A training dialogue report

Introduction to Climate Services for Aquaculture

WorldFish

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A training dialogue report: Introduction to Climate Services for Aquaculture

Authors

Shammunul Islam,[1] Peerzadi Rumana Hossain,[2] Mélody Braun,[1] T. S Amjath Babu[3] and Farah Anjum[4]

Authors' Affiliations

[1] International Research Institute for Climate and Society (IRI), Columbia University
[2] WorldFish
[3] International Maize and Wheat Improvement Center
[4] International Centre for Climate Change and Development, Independent University of Bangladesh

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Contact

WorldFish Communications and Marketing Department, Jalan Batu Maung, Batu Maung, 11960 Bayan Lepas, Penang, Malaysia.
Email: worldfishcenter@cgiar.org

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Contents

Executive summary 1
Introduction 3
Background 4
Climate impacts on aquaculture 4
Climate service needs 4
Objectives 5
Day 1: October 27, 2019 6
Introductory remarks 6
Session: Participant introductions and presentations on decision-making flowcharts 7
Session: Introducing the basics of climate science 9
Exercise: Introducing timescales to participants 10
Session: Climate of Bangladesh 12
Day 2: October 28, 2019 12
Session: Timescales of information 12
Session: Climate impacts on aquaculture and food security 13
Session: Agro-meteorological and early warning tools 15
Session: Communication processes to deliver and support rural climate service 16
Session: Climate services for agriculture 18
Exercise: Daily takeaways and discussion 19
Day 3: October 29, 2019 21
Exercise: Stakeholder mapping for climate services in aquaculture 21
Session: Current opportunities for climate services for aquaculture 22
Session: Overview of ENACTS 23
Demonstration of ENACTS Maproom 24
Exercise: ENACTS Maproom 24
Day 4: October 30, 2019 24
Session: ENACTS Maproom hands-on training 24
Day 5: October 31, 2019 25
Group work: Presentation on Maproom 25
Group work: Identifying needs and recommendations for aquaculture climate services 26
Recommendations 27
Feedback 28
Concluding remarks 29
Certificate distribution ceremony 30
Conclusion and way forward 31
Notes 32
List of tables 33
List of figures 33
Annex 34
Bios of the resource persons and facilitators 41

Executive summary

From October 27 to 31, 2019, the Bangladesh Meteorological Department (BMD) in Dhaka hosted a weeklong training dialogue called Introduction to Climate Services for Aquaculture. The event's focus on climate services for aquaculture was the first of its kind in Bangladesh. It engaged a range of aquaculture sector stakeholders, including farmers, farm managers, government officials, and researchers.

The event is the second training dialogue held by the Bangladesh Academy for Climate and Services (BACS). BACS consists of the International Center for Climate Change and Development (ICCCAD) at Independent University, Bangladesh (IUB), the International Research Institute for Climate and Society (IRI) at the Earth Institute of Columbia University, the International Maize and Wheat Improvement Center (CIMMYT) and the BMD. The event was co-organized and funded by WorldFish under the Capacitating Farmers and Fishers to Manage Climate Risks in South Asia (CaFFSA) project, in collaboration with CIMMYT, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the IRI. It was also funded by the CGIAR Research Program on Climate Change Agriculture and Food Security (CCAFS). The IRI provided additional financial and in-kind support via the Adapting Agriculture to Climate Today, for Tomorrow (ACToday) Columbia World Project, CIMMYT via the Climate Services for Resilient Development (CSRD) project, the CGIAR Research Program on Fish Agri-Food Systems, and the BMD.

Aquaculture is critically important to food and nutrition security in Bangladesh. It provides 60 percent of animal protein requirements for Bangladeshis[1] and makes up 3.65 percent of the country's GDP.[2] It has pulled more than 2 million of the 18 million Bangladeshis who have come out from poverty.[3]

However, the sector is vulnerable and impacted by climate variability. High temperatures can affect fish growth and reproduction, and erratic rainfall and fluctuation in temperature impact fish spawning. Shallow pond fish are particularly vulnerable to high temperatures. High temperatures also increase the growth of microphytes, leading to oxygen depletion and habitat degradation.

Against this backdrop, climate services hold tremendous potential for aquaculture by providing timely information and tools to support more climate-resilient decisions. So far, however, climate services research and projects addressing food security in Bangladesh have largely focused on land-based agriculture. Information about the specific needs for climate services in the aquaculture sector remains scarce. This report addresses this gap.

