• Can analysis of the relationship between socio-demographic characteristics of farmers and the level of GAqP increase adoption rate of GAqPs in traditional technology-based fishpond?
B.11	Less interest and poor investment in aquaculture as per its potential	• How and at what extent can the development of small-scale aquaculture improve the socio-economic condition of farmers? • How effective are the government policies in aquaculture because of the diversity of production, environmental, and regulatory issues the farmers confront? • Do the R&D and extension programs ameliorate any slow growth by developing and extending new technologies that significantly lower the production cost?
B.12	Less water availability for fish culture (drought)	• How is to manage and mitigate the risks from the drought-related impacts on inland aquaculture?

Sl. No.	Constraints/Problems	Broad Research Questions
B.13	Poor farm infrastructure and inadequate water management in and around the coastal polder system	• What are the main coastal aquaculture farms and how can those be improved synchronizing with crop production systems within the coastal polders?

C. ***Marine fisheries (capture)***

Sl. No.	Constraints/Problems	Broad Research Questions
C.1	Heavy overfishing inshore marine waters	• To what degree must the foraging needs of top predators and other animal species be considered in exploitation of fish stocks to ensure healthy ecosystems? • How can the impacts of bycatch from IUU fisheries be reduced to a level that will allow reversal of declining trends in affected fish stocks?
C.2	Inadequate information on standing stock, habitats, behavior of fish and fishing effort	• How can the development of a stock assessment data type, method, or stock-specific model benefit assessment of fish stock? • How does understanding fish behavior in relation to capture processes in marine fisheries impacts on reducing bycatch and discards, and on enhancing fish recruitment. • How is to promote recovery of fish populations, i.e., stock rebuilding to abundance levels that readily supports maximum sustainable yields.
C.3	Poor technological know-how to explore marine water resources	• How do innovations in fishing technology help achieve sustainable exploitation of marine fishes.
C.4	Loss of fish and shrimp biodiversity	• How will global climate change and acidification affect ocean productivity and ultimately biodiversity?
C.5	Lack of marine aquaculture	• What are the suitable organisms that can be grown by maricuture in marine environment? • What are the appropriate mariculture methods that can be practiced?

Sl. No.	Constraints/Problems	Broad Research Questions
		• Can the seeds of mariculture species be made available? • What are problems and potential that can occur in mariculture?
C.6	Weak enforcement of fishing regulation	• Does policy research facilitate the enforcement of fishing regulation?
C.7	Illegal, Unreported and Unregulated (IUU) fishing	• What are the impacts of IUU fishing and how and what are the policy solutions to address it?
C.8	Inadequate Vessel Monitoring System (VMS)	• What are the fishing related activities that warrant the use of VMS data and information for verification purposes? • What are some of the limitations and scope of VMS as a surveillance mechanism? • How can processes within offshore fisheries be improved to best serve the objective of VMS.

Fisheries protection and conservation perspectives

Sl. No.	Constraints/Problems	Broad Research Questions
1	Loss and degradation of fish habitat	• Does the analysis of the extreme magnitude and extent of fragmentation and loss of fish habitat enable the development of appropriate restoration and conservation methods?
2	Aquatic pollution from different sources	• How does pollution from different sources affect aquatic ecosystem and fish abundance and what are the measures to mitigate pollution?
3	Indiscriminate fishing and over exploitation	• How can fishing gear and techniques be improved to minimize indiscriminate fishing? • In what circumstances do no-take zones produce benefits to surrounding fisheries?
4	Climate change impacts	• How will climate change influence the distribution, richness, relative abundance, and prevalence of fish diseases in the freshwater and marine environment?

Sl. No.	Constraints/Problems	Broad Research Questions
		• How will aquatic ecosystems and species adapt and respond to the individual and interactive effects of climate change and to what extent is mitigation possible?
5	Loss of natural breeding ground and biodiversity	• How can key fish/shrimp/prawn breeding grounds and biodiversity along with large-scale ecological processes be identified, protected, and restored?
6	Invasive species	• How can the ecological impacts of invasive species and the mechanisms of invasion be quantified? • Can the development of cost-effective tools, techniques, and approaches benefit for detection, prevention, and control of invasive species and restoration of invaded ecosystems?
7	Illegal and arbitrary fishing	• What are the most cost-effective ways to prevent illegal, unreported, and unregulated harvesting in marine ecosystems?
8	Weak enforcement of Fisheries Conservation Act	• What are the major challenges to and policy issues for the effective enforcement of fishery laws in the country?

Fish germplasm collection, characterization, conservation and improvement

Sl. No.	Constraints/Problems	Broad Research Questions
1	Increase of threatened fish species	• What are the research innovations needed to help restore fish biodiversity?
2	Loss of biodiversity due to anthropogenic and natural interventions	• How do the concerned people proactively incorporate climate change adaptation into freshwater biodiversity conservation?
3	Lack of ex-situ conservation	• Where and why have past conservation efforts been successful or failed, and how can the people learn from these outcomes?
4	Inadequate and improper management of in-situ conservation	• At what spatial and temporal scales are management interventions best applied to benefit fish germplasm conservation?
5	Invasive species	• What are the best ways to manage freshwater invasive species and diseases to ensure proactive

Sl. No.	Constraints/Problems	Broad Research Questions
		and meaningful improvements to fish germplasm?
6	Unplanned hybridization	• What are the best genetic approaches to prevent/control inbreeding problems and potential genetic impacts of hybrids on wild populations?
7	Inbreeding depression	
8	Inadequate capacity in aquatic genetic resource improvement and management	• How is the planning, designing and application of modern techniques and protocols effective for the improvement of fish genetic resources?
9	Irresponsible exchange of fish germplasm	• What is the multidisciplinary research coupled with networking effective tools in fish genetics research and exchange of germplasm.

Fish harvesting, post-harvest and processing management

Sl. No.	Constraints/Problems	Broad Research Questions
1	Use of destructive fishing gear	• How can fishing gear and techniques be improved to minimize indiscriminate fishing?
2	Natural and physical hazards	• What are the appropriate tools for identification and control of hazards, and monitoring of the effectiveness of the control?
3	Covid-19 impact	• How and what extent has the Covid-19 impacted on fish post-harvest loss and what are suggestive measures for addressing the likely problems in future?
4	Poor handling on board and landing center	• What are the determinants of fish catch and post-harvest fish loss (PHFL) from harvesting points to consumers? • What are the effective tools for surveillance and assessment of fish post-harvest loss? • How will standard package of practices to minimize the PHFL be useful for the development of loss reduction intervention strategies?
5	Improper preservation and transportation	
6	Use of no or low quality and contaminated ice	
7	Post-harvest loss (physical, quality, market)	
8	Microbial and chemical contamination in fish processing	• How is the degradation of fish quality due to a complex process in which physical, chemical and microbiological forms of deterioration implicated?

Technology validation and adoption

Sl. No.	Constraints/Problems	Broad Research Questions
1	Discriminate gender, old age and poor educational status	• How is to measure end users' propensities to adopt a new technology? • What are the scientific tools, approaches and models for successful technology validation and adoption? • How does technology-driven fish marketing influence the wider adoption of new technologies? • How do social and economic factors affect adoption of modern technology by farmers? • What are the best practices to follow for technology adoption?
2	Mastery of the existing technology	
3	Credit	
4	Reliability of the technology	
5	Compatibility with socio-cultural condition	
6	Fisheries extension support	
7	Farmers support group (cooperative),	
8	Availability of market support	

Research Needs and Prioritization

Fast-growing national as well as global demand of aquatic food represents a critical opportunity for the national fisheries sub-sector to enhance aquatic productivity and production, and their management to achieve food and nutrition security. Consequently, investment in the R & D and application of technology for ensuring successful and sustainable development of fisheries and aquaculture is an imperative agenda for the national economy. R & D investments in location- and resource-specific fisheries and aquaculture must be thoughtfully undertaken based on national priorities with consideration of entire value chain of the fisheries industry, ecosystem and the society in which it operates. Policies should provide an enabling business environment that fosters efficiency and further technological innovations in aquaculture feeds, genetics and breeding, disease management, product processing, and marketing and distribution. This section aims to rebuild the research thematic/focus areas, discuss the research needs, identify research areas and prioritize these areas considering the government policies, plans and voices of different stakeholders.

Rebuilding thematic research area

In the process of priority setting, it is very important to identify the research focus areas. Research priorities can be set at a broad thematic area, an intermediate topic level, or at the level of specific research questions. The Agricultural Research Vision 2030 and Beyond (BARC 2012) identified the following research thematic areas for fisheries sub-sector viz.

i) fish production and productivity;
ii) fisheries protection/conservation/management;
iii) fish feed nutrition;
iv) fish health management; and
v) socio-economics and marketing.

Considering the stakeholder's opinions, comments, and suggestions on different areas of research problems, the thematic research areas for fisheries sub-sector were revised into eight broad thematic research areas. The revised thematic research areas along with sub-thematic areas are given in Table 31.

Table 31. Revised thematic research areas and sub-thematic areas for fisheries sub-sector

Broad Thematic Area	Sub-thematic Area
1. Enhancement of fish productivity and production	1.1 Production system 1.2 Fish nutrition, feed and feeding management 1.3 Fish health management
2. Fisheries protection, conservation and management	
3. Fish genetics and improvement	3.1 Fish breeding 3.2 Fish germplasm collection, characterization and conservation 3.3 Fish genetic improvement
4. Fish harvesting, post-harvest, processing and value addition	4.1 Fish harvesting 4.2 Post-harvest, processing and value addition
5. Blue economy	
6. Fisheries socio-economics and marketing	
7. Climate change	
8. Technology validation and adoption	

Research needs for fisheries development

Enhancement of fish productivity and production

Current fish production technologies and management tools provide the foundation for further innovation in fish production, resource management, and economic development. However, continuous improvements are needed for further increase in productivity to feed an increasing population through the enhancement of production systems and improvement of technologies. The need for practices to increase fish production in a way that avoids or minimizes harm to the environment resonates in fisheries production systems. Current production systems are not always well managed, and much more food could be produced by simply improving management practices, regardless of the scale of aquaculture operations. Successful fish production system depends on –

- healthy ecosystems providing clean water and nutrient recycling that process or reuse wastes and co-products;
- production efficiency that starts with properly matching species to appropriate production environments; and
- efficient and effective aquaculture production systems that reduce inputs, operating costs, wastes and create optimal conditions for growth, adaptability, and reproduction.

In the pace of fisheries and aquaculture technological advancement, biological sciences and engineering field converge at a critical juncture of the organism, the culture system, and the environment. Therefore, optimizing fisheries and aquaculture production requires matching the biology of the species with a production system they can thrive in with minimal impacts on the external environment. While closed land-based systems are often preferable for larval and juvenile stages, larger open systems are often better suited for production of more robust fish ready for grow-out ponds. Operational systems research in fish production system management is required.

In aquaculture production system, feed is the most vital input that constitutes the major share (60-70%) of the recurring cost. Marine-origin ingredients (i.e., fishmeal and fish oil) continue to be strategic components of aquafeeds. However, fishmeal-rich diets typically result in high feed cost and increased phosphorus and nitrogen discharge in water contributing to eutrophication in aquatic ecosystems. Fishmeal replacement by complementary protein sources is, therefore, a viable alternative to address these negative impacts. As successful replacement of fishmeal continues, a key quality challenge has emerged concerning the shifting of essential fatty acid profiles in aquaculture products. With the high restrictions on antibiotic use in aquaculture, it is imperative to find alternative feed additives to improve immunity/health and consequently the growth performance and survival of aquaculture species. Components derived from plants and herbs have emerged as eco-friendly alternatives to antibiotics (Rombenso et al., 2022). Therefore, nutritionally balanced low-cost and low-environment impact aquafeeds, their judicious use and proper feeding strategy are very essential requirements for improved growth, survival, immunity and reproductive potential of fish. While the generic feeds are used for fish polyculture, species-specific feeds are used for monoculture. As the nutrient requirement varies with different life stages of the same species, different types of feeds are needed for brood stock, spawn/larvae, fry, fingerlings, and grow-outs.

The current and future trend in aquaculture development is towards increased intensification and commercialization of aquatic production. Intensification of fish farming inevitably leads to increased prevalence of fish diseases and environmental contamination hindering the sustainability of aquaculture. Higher survival rate of aquaculture species through the production cycle, particularly for the larval phases, has the potential to markedly increase fish productivity and production. Diseases and epizootics are considered to be major bottlenecks for increasing production through aquaculture, and for sectorial development. In general, diseases have caused serious economic losses to fin and shellfish aquaculture. Disease control is becoming a challenging task for aqua-culturists as implementation of control measures is difficult, and resources for prevention are very meagre or limited. Another challenge is that the movement of fish stock carries the highest risk of pathogen dispersal to a farm, region or country. Nowadays, lots of new emerging and transboundary fish and shellfish diseases are diagnosed and reported in a few pockets of the globe (Mishra et al., 2017). Biosecurity measures and plans minimize the risk of transmitting pathogens.

Albeit preventative management measures are effective and successful even when prioritized over therapeutic approaches, introduction of commercial vaccines supports reduced use of antimicrobials. Access to diagnostic services, and rapid testing and identification of disease are core tenets of disease management. Disease outbreaks continue to affect aquaculture production. Therefore, new technologies (e.g., advanced diagnostic technologies, vaccines, dietary supplements etc.) and wider application of best management practices (e.g., reducing water exchange in ponds or tanks, reducing water seepage in ponds, improving feed and feeding practices, improving sanitation etc.) will be essential to lessen risk from disease.

Fisheries protection, conservation and management

Bangladesh has the third greatest aquatic fish biodiversity in Asia due to the contributions of the three main rivers systems - the world's largest flooded wetland, the Delta, and the marine waters (Hossain, 2001). Fish biodiversity from wild sources have significant importance for aquatic food supply and rural livelihoods. However, despite an increasing trend of production from capture fisheries, it accounts for 43% of the country's fish production compared to the inland aquaculture production. A study found that fisheries in Bangladesh have low adaptive capacity and high vulnerability to climate change (Allison et al., 2009). In addition to the challenges posed by climate change, capture fisheries are threatened by overexploitation due to poor management and habitat degradation. To mitigate these challenges, one of the country's research and development priorities in capture fisheries development is to improve conservation and management of both inland and marine fisheries resources, and restore threatened and degraded fisheries habitats through efficient science-based actions. It is noteworthy that conservation actions will be most effective when supported by sound evidence, and that research and action in line with conservation and management rules and policies must complement one another.

Fish genetics and improvement

The fish genetic resources in Bangladesh are highly variable and important for their role in direct consumption, providing new species for aquaculture diversification, genetic diversity to improve domesticated species, and also providing the products of commercial value. The availability of genetic diversity, within and between species, is of utmost significance in mitigating the impacts of climate change. However, to maintain the stake of genetic diversity on its natural aquatic wealth and potential benefits, the challenge lies with collection, characterization, and conservation of fish germplasm. There is a need to develop repositories of genetic resources that store the registered germplasm accessions. Genetic improvement of production traits via well-designed and managed breeding programs has great potential to help meet the rising aquaculture industry.

During the next decades, fish breeding and genetic improvement leading to domesticated species needs to expand through classic selection and selective breeding

programs. With the advancement of aquaculture industry, there will be increased demand for the selection of traits with efficient digestibility, nutrient profile, other consumer-appealing product characteristics, and disease resistance. However, the challenge of producing selectively bred fish species that do not present a threat to existing wild populations in terms of invasive or polluted genetic material will become increasingly acute. A better understanding of the impact of potential gene flow out of open farming systems will need to be gathered to effectively address concerns about the impact on natural populations. It will also be crucial for retention of specific pathogen-free (SPF) and specific pathogen-resistant population status complementing with advances in maintenance of genetic diversity. Finally, genetic research efforts must be developed with an in-depth understanding of consumer attitudes, beliefs, and social acceptance related to products of genetic selection and modification. Recognition and application of effective communication of how new products are developed and work towards greater understanding of the science of genetics are essential.

Fish harvesting, post-harvest, processing and value addition

Fish is considered very important for human nutrition providing about 17% of the global intake of animal protein (FAO, 2020). Fish is also an important supplier of key micronutrients, vitamins, and essential fatty acids which are deficient in the diets of poor population (Thirsted et al., 2016). Fish is a perishable food that has a high potential for waste and loss. Only about 60% of global captured and cultured fish production are utilized by end-users about 30%converted into animal feed or lost, and the remainder (10%) is lost due to decay (FAO, 2014). Post-harvest losses of fish are a matter of great importance to the fishing industry. A multitude of value chain actor combinations, harvesting techniques, fish products, and geographical contexts create a wide range of possibilities for fish to be supplied to consumers. Research efforts are needed for responsible fishing, maintaining the fish quality after harvest, extending shelf-life, product development, and value addition.

The reduction of global food waste is one of the targets of the United Nation's Sustainable Development Goals (SDGs)-Goal 12: "Responsible Production and Consumption". Reducing food loss and waste is especially pertinent to fish value chains in Bangladesh, where millions of people rely on aquatic resources for food and income. However, post-harvest losses are rarely estimated in fish value chain or stock assessments. Fish loss assessment methodologies need to account for a large diversity in fish species, types and sizes of fisheries, a lack of uniformity in weight units of catch, variability of spoilage rates between fish species, and variability of post-harvest cold chains within fish value chains. In addition, many fish value chains engage multiple actors along the chain which increases the nodes where fish may be lost and complicates efforts to accurately measure loss (Kruijssen, 2020). Therefore, there have been challenges to:

- develop real-life methodologies that accurately measures the magnitude and sources of post-harvest losses in capture fisheries and aquaculture, and promote their use by key institutions within target fisheries; and

- develop and promote appropriate value addition and loss reduction processes and technologies applicable to major stakeholder groups including the poor. Reduction of the loss through appropriate measures and development of value-added fish products from low value fishes are also essential to make the quality fish protein available to the common people and develop a good national and international market.