The training dialogue began with participants identifying different climate-sensitive management decisions they make and the climate information needed to inform those decisions. Climate plays a critical role in activities and decisions regarding releasing fingerlings, the timing of fish spawning, fish culture periods, pond aeration and pumping water. Water temperature, for example, can impact decisions on a variety of important factors, including irrigation, feeding, applying lime, managing water depth, netting, stocking fish feed, breeding and fertilizing. Rainfall can impact decisions on the use of input materials like paddle wheels, aqua medicine, aerators, zeolite, protective nets in ponds as well as feed management.

Participants were then introduced to the basics of climate and climate services as necessary to directly address decisions and needs for aquaculture. Key concepts covered climate, weather, climate variability, timescales in weather and climate information, the source of climate data (buoys, weather stations, satellites), types of climate data (observational data, satellite data, model data), and lead time, uncertainty and sources of the predictability of forecasts. The four pillars of climate services - production, translation, communication, use - were also described.

A series of hands-on exercises was followed. This allowed participants, trainers and facilitators to jointly unpack information needs and identify climate service opportunities and challenges. They did so according to timescale, specific aquaculture activities and through mapping the flow of information among stakeholders and along the four pillars of climate services. Through stakeholder mapping, suggestions for including new entities arose, such as the Ministry of Fisheries and Livestock (MOFL), shrimp farmers associations and trawler associations.

Examples were then given of climate services already developed for agriculture. Examples included participatory communication processes, such as the Participatory Integrated Climate Services for Agriculture (PICSA) approach developed by the University of Reading with the CCAFS. Other examples included tools developed under the CSRD by CIMMYT, or the Intelligent Agricultural Systems Advisory Tool (ISAT), which is an advisory tool by ICRISAT. Some relatively new aquaculture applications were also presented, including the BMD aquaculture app as well as the Rupali app by the ACI, which is supported by WorldFish.

After discussing the strengths, weakness and applicability to aquaculture of these climate services, the training dialogue familiarized participants with readily available climate products at the BMD. These included the Maprooms and Enhancing National Climate Services (ENACTS) data products, recently developed under ACToday, which are based on a gridded dataset merging both BMD observation data and satellite data along with re-analysis data. Through hands-on exercises, the participants explored how to access rainfall and temperature information online using the freely available interactive Maproom interface. They were also given the opportunity to discuss different aspects of these tools and suggest improvements.

Over the various activities of the week, participants identified threats and opportunities and provided recommendations for different stakeholders to enhance the development of climate services for aquaculture. Suggested recommendations included strengthening collaboration among different government organizations, such as the BMD, Department of Fisheries (DOF), Bangladesh Fisheries Research Institute (BFRI) and the Department of Agriculture Extension (DAE). They also emphasized the need for follow-up training, as well as capacity building of different stakeholders, such as aquaculture personnel, extension officers and researchers.

It is important to highlight that women were not represented at the event, except for one participant and some of the facilitators. Although unintentional, participants selected from value chain actor organizations were male. This opened the door for possible gender biases. These include assessing climate-sensitive decision-making processes and information needs relevant to only male value chain actors, and considering the strengths and weaknesses of existing climate services solely from the perspective of male stakeholders. To avoid gender biases outcomes in future training events, more deliberate efforts are necessary to represent the diversity of actors' perspectives in selecting participants.

Trainning participants, resource staff and guest speakers.

Introduction

The overarching objectives of the training dialogue were (1) to identify and prioritize potential climate services that CaFFSA, BACS and ACToday can develop and support, and (2) to gain a better understanding of climate-sensitive aquaculture decisions and management. Current use of climate information and the bottlenecks that come with using them were also identified.

Participants were equipped with a basic understanding of climate, climate services and existing climate service products. They were also provided with hands-on training on the different aspects and use of climate services, including products from ENACTS. This allowed participants to learn strategies for initiating, improving or tailoring the use of climate services in existing decision systems.

To have a clear understanding of how climate variability affects different actors in the aquaculture value chain and how they cope with it, participants from different aquaculture value chain components were included in the 5-day long training dialogue. For participants, the dialogue provided them with an interactive platform to communicate with climate scientists and sectoral experts on their specific needs. For climate scientists and sectoral experts, it provided them with a unique opportunity to directly learn from different stakeholders in the aquaculture and fisheries sector and to identify areas for improving or introducing climate services.

An official from the aquaculture ministry asks questions about mapping technology at the BMD.