Blue economy

To achieve the sustainable development goals, the world has made a journey from the fossil fuel-based economy, generally known as brown economy, to an earth-friendly green economy. Green economy is generally termed as 'blue economy' that ensures the optimum use of natural resources with green technology and considers sustainability (Sayed et al., 2022). The blue economy refers to all directly or indirectly reliant ocean- or coastal, marine-based and ocean-related economic activities including fisheries and aquaculture. Marine ecosystem services have substantial economic value having the estimated figures in the order of trillions of US dollars annually. Nearly three-quarters of this value remains in coastal zones. These ecosystem services offer a renewable opportunity to meet basic human needs, support a healthy and sustainable economy, and provide jobs for a growing global population (Ababouch, 2015). Despite the country's abundant marine resources, the full fisheries and aquaculture potential of the Bay of Bengal is yet to harness.

This comes at a crucial time when the need for food and resources from the ocean is increasing rapidly to meet the demands of the growing population. However, there are a number of key challenges for the promotion of the blue economy concept and approach. These challenges are given below:

i. conservation and environmental protection at the cost of economic growth and social development; and
ii. the collection of data and information along with their sharing across a range of scientific domains and the development of analytical methodologies on a range of criteria for different dimensions of sustainability are of particular concern for the future (Ababouch, 2015).

Therefore, to qualify marine fisheries as components of a blue economy (FAO, 2017) and to capture the nation's future marine-based prospects, the marine fisheries research activities need to –

i. restore, protect, and maintain the biodiversity, productivity and resilience of marine ecosystems;
ii. develop offshore aquaculture systems that provide viable and sustainable growth opportunities;
iii. develop marine biotechnology for marine derived bio-products; and
iv. provide social and economic benefits for current and future generations through building sustainable fisheries.

Fisheries socioeconomics and marketing

In the past and present too, fisheries research has been placed mostly on biological rather than socioeconomic research. Although there is relatively great demand for biological information which derives in part from the need for measuring an unseen resource in order to manage it, this has led to a serious shortage of socioeconomic analysis. However, decisions in fisheries management and development have always been based on a number of socioeconomic factors. Even where these factors have not been made explicit, the decisions would not have been taken except in response to demands for the enhancement (or protection) of socioeconomic benefits. In recent years, the need for socio-economic information has increased greatly due to the effects of extended fisheries jurisdiction, a growth in awareness of resource constraints, and an increased interest in artisanal fisheries amongst other reasons.

Sustainability of fisheries and aquaculture cannot be achieved without adequate attention to socioeconomic issues including safe and humane working conditions. In most cases, the current fisheries governance has more attention on the assessment of the conditions pertaining to fish harvest than the assessment of the conditions of the people who are harvesting the fish. Therefore, with regard to SDG 14 and other SDGs, such as SDG 8 that deal *inter alia* with decent work conditions, there is a need of finding key way forward to address socioeconomic issues pertaining to fisheries and aquaculture development (Haward and Haas, 2021). There is an increasing push from market states and non-state actors to consider social issues in the fisheries sector.

The marketing system and structure is one of the main circumstances of socio economic condition of the local people and production system of any area. Taking into account intra-linkage within and inter-linkage between production sector and consumer sector, there is a chain of various systems involved in marketing. As fish and fishery products are highly traded commodities, fish production and development of premium export products are necessary parts of the marketing process to capture new markets ensuring that the expectations of consumers are met. Ultimately, consumers will drive what aquaculture products, which supply chains, and which product attributes they are willing to support with their pure chasing capacity.

Climate change

Climate change is inevitably a challenge for fisheries and aquaculture. There can be many different manifestations of climate change and its cumulative and dynamic impacts on nature and fisheries as well. The most noticeable effect is an increase in average seawater temperature over time, but the seasonality of warming and cooling is also expected to change. Climate change can also encompass other environmental influences or parameters such as changes in precipitation and run-off (and hence salinity and stratification), and storm frequency and intensity that may in-turn greatly impact fishing operations, and changes in chemical conditions such as dissolved oxygen concentrations, carbonate chemistry and seawater pH. Rising temperatures, acidification, and sea-level

rise are altering ocean conditions and displacing fish stocks. Climate change will have consequences not only to fisheries biological responses but also direct and indirect implications to fishery operations (Pinnegar et al., 2016). As a consequence, the maximum catch potential of some stocks is shifting from one country's Exclusive Economic Zone (EEZ) to those of other countries. This phenomenon is expected to accelerate over the next decades resulting in dire economic consequences, food insecurity, and loss of livelihoods for entire communities and countries (Fontaubert, et al., 2022). Rigorous research on impacts of climate change on fisheries and aquaculture, and its mitigation and adaptation combining with local, national and regional practical actions are required to generate new knowledge to inform solutions for the decades to come.

Technology validation and adoption

During the last decades, research and development efforts of the country have been introducing various aquaculture and management technologies devoting considerable resources. The technological development in fisheries sector will offer better prospects for all sections of rural people, particularly for those besides large-scale farmers, who have poor land base and abundant labor force. However, in spite of significant advancement of fisheries sector there is still moderate to low adoption of modern fisheries production technologies due to lack of appropriate technology adoption framework at place. In addition, there is considerable evidence which suggests that non-adoption of recommended technologies is often related to non-technological factors, such as social, psychological, cultural and economic factors (Chattopadhyay, 2017). Given the rapid rate of technological obsolescence in most cases, the ability to accurately forecast demand for and user acceptance of technologies and services is essential for end-users. Therefore, innovative and appropriate working models and practices need to be developed for effective adoption of fisheries and aquaculture technologies and their wider dissemination.

Research areas and priorities

There is a comprehensive list of research priorities for each of thematic areas. Research priorities are separated into three different categories viz, high, medium and low. Within each category, the different research areas are then prioritized into short-term, medium-term and long-term. Research projects under short to medium-term priority areas will provide a tactical approach to answer specific scientific and management questions in which data collection and research should be completed in a period of 3-5 years with relatively less resources. Addressing these short- to medium-term projects will lead to incremental advances in support of long-term priorities. These priorities are more strategic and will seek to address larger concepts and issues that likely require significant resources over an extended period of time.

Thematic area 1: Enhancement of Fish Productivity and Production

Sub-thematic area : **Production system**

Sl No.	Research area/issue	Time-scale priority		
		Long	Medium	Short
High priority research areas				
1	Intensification of inland open water aquaculture (cage, pen, beel nursery, etc.) and making these as efficient as possible across all indicators of environmental performance	√		
2	Design and management of low impact and resource efficient intensive closed aquaculture system (RAS, IPRS, Biofloc, etc.)		√	
3	Species diversification in freshwater and coastal aquaculture		√	
4	Harnessing potential of nutrition sensitive aquaculture		√	
5	Recycling and reuse of aquaculture wastes in the form of bio-deposits (closed-loop aquaculture system)		√	
6	Innovative aquaculture management in the age of 4IR (mechanization, precision aquaculture, robotics, farm design, etc.)	√		
7	Development of appropriate tools/methods (e.g. life cycle assessment) for environmental performance of major aquaculture production systems		√	
8	Zoning for different aquaculture systems based on geo-morphological characteristics			√
9	Development of suitable aquaculture systems in fragile aqua-ecosystem (e.g. barind tract, coastal areas, haors, char and seasonally waterlogged areas)		√	
10	Development of carrying capacity estimation of tools for site selection and their use for implementation in aquaculture		√	
11	Producers centered action research on fresh- and brackish-water Good Aquaculture Practices (GAPs)		√	
12	Aquaculture potential and sustainable grow-out practices of non-conventional fisheries commodity	√		

Sl No.	Research area/issue	Time-scale priority		
		Long	Medium	Short
13	Application of biotechnology and nanotechnology for enhanced growth rate and survival of cultured fish	√		
14	Promotion of organic aquaculture and quality of aquaculture products.			√
15	Managing resource tradeoffs to bring down production costs, and development of additional low-impact systems that ease resource constraints		√	
16	Productivity enhancement in Kaptai lake, baors through adoption of technology and management approach		√	
Medium priority research areas				
17	Ecosystem-based management approach to aquaculture practices in haor environment (climate smart/resilient aquaculture)		√	
18	Innovative integrated aquaculture production system (IMTA, IAA, Aqua-silviculture, etc.)		√	
Low priority research areas				
19	Semi-closed intensive aquaculture system (siting along tidal river course) for production of suitable species (e.g., pangas)		√	

Sub-thematic area: Fish nutrition, feed and feeding management

Sl No.	Research area/issue	Time-scale priority		
		Long	Medium	Shor
High priority research areas				
1	Nutritional requirements of important aquaculture species	√		
2	Nutrition- and cost-efficient aquafeed formulations, using conventional and alternative dietary ingredients	√		
3	Development and optimization of feeding strategy/regimen for different ontogenetic stages of commercially important fish and shellfish		√	
4	Assessment of dietary supplements (e.g., bioavailable amino acids, nucleic acids,		√	