Background

Climate impacts on aquaculture

Climate change manifests as enhanced variability of key climate variables and increased frequency of extreme events (such as floods and droughts), which can affect food security in Bangladesh, aquaculture specifically. Higher water temperatures can affect fish growth and reproduction, especially for shallow pond fish, and increase the growth of microphytes leading to oxygen depletion and habitat degradation. The loss of connectivity between water bodies from drought affects the breeding and growth of fish and their migration among water bodies. These changes can significantly impact the economic viability of aquaculture and may force fishers to change their occupation or migrate to cities. Financial stress may increase gender-based violence in fisher households as well.

Salinity intrusion from a rise in sea levels reduces freshwater availability for freshwater fish production but increases the area for shrimp production. According to climate change scenarios, sea surface temperature is estimated to rise between 1.2°C and 3.2°C by the end of the century, depending on greenhouse gas emission levels. This is expected to have a negative impact on marine fish production.

Climate service needs

The event's focus on climate services for aquaculture was the first of its kind in Bangladesh and is largely new around the world. The event intended to explore the following needs and opportunities in each of the four pillars of climate services:

1. generating climate data following international best practices
2. translating available data into valuable and useable information for end-users across the value chain
3. transferring information to users through appropriate socially inclusive channels, such as radio, TV, mobile phones and the internet
4. the final use of information by fishers and associated stakeholders to take steps for addressing climate change and climate variability.

Participants from across the value chain emphasized the new character of the discussions around the use of climate information in aquaculture and their importance in reducing losses from climate events. While large efforts have been invested in understanding climate information needs in aquaculture over the past decades, the specific needs for climate information to influence and improve decision-making throughout the aquaculture value chain have not yet been clearly identified. The BMD is providing basic weather information through its aquaculture app. This was identified as a useful and desirable channel, but many stakeholders are not yet aware of its existence or equipped to understand how to use this information. With a better understanding of the variables and the timescales of importance for aquaculture practitioners, tailored information could improve the aquaculture app through collaboration among climate scientists, data providers, aquaculture scientists and end-users.

Against this backdrop, the training dialogue was arranged to identify aquaculture-specific decisions and activities that can benefit from climate services, along with needed information or services. It also introduced participants to the basic concepts of climate science, climate services and existing climate services relevant to aquaculture. The training was designed in a way that allowed the participants, on one side, and the trainers and facilitators, on the other, to learn from each other through presentations, open discussions, hands-on exercises, demonstrations of applications and feedback from participants. Drawing from examples of successful uses of climate services in the agriculture sector and from the identification of climate-sensitive aquaculture-specific decisions and activities and their associated needs and bottlenecks, the training dialogue identified pathways for building successful aquaculture climate services.

Objectives

The overarching objective of this training was to gain a better understanding of the specific needs and potential for climate services in the aquaculture sector. In doing so, stakeholders in the aquaculture value chain, from fishers to owners and managers of fisheries, from government officials to researchers and academics, were convened along with the providers of climate information, the BMD.

Under this objective, the training dialogue had three main sub-objectives:

1. The first was to develop an understanding of existing decision-making process of different stakeholders or organizations along the aquaculture value chain and to identify climate impacts and climate-sensitive decisions within it.

2. The second was for participants to develop a critical assessment of the current use of climate information within their field or institution as well as the bottlenecks and pathways for improvement. In achieving this sub-objective, participants were equipped with a basic understanding of climate, climate services and available products in Bangladesh.

3. The third one was to create an opportunity for bridging the gap between users and providers. To that end, the dialogue supported BMD engagement with stakeholders representing different parts of the aquaculture value chain. It was designed to enhance the BMD's understanding of the decisions, needs and bottlenecks of users. The exchange between providers and users is critical to successfully developing and sustaining efficient, contextualized and demand-driven climate services.

Participants of the training gather around Ashely Curtis (IRI) and Mélody Braun (IRI) to discuss a group activity.

Day 1: October 27, 2019

The first day began with a note of welcome from the BMD followed by introductions for participants and organizers. A Bangla translation was provided to ensure that all participants could participate meaningfully.

Introductory remarks

Mr. Shamsuddin Ahmed, director of the BMD, briefly discussed BACS and its objectives to support climate-resilient development in Bangladesh.

The first BACS short course was held in 2018. Its theme was to introduce climate services as a potential pathway to address the needs of climate vulnerable communities. The second BACS training module, however, was designed only for participants from the aquaculture sector. The aim was to identify and prioritize potential climate services for capacity development of farmers and relevant stakeholders in the sector.

Mr. Shamsuddin highlighted the need to assess the current use of climate information and the knowledge gap in climate service products. Together, they would explore the priorities of climate information in aquaculture and capacity development of the DAE and to enhance further collaboration among BACS alumni.