Sl No.	Research area/issue	Time-scale priority		
		Long	Medium	Shor
	nucleotides, cell wall extracts, enzymes) to enhance fish growth and immunity			
5	Molecular nutritional programming strategies and the epigenetic mechanisms regulating fish growth (and health) from brood stock to production	√		
6	Use of marine plants and single cell protein (SCP) and microbial floc meal as a replacement of animal protein sources in fish feed	√		
7	Identification and use of localized microorganisms capable of producing anti-nutritional factor degrading enzymes while using plant-based fish feed	√		
8	Isolation, characterization and propagation of probiotic and prebiotic from indigenous sources	√		
9	Mass culture and maintenance of locally isolated potential live feed organism		√	
10	Fishmeal and fish oil replacements of novel origin and development of essential fatty acid supplements.		√	
11	Formulation of alternatives to *Artemia* sp. and other live feeds to address biosecurity considerations in finfish and shellfish hatcheries		√	
12	Application of mechanization and IoT for optimizing feeding practices and maximizing the efficiency and minimizing waste and production costs		√	
13	Precision nutrition, metabolism, and nutritional regulation for optimal fish production performance		√	
Medium priority research areas				
14	Potential of alternative non-conventional ingredients (e.g. insects larvae, blue mussels etc.), feed additives and functional food aids in fish and shrimp feeds		√	

Sub-thematic area: Fish health management

Sl No.	Research area/issue	Time-scale priority		
		Long	Medium	Short
High priority research areas				
1	Fish diseases diagnosis, prevention and control measures including optimization of environmental conditions and use of immune stimulators		√	
2	Biotechnology and nanotechnology for early disease diagnosis and resistance to disease	√		
3	Traits and variety improvement of aquaculture species resilient to health problems and resistant to specific pathogens	√		
4	Biosecurity, bacterial control, water quality and early warning indicators for disease onset.		√	
5	Epidemiology of emerging pathogens causing fish and shellfish disease outbreak		√	
Medium priority research areas				
6	Diversity and temporal-spatial dynamics of fish-associated microbial communities and their impact on growth and health of their aquatic hosts		√	
7	Novel fish and shellfish disease surveillance and diagnostics tools with a focus to farm-level biosecurity		√	
8	Vaccines and Nano medicine against microbial diseases of cultured fish and shellfish species.	√		
9	Area based management (ABM) approaches in fish health management		√	
10	Isolation, characterization and utilization of pharmacologically important bioactive substances and industrially important enzymes from aquatic sources	√		
Low research priority areas				
11	Identification of emerging pathways and integrated risk assessments of the spread of invasive species			√

Sl No.	Research area/issue	Time-scale priority		
		Long	Medium	Short
12	Rapid tests for disease diagnosis and Integrated Pest Management (IPM) in aquaculture system			√
13	Molecular mapping of aquatic microbes as a tool to prevent indigenous genomic wealth			√
14	Mapping of typical fish health hazards based on species and aqua-ecological zones			√

Thematic area 2: Fisheries Protection, Conservation and Management

Sl No.	Research area/issue	Time-scale priority		
		Long	Medium	Short
High priority research areas				
1	Novel genetic tools for fish stock structure analysis and assessment	√		
2	Changes in distribution and habitat use for fish species and evaluation of implications for stock productivity	√		
3	Characterization and understanding of fisheries habitat change over time and identification of areas of greatest need for protection	√		
4	Identify key biodiversity areas for the improvements to the condition of healthy aquatic ecosystems and fish biodiversity		√	
5	Nature-based solutions applicable to point and nonpoint source of pollution in aquatic ecosystems		√	
6	Effective detection and mitigation of newly emerging contaminants such as pharmaceuticals, micro-plastics etc. in aquatic systems		√	
7	Novel techniques (e.g. eDNA) for monitoring, conservation, and restoration of fish biodiversity	√		
8	Improvement of management tools, such as fish sanctuary, stocking, etc. for conservation of fish biodiversity	√		

Sl No.	Research area/issue	Time-scale priority		
		Long	Medium	Short
9	Fisheries resource management strategies that effectively decrease the negative effects of synergistic and additive stressors	√		
10	Novel tools for Environmental Impact Assessment (EIA) and Ecological Risk Analysis (ERA) of aquaculture operations	√		
11	Assessment of ecosystem-level impacts of commercial fisheries and associated bycatch		√	
12	Hilsa resources management: reproduction and migration biology, genomic and population genetic analysis, designing effective sanctuaries and transboundary issues	√		
Medium priority research areas				
13	Single and multi-species assessment and management models incorporating ecosystem level data	√		
14	Effective innovative protocols/models for sustainable harvesting and improved conservation practices	√		
15	Remodeling and operation of dams to reduce impacts on fish species			√
16	Reformation of land-based agricultural practices integrating loss of fish biodiversity			√
17	Carbon and nutrient trading framework for promoting aquatic habitat restoration	√		

Thematic area 3: Fish Genetics and Improvement

Sub-thematic area: Fish breeding

Sl No.	Research area/issue	Time-scale priority		
		Long	Medium	Short
High priority research areas				
1	Reproductive biology of indigenous cultured as well as wild fish species targeting to captive breeding, cryopreservation and other purposes	√		

Sl No.	Research area/issue	Time-scale priority		
		Long	Medium	Short
2	Domestication, artificial breeding and mass seed production of commercially important indigenous finfish and shellfish species	√		
3	Innovative fish hatchery systems and captive breeding program of genetically upgraded fish species		√	
4	Biotechnology and nanotechnology for reproductive success		√	
5	Efficient prawn and crab hatchery system for mass seed production		√	

Sub-thematic area: **Fish germplasm collection, characterization and conservation**

Sl No.	Research area/issue	Time-scale priority		
		Long	Medium	Short
High priority research areas				
1	Real time working model(s) of germplasm collection, characterization and conservation of prioritized and selected fish species		√	
2	Protection, maintenance and distribution of genetic resources developed through genomic technologies	√		
3	Characterization of genetic stocks/races in wild populations for cultivation and conservation		√	
Medium priority research areas				
4	Develop novel tools of mapping and visualizing fish distribution and their abundance for zoning, site selection and managing in-situ conservation			√
5	Identification and characterization of new productive and resilience traits in fish genetic improvement programs	√		
6	Building gene and tissue bank for long-term retrieving the genetic information and future genetic manipulation	√		

Sub-thematic area: Genetic improvement

Sl No.	Research area/issue	Time-scale priority		
		Long	Medium	Short
High priority research areas				
1	Gene mapping, genome sequences, and development of platforms for high-throughput genotyping of major commercial aquaculture species.	√		
2	Genetic basis of different traits applying genomic tools and species-specific resources		√	
3	Development of genetic markers for fish population genetic analysis and improvement			√
4	Genetic improvement of prawn and shrimp for growth and biotic-abiotic stress tolerance	√		
5	Production of genetically all male and genetically all female for suitable fish and shrimp population.	√		
Medium priority research areas				
6	Genetic improvement and introduction of new traits integrating new genetic tools into selective breeding and culture program	√		
7	Discovery of functional genes and variants underpinning quantitative trait loci associated with key production traits	√		
8	Identification of conserved regulatory mechanisms and pathways for different traits among aquaculture species.		√	
9	Characterization of the gene regulatory networks underlying phenotypic traits important to commercial aquaculture production	√		
10	Development of transgenic aquaculture species, considering environmental risk and food safety	√		

Thematic area 4: Fish harvesting, Post-harvest, Processing and Value addition

Sub-thematic area: Fish harvesting

Sl No.	Research area/issue	Time-scale priority		
		Long	Medium	Short
High priority research areas				
1	Evaluation of traditional fishing systems and improvement in terms of efficiency in energy consumption and ecological impacts		√	
2	Application of electronic instruments and integration of IT for fish stock tracking and harvesting		√	
Medium priority research areas				
3	Cost-effective and innovative fishing gears with bycatch reduction devices		√	
4	Designing new generation and fuel efficient fishing vessel	√		
5	Optimization of craft-gear combination for sustainable harvesting		√	

Sub-thematic area: Post-harvest, processing and value addition

Sl No.	Research area/issue	Time-scale priority		
		Long	Medium	Short
High priority research areas				
1	Innovations to tackle the fish post-harvest loss and waste in fish value chain		√	
2	On-board and out-board fish, and by-catch preservation and utilization			√
3	Consistent approaches and indicators that measure multiple aspects of fish loss and waste		√	
4	Need-based and species-specific fish processing and value-addition		√	
5	Ready-to-cook (RTC) and Ready-to-eat (RTE) fish products development, processing and preservation		√	
6	Appropriate packaging materials (such as vacuum, MAP, HPP, Antimicrobial packaging) for marketing of fish and		√	

Sl No.	Research area/issue	Time-scale priority		
		Long	Medium	Short
	products in the domestic and overseas markets			
7	Effective IT-based monitoring systems for traceability, and levels of nutrients, pollutants and toxicants		√	
8	Bioactive compounds and functional product development from fish wastes, by-catch, low value fish, etc.	√		
9	Food safety (physical, chemical and biological hazards) and mitigation	√		
10	National database on fishing and fish processing parameters	√		
11	Value-added products development, processing and preservation of seaweeds			√
Medium priority research areas				
12	Development of adaptive options to involve vulnerable poor fisher households as producer or value chain actors and small-scale entrepreneurship			√
13	Post-harvest management of the marine fish especially, the low-price small pelagic species of fish			√
14	Long distance energy-efficient transportation of preserved and live fish			√
15	Bio-preservation of fish and fish products and bio-signaling of aqua-food products	√		
16	Rapid estimation methods for biochemical and universally accredited quality control parameters of fish and fishery products	√		
Low priority research areas				
17	Use of nanotechnology for the preservation of value-added fish and fishery products	√		
18	Development of standards for novel and value-added fish and fishery products	√		
19	Carbon foot printing, carbon labelling and Life Cycle Assessment (LCA) in fish processing industry		√	

Thematic area 5: Blue Economy (marine fisheries)

Sl No.	Research area/issue	Time-scale priority		
		Long	Medium	Short
High priority research areas				
1	Management and restoration of coastal wetlands, mangroves and shorelines to support fisheries production	√		
2	Eco-labeling for sustainability of marine fisheries	√		
3	Exploration for new fishing grounds and marine fisheries potential	√		
4	Efficient use and impacts of MPAs and ECAs to maintain functionally resilient ecosystems, fish recruitment and abundance		√	
5	Maximum exploitation of fish stocks from all depths ensuring healthy ecosystems		√	
6	Spatial planning development for site selection of marine aquaculture of fish, shellfish and others like seaweeds	√		√
7	Domestication, captive breeding and mariculture of potential marine fish and shellfish species	√		
8	Propagation and use of marine living resources for pharmaceutical products and chemical applications		√	
Medium priority research areas				
9	Loss of marine biomass to ghost fishing and find effective ways to reduce this source of mortality		√	
10	Improvement of fishing gear, vessels and techniques to minimize habitat and biodiversity damage			√
11	Cost-effective way to prevent IUU harvesting in marine ecosystems		√	
12	Reducing impacts of by-catch for the reversal of declining trends of affected species		√	
13	Identify, protect, and restore the key large-scale marine ecological processes		√	

Sl No.	Research area/issue	Time-scale priority		
		Long	Medium	Short
Low priority research areas				
14	Digital innovations for improving the efficiency of fishing gear and vessels		√	√
15	Use of modern genetic technologies in assessing fisheries stock structure and conservation	√		

Thematic area 6: Fisheries Socio-economics and Marketing

Sl No.	Research area/issue	Time-scale priority		
		Long	Medium	Short
High priority research areas				
1	Development of pro-poor cooperative fish farming and aqua-business framework model		√	
2	Circular economy in fisheries and aquaculture		√	
3	Socio-economic aspects of blue growth/blue economy	√		
4	Nature and characteristics of small-scale fishing communities and the national rules and regulations under which they operate			√
5	Social Impact Assessment (SIA) of fisheries and aquaculture technologies and policies			√
6	Food and nutrition security: pro-poor and pro-gender analysis in fisheries sub-sector			√
7	International fish marketing and trade		√	
8	Fisheries supply chain, fishing activities, fish quality and distribution		√	
9	Socio-economy and market promotion for safe dry fish production and distribution			√
10	Cost-effective e-marketing of fisheries		√	
11	Governance and structural strategies addressing climate change, economy and livelihood.		√	
Medium priority research areas				
12	Challenges, opportunities and improvement of fish value chain and marketing channels		√	
13	Multifaceted and multifunctional relationships between fishing and livelihoods		√	

Sl No.	Research area/issue	Time-scale priority		
		Long	Medium	Short
14	Assessing the present and likely future costs associated with overexploitation			√
15	Market research for assessment of producers' adaptation and consumers' preference			√
16	Gender responsiveness and equity in fisheries and aquaculture supply and value chain			
Low priority research areas				
17	Optimization of fisheries resource use for development of community livelihoods		√	

Thematic area 7: Climate Change

Sl No.	Research area/issue	Time-scale priority		
		Long	Medium	Short
High priority research areas				
1	Ecological and socio-ecological impacts of climate change on commercial fish stocks and fisher communities		√	
2	Social, cultural, and economic impacts of climate change on the aquaculture industry and communities		√	
3	Efficient use of land and water in aquaculture that reduces energy consumption and optimizes gas emissions		√	
4	Climate linked stressors to ecology, fisheries biology, and fishing operation			√
5	Mitigation of climate change impacts on water resources to maintain optimal ecosystem function and services	√		
6	Water retention techniques in aquaculture ponds under climate-driven drought condition		√	
Medium priority research areas				
7	Application of lessons from individual and community to build resilience to climate change			√

Sl No.	Research area/issue	Time-scale priority		
		Long	Medium	Short
8	Spatial dimensions of biophysical change in ecologically critical areas and their implications for dwelling communities		√	
9	Climate change impacts on small-scale fisheries		√	
10	Economic impact of climate change on fisheries and aquaculture		√	
11	Framework for adaptation policies and drawing on inputs from stakeholders across the fisheries sector			√

Thematic area 8: Technology Validation and Adoption

Sl No.	Research area/issue	Time-scale priority		
		Long	Medium	Short
High priority research areas				
1	Innovative participatory approach for technology validation	√		
2	Development of techno-economic evaluation of fisheries and aquaculture technologies		√	
3	Strategic communication and dissemination model/practice for effective technology adoption		√	
4	Strategy for strengthening of linkages among research, extension and industry			√
5	Innovation and application of appropriate information technology in dissemination and adoption process	√		
Medium priority research areas				
6	Impact of e-extension, patenting and commercialization of fisheries and aquaculture technologies		√	
7	Perceptions and determinants of fisheries technology adoption			√

Strategies and Framework

The fisheries sub-sector in Bangladesh has demonstrated an outstanding faster growth during the last decades. The sub-sector has not only been providing a pivotal role in meeting the nutrition and food security of the country but has also been an instrument of livelihood for a large section of the economically backward population. It generates export earnings, creates income and employment opportunities, and stimulates the growth of a number of subsidiary industries and it has immense potential to enhance its production, commercialization, and exports. The main strategic objective of the sub-sector is to achieve economically and environmentally sustainable aquaculture, exploitation, and utilization of fisheries resources for enhanced production for the development of the economy and the national well-being.

Fisheries is considered a strategic and an important sub-sector in the national strategy which requires sustained and focused attention in research and development programs through policy and financial support to accelerate development of the sub-sector in a sustainable, rational, inclusive, and equitable manner. In this policy, a number of priority research have been identified under different thematic areas to develop, enhance, protect, and manage the fisheries production aligning with the development plans of the country. As a result of the implementation of the proposed research, in the short, medium, and long term, a revolutionary change in the fisheries sub-sector based on the increasing integration of the culture and capture fisheries would be visualized into the national economy. In concurrence, this chapter briefly deals with essential aspects of the strategic objectives and stated plausible framework approaches to be followed to foster viable and vibrant growth in the sub-sector.

Objective 1: Improvement of fish productivity

Aquaculture assumes greater significance in increasing fish production in the country to more than double by 2050. Unless the aquaculture industry finds a way to produce more fish while minimizing its reliance on likely to be limited inputs (land, freshwater, seed, feed, energy, etc.) and environmental impacts, its growth will be hampered. The following approaches could be followed to achieve improvement in aquaculture production.

- Increase access to high-quality seeds of various species based on demand in local, regional, and global markets.
- Ensure widespread availability of sustainably sourced, reasonably priced, and high-quality feed suitable for a range of species.
- Shifting from improved-extensive systems to sustainable significant intensification.
- Combine new technologies (e.g., diagnostic technologies, vaccines) and wider application of best management practices to minimize fish production loss from diseases.
- Establish and/or expand improved breeding, genetics, and hatchery technology.

- Harness potentials of low-impact production systems considering the environment.
- Increase and diversify fish production by species, systems, and techniques.
- Use spatial planning and zoning to guide aquaculture growth at the landscape and seascape level.
- Promote the development of unexploited resources through improved aquaculture.
- Increase public-private investment in technological innovation and transfer.

Objective 2: Management of fishery resources and strengthening of conservation system

Fish supplies from wild catch have stagnated and future supply is under threat. A sustainable management system for fishery resources and fishery activities needs to be built to ensure sustainable resource use. While the focus of doubling fish production by 2040 goes mainly on aquaculture, an important and complementary menu item for a sustainable aqua-food future is to be restored and then wild fish catch stabilized. The first step toward a sustainable fish supply is to curb overfishing and maintain the fish stock. Key approaches for sustainable fisheries exploitation, while our wild fish stocks are expected to be on the rebound are outlined below.

- Characterize fisheries habitat over time and identify areas of the greatest protection.
- Setting up of fishing grounds information system.
- Maintain a healthy aquatic ecosystem and biodiversity.
- Reduce the wild fish catch in the short term to allow depleted stocks to recover.
- Research-based management of illegal, unregulated, and unreported (IUU) fishing.
- Improvement of single (e.g. Hilsa) and multi-species standing stock assessment.
- Incorporate social and economic data into the fishery management decision process.
- Assess the impacts of climate change on stock productivity and distribution shifts.
- Minimize water pollution and fish habitat degradation.
- Promote the development of unexploited resources through improved fishing techniques.