Ms. Mélody Braun, senior staff associate, IRI Columbia University, and ACToday Bangladesh country lead, introduced the work of the IRI in helping bridge the gap between climate scientists and multisectoral experts, users and practitioners. She mentioned that the training dialogue was designed to understand the climatic impacts on aquaculture and how integrating climate information could help improve decision-making for actors working in the sector. This would help both scientists and the practitioners identify the needs and the ways to develop solutions.

Dr. Feisal Rahman, research coordinator for the ICCCAD, mentioned two aspects needed for ensuring effective climate services. One is to identify the need for the people working at the micro level. Another is to reveal current research gaps in formulating sound recommendations for farmers to make decisions. To accomplish this, a joint partnership is needed to organize training sessions like this every year. In this regard, the ICCCAD has hosted BACS to build a common platform to bring together field-level people as well as researchers.

Mr. Rahman also highlighted the importance of gender-balanced participation in any interventions to ensure inclusive development.

Dr. T. S Amjath Babu, an agricultural economist for CIMMYT, shared his excitement in introducing the climate products and sharing the experience of CIMMYT with the stakeholders. He added that a two-way education for the scientists, practitioners and users should follow the involved learning experience of the training dialogue.

Mr. Christopher Price, country director for WorldFish, highlighted several points about the aquaculture sector. It was initiated in 1980s and faced a lot of challenges from climatic threats. Over time, production rates have increased and farmers now invest more than ever before. Yet various climatic events have significantly impacted many farms and fisheries. Mr. Price believes that climate information services will help farmers reduce their losses.

Session: Participant introductions and presentations on decision-making flowcharts

Facilitator: Ms. Mélody Braun, IRI, Columbia University

Participants were asked to describe the relationship of their activities with climate change and variability, and then asked to provide answers and present the weather and climate information they were using currently. They also provided information on the preventive measures for preparing for and reducing risk regarding advanced information for three different timeframes: 1 week, 1 month and 3 months. They also gave answers on the worst that could happen in the event that preventive action is taken when the risk does not happen, their tolerance to uncertainty and tradeoffs, and what they would need.

All participants gave a presentation on the answers they provided. This gave the trainers and facilitators a glimpse of the climate sensitive activities and risk-reducing measures taken within the aquaculture sector. It also allowed participants representing different parts of the aquaculture value chain to learn about each other and from themselves about how different actors are dealing with risks posed by climate variability. The information gleaned from these presentations is summarized in Table 1. (See Table 6 in the Annex for more details.)

Dr. Mannan, a meteorological scientist at the BMD, shows the training participants around the Storm Warning Center at the BMD.

Stakeholders	Climate-related impacts	Preparedness activities that could be taken with appropriate information	Needs
Farmers, hatchery managers, fisheries owners	• Decreased spawn production and growth performance • High mortality • Water crisis • Disease outbreak	**1 week in advance** • Artificial showering • Water shelter for fish • Prepare sheds, feeds and water pump • Supply ground water • Adapt feeding management • Catch short-cycle species • Consult with fisheries officers • Arrange medicine in case of disease outbreak **1 month in advance** • Arrange for alternative water reservoir or pump to deal with high temperatures • Improve management techniques • Adopt feeding management • Maintain water depth and pond quality to limit changes in water parameters • Arrange netting around the pond to prevent flooding • Co-management by communities **3 months in advance** • Plan for short-cycle species or high temperature tolerant species • Reconsider stocking and harvesting pattern; stock later in season • Ensure backup brood • Improve surveillance system of diseases	• Information at household, upazila and district levels • Lead time for forecasts was mostly 1 week, followed by 10–15 days
Laboratory analysts, quality control officers	• Load shedding during heavy rain or high temperatures damages work	**1 week in advance** • Check whether there is enough fuel for using a generator to ensure the supply of electricity during heavy rainfall and cyclone events **1 month in advance** • Check generator and do maintenance work if necessary **3 months in advance** • Check whether the generator is functional for providing continuous electricity during heavy rainfall and cyclone events	• Prepared weather forecast

Table 1. Summary of the decision-making flowchart activity.

Session: Introducing the basics of climate science

Facilitator: Dr. Tufa Dinku, research scientist, IRI, Columbia University

Understanding the basics of climate science is pivotal to the understanding and use of climate services. To equip participants with these concepts, Dr. Dinku conducted a session where he discussed the concept of weather and climate, climate principles, global versus local climate, and climate variability. Highlights from his presentation included the following:

- **Weather** is a short-term condition and **climate** is a decadal phenomenon. Climate is always "what we expect" whereas weather refers to "what we get."

- **Climate system** is the climate of an area in a certain period of the year. It has several components, including oceans, atmosphere and space. They interact with each other to form a certain climatic condition over an area.