Objective 3: Increasing the quality and value of fish production and fishery products

Fish production efforts must ensure the supply of safe and nutritious food. Developments in fish processing and distribution systems and the quality and improved hygienic standards for fishery products are needed to meet the consumer's demand. Through such efforts, it is expected to improve the supply of safe fish and fishery

products and minimize waste, and income. However, the research-based approaches may be as below:

- Improvement and adoption of best aquaculture practices.
- Reduce fish post-harvest loss and fish waste recycling across the fish value chain.
- Develop and promote fish processing and packaging technology.
- Improve fish distribution network and diversify markets.
- Set hygienic standards for fishery products at both domestic and international levels.
- Improve fishery socio-economic situation and marketing systems.
- Promote optimum utilization of fish and by-catch.

Objective 4: Harnessing prospects of marine fisheries

There are many challenges and gaps that must be taken into consideration for the development and making of marine fisheries sustainable in the country. There is a need for research that generates technology on sustainable use, protection, and restoration of coastal and marine ecosystems, as well as ecosystem services. However, the major research approaches to harness the potential of the blue economy are given below:

- Enhance knowledge generation and identify best practices to maintain the productivity and resilience of marine ecosystems.
- Develop marine aquaculture.
- Use of marine biotechnology for marine-derived by-products.
- Formulate policy for marine ecosystem assessment.
- Prioritize, synergize, and find novel ways to leverage resources and capacity.
- Improve data quality to ensure sustainable industrial and artisanal (small-scale fisheries) fisheries.

Objective 5: Mitigating climate change and ecosystem impacts

Climate change would bear an enormous impact on future activities and the economic stability of society, especially, coastal communities. Bangladesh is often extremely vulnerable to climate change due to typically geographically small with limited resources and limited capacity for resilience. Climate change impacts should be incorporated into adaptation planning strategies and decision-making with the following approaches.

- Fill the knowledge gaps in climate change impacts as well as increase the capacity of coastal and marine managers and communities to anticipate climatic and associated impacts and mitigate risk.
- Develop early warning and management plans.
- Generate political will and build partnerships to improve the implementation of existing policy frameworks, and support innovation for emerging challenges

Objective 6: Developing an effective technology dissemination system

There are mechanisms to adopt the generated technologies which are being practiced to some scale. However, the adoption process is lagging behind which is a serious challenge. There are a number of factors, such as labour, land, availability and access to credit, and other critical inputs that determine the adoption decision-making. To achieve the strategic objective, intended research approaches may be advocated as below:

- Conduct need analysis, farmers' perception and design an end-user-focused solution.
- Conduct research-extension-farmers participatory pilot programs.
- Develop and deploy a comprehensive communication for knowledge mobilization across the stakeholders.
- Provide adoption support through custom training to end-users.

Regardless of the domain where the high-quality basic, strategic, and applied research is approached and being conducted, there are a few strategic drivers determining focused topics for our industry development through the advancement of knowledge and technology innovation. These drivers are important for the sustainability of fish production, product development, market, and consumers, policy and regulation, and addressing challenges the industry faces. A combination of a number of strategic categories that stand out for different strategic circumstances and can contribute to sustainable fisheries and aquaculture has been displayed in the next page. The diagrammatic framework recognizes the challenges faced in bridging the research and policy gap and shows a visual outline of activities that are required to make up an overarching strategy for research to realize short to long-term benefits of fisheries sub-sector.

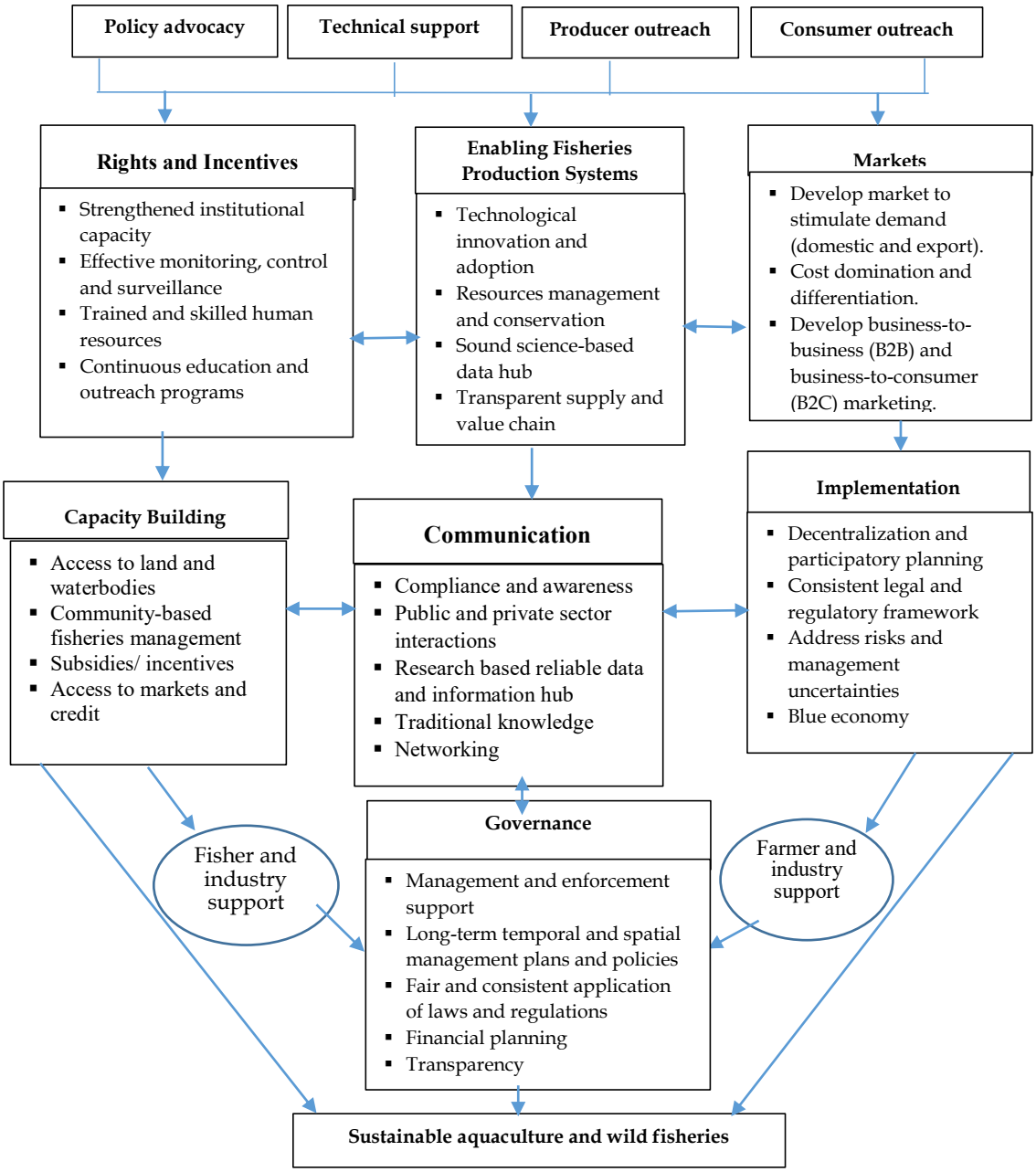

Fig 40. Combined strategic drivers towards sustainable aquaculture and fisheries

Way Forward

The population of Bangladesh is expected to reach between 230 and 250 million by 2050 as per UNDP estimate (The Daily Star, 2022) increasing the pressure on the food sectors to maximize production and reduce waste. Production increase must occur in a sustainable way and in a context where key resources such as land and water are likely to be scarce and where climatic change impact will intensify. The fish production sector is no exception.

In this context, fisheries and aquaculture should be able to maintain the current annual per capita national fish consumption rate of 22.84 kg i.e. is 62.58 gm/capita/day against the health requirement of a person as per FAO standard (63 gm/capita/day). So far, technological and institutional innovations have ensured that the combined production of fish through fisheries and aquaculture has been faster than the national demand of fish. The great concern is now to keep up this pace with another 60-80 million people added to the national population in the next 30 years balancing the four dimensions of food security (availability, accessibility/affordability, utilization and stability). The global as well as our national growth and contribution of aqua-food sector has demonstrated that sustainable fisheries and aquaculture will be able to help address the daunting food security issue in the coming decades. Aquaculture will become a substitute form of protein for some of the less efficient food production systems or even be used to compensate for the decline in farming systems' productivity due to the impact of climate change. However, achievement of this speculation will largely depend on the development of an environmentally and economically sustainable fisheries and aquaculture industry by generating and adopting science-based information and technologies.

In this document, attempts have been made to identify the constraints for the development of fisheries sub-sector in Bangladesh and priority research areas to address the present and up-coming challenges. Setting future research priorities is a risky business as the chances are very high that someone in somewhere is likely to feel that a specific priority has not been addressed. Keeping this in mind, eight thematic research areas have been defined, and a number of research areas/issues have been identified and prioritized under each thematic area through rigorous stakeholder consultation and consensus. This document is prepared to help guide researchers with a comprehensive list of the research areas believing that the effort can yield the greatest impact on improving and increasing commercial fisheries and aquaculture outputs over the coming decades. This chapter tailors the following way forward taking into account the future needs of sustainable fisheries and aquaculture production in the country and addressing emerging challenges and issues.

Research through effective coordination and team building

The development of fisheries sub-sector in Bangladesh needs a more inclusive, coordinated, and holistic approach to plan and implement research to maximize fisheries

production potential centering on environmental stewardship and effective use of available resources and capacity. Research efforts must be integrated across disciplines by teams of researchers who work together effectively to meet the future needs of fisheries and aquaculture.

Research into practice with policy supports

Given the increasing amount of funding allocated to research by the Government and non-government institutions, it is necessary to critically explore the issue of translating research into practice aligning with the policies of the country which will ensure the accomplishment of the core mission of discovery and innovation.

Periodic review of policies and research priorities

The existing fisheries laws, policies, and other related sectorial policies and plans have visible outlook for sustainable production of fish and fishery products, judicious utilization, exploitations, restoration, protection and conservation of fisheries resources, improvement of socio-economy and livelihoods, etc. However, all fisheries policies should be reviewed in every decades planning cycle in line with climatic changes, crucial emergent issues, international code of conducts and with far-reaching changes in strategic development needs. Fisheries research programs and priorities should also be revised and updated in the same planning cycle so that national policy makers are informed on the research-based issues to meet the policy thrusts.

Implementation of recommendations on crucial issues

Risks and uncertainties are inevitable, and many other key research areas either may not have been included here or will emerge in course of future socio-economic and environmental changes. However, this will serve as a hands-on document to identify and develop research projects and also will provide a basis for discussion and consideration for the development of future research areas. To harvest the full benefits of research outputs, several crucial issues were raised in the regional workshops and some of those are listed below as recommendations to be implemented:

- Ensures welfare of fisheries, fishermen and farmers, particularly in case of small-scale fisheries and aquaculture.
- Strengthen fisheries and aquaculture governance and institutional frameworks to set clear objectives with R and D paths for the sector.
- Develops public relations and stakeholder communication activities by establishing a new, better targeted and resourced outreach programs in public universities.
- Ensures technical and financial support to transitioning the sector to low-impact and fuel/energy efficient, and blue carbon enhancement.
- Enhances institutional capacity to address the research areas in the age of 4IR.
- Develops and implements bi-lateral, multi-lateral and co-investment models for R and D programs.

- Empowers the public extension agency, i.e., DoF for enacting existing fisheries laws and regulations.
- Ensures producer-friendly marketing system and equity of all fisheries supply and value chain actors to increase access to market.

Minimizing duplication of research

In the current context, it is more important than ever to avoid unnecessary duplication of research efforts. Duplication represents inadvertent, unconscious or sometimes deliberate repetition of research thus leading to research waste. Mechanisms should be in place to limit unnecessary duplication of research that may include establishment of a coordinated web-based national repository of all fisheries research being conducted by research institutes, universities, and other national and international organizations.

Increasing research fund

Although the research organizations and universities have ample research facilities and there are several national sources for supporting research fund these are and will not be adequate to plan and manage all research as needed for an organization and individual scientist. In this case, investment to fisheries research has to be increased particularly from the Government sources as the grant aid from doner agencies has been declining. National and international collaboration can also help research organization and individual scientist get the access much-needed funding, equipment, and knowledge. Depending on the research area and team constellations, collaborations may be driven by research ideas, questions, theories, equipment, and resources or data. The collaboration may offer chances to build networks, pool resources and expertise, and potentially accelerate innovations.

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Appendices

List of members and lead officers for preparation of research priority in fisheries sub-sector for Khulna Division

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1	Enhancement of Fish Productivity and Production	Mr. Md. Tofaz Uddin, DD, DoF, Khulna DIvision
		Dr. Md. Latiful Islam, CSO, BFRI, Paikgacha, Khulna
		Mr. Firoz Ahmed, DFO, Distict Fisheries Office, Jashore
		Mr. Md. Shaun Ahmed, SO, BFRI, Paikgacha, Khulna
2	Fisheries Protection and Conservation	Mr. A.S.M. Rasel, DFO, Distict Fisheries Office, Bagerhat
		Dr. Hasmi Sakib, SSO, BFRI, Paikgacha, Khulna
		Dr. S.M. Tanbirul Haque, SSO, BFRI, Bagerhat
		Mr. Md. Anowarul Kabir, DFO, Distict Fisheries Office, Magura
		Mr. Jaydeb Paul, DFO, Distict Fisheries Office, Khulna
3	Fish and Shrimp Harvesting, Post-Harvest and Processing Management	Mr. Md. Anisur Rahman, DFO, Distict Fisheries Office, Satkhira
		Mr. H.M. Rakibul Islam, SSO, BFRI, Bagerhat
		Mr. A.S.M. Tanbirul Islam, SSO, BFRI, Bagerhat
		Dr. Md. Ashraful Haque, SSO, BFRI,Jashore
4	Fish Germplasm Collection, Characterization, Conservation and Improvement	Mr. Md. Tofaz Uddin, DD, DoF, Khulna DIvision
		Mr. Jaydeb Paul, DFO, Distict Fisheries Office, Khulna
		Mr. Nripendra Nath, DFO, Distict Fisheries Office, Kushtia
		Mr. H.M. Badruddoza, DFO, Distict Fisheries Office, Narail
		Mr. Md. Shariful Islam, SSO, BFRI, Jashore
5	Technology Validation and Adoption	Mr. Md. Harunur Rashid, PSO, BFRI, Jashore
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		Mr. Md. Abubakar Siddique Sarker, SUFO, DoF, Dumuria
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List of members and lead officers for preparation of research priority in fisheries sub-sector for Rajshahi Division

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		Mr. Md. Abdur Rouf, DD, DoF, Rajshahi
		Sharker Anowarul Kabir Ahmad, DFO, District Fisheries Office, Bogura
		Mr. Md. Jahangir Alom, DFO, District Fisheries Office, Rajshahi
		Dr. Md. Aminul Ahsan, DFO, District Fisheries Office, Naogaon
		Mr. Md. Abul Kalam Azad, DFO, District Fisheries Office, Natore
2.	Fisheries Protection and Conservation Perspectives	Mr. Sharker Mohiuddin, DFO, District Fisheries Office, Joypurhat
		Dr. Md. Aminul Ahsan, DFO, District Fisheries Office, Naogaon
		Dr. David Rintu Das, PSO, BFRI, Bogura
		Mr. Md. Mehedi Hasan Pramanik, SSO, BFRI, Santahar
		Mr. Md. Abul Kalam Azad, DFO, District Fisheries Office, Pabna
		Mr. Nur Nabi, SUFU, Senior Fisheries Upozila Office, Kahalu, Bogura
		Mr. Md. Abul Kalam Azad, DFO, District Fisheries Office, Natore
3,	Fish and Shrimp Harvesting, Post-Harvest and Processing Management	Dr. Md. Toriqul Islam, Professor, Fisheries Department, RU, Rajshahi
		Mr. Md. Shahinur Rahman, DFO, District Fisheries Office, Sirajganj
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		Mr. Md. Anowar Hossain, SUFU, Senior Fisheries Upozila Office, Sirajganj
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		Dr. Md. Yiamin Hossin, Professor, Fisheries Department, RU, Rajshahi
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Sl	Title of Manuscript	Name, Designation and Address
		Mr. Kamruzzaman, UFU, Upozila Fisheries Office, Joypurhat
		Ms. Ayshea Khatun, SUFU, Senior Fisheries Upozila Office, Natore
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		Mr. Md. Shahinur Rahman, DFO, District Fisheries Office, Sirajganj
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		Mr. Md. Bayezeed Alom, SUFU, Senior Fisheries Upozila Office, Ullapara, Sirajganj
		Mr. Md. Shariful Islam, UFU, Upozila Fisheries Office, Atghoria, Pabna

List of members and lead officers for preparation of research priority in fisheries sub-sector of Barishal Division and greater Faridpur

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		Mr. Anisur Rahman Talukder, DoF, Barishal
		Mr. Md. Amirul Islam, PSO, Aquaculture Division, BFRI, Khepupara, Potuakhali
		Ripon Kanti Ghosh, DFO, Office of District Fisheries Officer, Jhalukati
2	Fisheries Protection and Conservation Perspectives	Mr. Muhammad Nasir Uddin, Asst, Director, DoF, Barishal
		Mr. S.M. Azharul Islam, DFO, Office of District Fisheries Officer, Potuakhali
		Mr. Md. Amirul Islam, PSO, Aquaculture Division, BFRI, Khepupara, Potuakhali
		Mr. Md. Abdul Bari, DFO, Office of District Fisheries Officer, Pirozpur
3	Fish and Shrimp Harvesting,	Dr. Md. Ariful Alom, Professor, Fisheries Biology and Genetics Department, PUST, Dumki, Potuakhali

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	Post-Harvest and Processing Management	Mr. Bishajit Kumar Deb, DFO, Office of District Fisheries Officer, Barguna
		Mr. Md. Manjurul Hasan, SO, BFRI, Khepupara, Potuakhali
		Mr. Molla Emdadullah, DFO, Office of District Fisheries Officer, Bhola
4	Fish Germplasm Collection, Characterization, Conservation and Improvement Perspectives	Mr. Md. Assaduzzaman, DFO, Office of District Fisheries Officer, Barishal
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		Mr. Md. Rubel Miah, Fish Cultivation Engineer, DoF, Barishal
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		Mr. Babul Krishna Ojha, Office of District Fisheries Officer, Madaripur
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List of members and lead officers for preparation for research priority in fisheries sub-sector for Chattogram Division

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		Mr. Sreebash Chandra Chand, DFO, District Fisheries Office, Rangamati
		Lft. Commander Mohammad Touhidul Islam, Manager, Fisheries Development Corporation, Rangamai
		Ms. Rabina Akther Lima, BFRI, River Sub Station, Rangamati
		Mr. Shahnur Jahedul Hasan, SSO, BFRI, Cox's Bazar
		Dr. Md. Assaduzzaman (Juel), Associate Professor, Marine Bio Resources, CVASU, Chattogram
		Ms. Farjana Lovely, DFO, District Fisheries Office, Chattogram
		Dr. Helena Khatun, Associate Professor, Faculty of Fisheries, CVASU, Chattogram
2	Fisheries Protection and Conservation Perspectives	Dr. Shaikh Ahmad Al Nahid, Fisheries Resource Management Department, CVASU, Chattogram
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		Mr. Md. Abu Said, Sr. Asstt. Director, DD Office, DoF, Chattogram
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		Dr. Abdullah Al Mamun, Professor, Department of Fisheries and Marine Science, NUST, Noakhali
		Mr. Md. Mizanur Rahman, Sr. Asstt. Director, Quality Assurance Manager, Quality Control Lab, DoF
		Mr. Ovijit Shil, DFO, District Fisheries Office, Banderban
		Mr. Sreebash Chandra Chand, DFO, District Fisheries Office, Rangamati
		Mr. Md. Badrujjaman, DFO, District Fisheries Office, Cox's Bazar
		Mr. Zahidul Islam, SO, Sea Fisheries and Technology Station, BFRI, Cox's Bazar

Sl	Title of Manuscript	Name, Designation and Address
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		Mr. Mritunjoy Paul, SSO, BFRI, Cox'Bazar
		Mr. Shahnur Jahedul Hasan, SSO, BFRI, Cox's Bazar
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		Mr. Md. Badujjaman, DFO, District Fisheries Office, Noakhali
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3	Fish and Shrimp Harvesting, Post-Harvest and Processing Management	Dr. Ajharul Ali, PSO, Sweet Water Sub Station, BFRI, Saidpur
		Mr. Sreebash Kumar Shaha, SO, Sweet Water Sub Station, BFRI, Saidpur
		Mr. Sharder Mohiuddin, DFO, District Fisheries Office, Joypurhat
		Mr. Tashrif Mahmud Minhaj, SO, Sweet Water Sub Station, BFRI, Saidpur
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		Mr. Barun Chandra Biswas, DFO, District Fisheries Office, Nilphamari
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		Mr. Md. Khalikuzzaman, DFO, District Fisheries Office, Thakurgaon
		Mr. Md. Monjurul Islam, Asst. Director, DoF, Rangpur Division, Rangpur
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List of members and lead officers for preparation of research priority in fisheries sub-sector for Sylhet Division

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		Dr. Md. Toriqul Alom, Professor, Aquaculture Department, Sylhet Agricultural University, Sylhet
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		Mr. Nura Alom Siddiqui, Fisheries Survey Officer, District Fisheries Office, Habiganj
		Mr. Kanik Chandra Sharma, UFO, Office of Upazila Fisheries Officer, Shayestaganj
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		Mr. Md. Abul Kalam Azad, DFO, District Fisheries Office, Sylhet
		Mr. Md. Ahsan Hasib Khan, Sr. Asstt. Director, DoF, Sylhet
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List of Members and lead officers for preparation of research priority in fisheries sub-sector for Mymensingh Division

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		Dr. Md. Julfikar Ali, CSO,BFRI, Mymensingh
		Dr. Md. Abdus Salam, Professor, Dept. of Aquaculture, BAU
		Dr. Durin Akhtar Jahan, PSO, Freshwater Station (FS), BFRI, Mymensingh
		Dr. Fazlul Kobir, Sr. Assistant Director, DoF, Mymengish
		Dr. Md. Sirajum Monir SSO, FS, BFRI, Mymensingh
		Dr. Md. Mashiur Rahman, SSO, FS, BFRI, Mymensingh
2	Fisheries Protection & Conservation	Dr. Md. Khalilur Rahman Director (Research & Planning), BFRI
		Dr. Md. Anisur Rahman Director (Admn & Fin), BFRI, Mymensingh
		Dr. Zoarder Faruque Ahmed, Professor, Dept. of Fisheries Management, BAU
		Dr. Mostafa Ali Reza Hossain, Professor, Dept. of Fisheries Biology and Genetics
		Dr. Harunur Rashid, Professor, Dept. of Fisheries Management

Sl #	Title of Manuscript	Name, Designation and Address
		Md. Shahjahan Kabir, DFO, DoF, Netrokona
		Md. Ashafuddoulah, SSO, FS, BFRI, Mymensingh
		Md. Shahidul Islam, Sr. Assistant Director, DoF, Netrokona
3	Fish Harvesting, Post-harvest & Processing Management	Dr. A. K. M. Nowsad Alam, Professor, Dept. of Fisheries Technology, BAU
		Dr. Fatema Hoque Shikha, Professor, Dept. of Fisheries Technology
		Dr. Muhammad Mehedi Hasan, Professor, Dept. of Fisheries Technology, BAU
		Mrs. Prianka Jahan, Assistant Professor, Dept. of Fisheries Technology, BAU
		Md. Mizanur Rahman, Assistant Director, DoF, Jamalpur
		Dr. Ehsanul Karim, SSO, BFRI, Mymensingh
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		Dr. Mohd Golam Quader Khan, Professor, Dept. of Fisheries Biology and Genetics, BAU
		Dilip Kumar Saha, DFO, Mymensingh
		Dr. Selina Yeasmin, SSO, Freshwater Station, BFRI
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5	Technology Validation & Adoption	Deputy Director, Mymensingh Division, DoF
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		Dr. Anuradha Bhadra, CSO, Freshwater Station, Mymensingh
		Md. Aminul Haque, DFO, DoF, Sherpur
		SM Khalequzzaman, DFO, DoF, Jamalpur
		Ms. Sultana Layla Tasneem, Sr. Asst. Director, DoF, Sherpur

List of Members and lead officers for Preparation of research priority in fisheries sub-sector for Dhaka Division

Sl #	Title of Manuscript	Name, Designation, Address
1	Enhancement of Fish Productivity and Production	Dr. Md. Amjad Hossain, Professor, Aquaculture Department, BSMRAU, Gazipur
		Prof. Dr. A.S.M. Rafiquzzaman, Fisheries Biolology and Aquatic Environment Department, BSMRAU, Gazipur
		Dr. M. Shabuddin, Professor, Aquaculture Department, SAU, Dhaka
		Mrs. Taslima Akther, Asstt. Professor, Aquaculture Department, BSMRAU, Gazipur
		Mr. Mir Mohammad Ali, Aquaculture Department, SAU, Dhaka
		Mr. B.M. Mostafa Kamal, DFO, Office of District Fisheries Officer, Dhaka
		Mr. Md. Belal Hossain, DFO, Office of District Fisheries Officer, Narsingdi
		Dr. Md. Shamsur Rahman, Professor, Fisheries Science Department, DU, Dhaka
2	Fisheries Protection and Conservation Perspectives	Dr. Dinesh Chandra Shaha, Fisheries Management Department, BSMRAU, Gazipur
		Dr. Md. Shakawat Hossain, Fisheries Biolology and Aquatic Environment Department, BSMRAU, Gazipur
		Dr. Nurunnabi Mandol, Asstt. Professor, Fisheries Management Department, BSMRAU, Gazipur
		Dr. Tasmina Akther, Fisheries Management Department, BSMRAU, Gazipur
		Mr. Md. Faisal Hossain, Aquatic Environment and Resource Management Department, SAU, Dhaka
		Ms. Afsana Ferdous, Marine Science and Oceanography Department, SAU, Dhaka
		Mr. Md. Saifur Rahman, DFO, Office of District Fisheries Officer, Manikganj
		Krishibid Ripon Kumar Pal, DFO, Office of District Fisheries Officer, Kishorganj
		Dr. Md. Hasan Faruque, Asstt. Prof., Fisheries Science Department, DU, Dhaka
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