- **Climate principles** help aid understanding of how climate works. The discussion highlighted the following:
  - The sun heats the surface and then the surface heats the air.
  - Water heats up and cools down very slowly. (Water bodies require 4000 times more energy to warm up than land.)
  - Air temperature decreases with height, which is why the temperature drops gradually as we go up.
  - Warm air can hold a lot more moisture than cold air.
  - Warmer moist air rises; colder air sinks.

- **Global climate**, which includes temperature and rainfall in an area, is determined by the energy and distribution of sunlight over different places in the world. Earth's tilt affects which areas of the planet receive sunlight. In determining local level climate, several factors have significant impact, including orography, albedo, land-water contrast and vegetation.

- **Climate variability** is the variation of the climate at all scales of time and space. It is important to adapt to current climate arrangements that would help in meeting future climatic challenges. Temperature variability and change can be compressed into three parts: trend, decadal change and also interannual variability, which explains most of the variability in comparison with the other two factors. Climate change is also going to make climate variability more variable. As a result, addressing interannual climate variability could combat the negative effects of climate variability and climate change.

Exercise: Introducing timescales to participants

Facilitator: Ms. Mélody Braun, IRI, Columbia University

Ms. Braun conducted a participatory session to introduce timescales of climate information and the important elements associated with it. The purpose was to do so from the perspective of the participants and to open a discussion about what timescales of information do people across the value chain perceive as useful or needed for their specific activities.

In the exercise, participants were given a card for a key activity they are in charge of. They then positioned the card on a timeline based on the kind of information they would need to carry out preparedness action to anticipate climate risks for this the activity: information about past climate, present climate (observations), 2 weeks into the future, 1 month or 3 months into the future. As shown in Table 2, the initial perception of users focused on short- and medium-term forecasts, as often observed. The exercise created an entry point to discuss the importance and role of historical information and observation data to inform decision-making and develop forecasts, as well as the uncertainty associated with forecasts at different timescales. All of this was further unpacked in the following days.

Timescale	Sector	Activity	Remarks/Comments
Past	Assistant director, DOF	Manages government fish farms and haors, and works with policy formulation in aquaculture	Needs past meteorological information to inform policy development
	Fishery lecturer, BAU	Assists in impact assessments	Requires past data
	Assistant director, DOF	Supervises fisheries activities	Past data needed for project planning
Present	N/A	N/A	N/A
Future (2 weeks)	Deputy manager, BRAC Fisheries	Produces fish seed	Future data will help in distribution of fish seed
	Quality control officer, DOF	Checks quality of fish products	Future information will assist in quality control activities of fisheries
Future (1 month)	Fish farmer, Bagerhat	Fish production and planning	Future data will help in advance fishery planning
Future (3–4 months)	Glorious Fisheries Ltd	Pond preparation, fingerling collection, fish feed, fish catch, marketing	Advanced climate information will help in decision-making
	BFRI	Breeding and developing prawn, farming calendar	Early forecasts would help to develop farming calendar and planning
	Pranti Aquaculture Ltd	Catch fish, monitor fish growth, randomized control trial, marketing	Assist in planning and management
	Farm manager, DOF	Production of fish, fingerlings and juvenile fish	Future climate data will help to plan fish farming in advance
	Mantaf Agro Ltd	Fish farming	Early climate information would help to take farming actions in advance
	Carp Genetic Improvement Program (CARP-GIP), WorldFish	Breeding, rearing spawn and brood development	Need future climate data to plan fisheries activities
	Fish farmers	Fish farming and fruit gardening	Assist in fish farming decision-making in advance
	Bangladesh Institute of Maritime Research and Development (BIMRAD)	Conducts research and capacity development activities for coastal aquaculture	Better integration of forecasts would be beneficial in conducting research and producing useful information for beneficiaries
	Coast Trust	Transferring technology, training, courtyard meeting, monitoring, planning	Climate forecasting helps to take suitable decisions and planning for future decision-making

Table 2. Timescale activity.

Training participants collaborate during an exercise.

Session: Climate of Bangladesh

Facilitator: Dr. Md. Abdul Mannan, meteorologist, BMD

As participants were familiarized with the basics of climate science, the natural follow-up was an overview of the climate of Bangladesh. To that end, Dr. Mannan held a brief session on the climate and climate variability of Bangladesh. He discussed the location, position and weather conditions of Bangladesh and highlighted the impact of temperature, rainfall and natural disasters on the fisheries sector.

As the country's mandated climate data provider, the BMD generates climate data and forecasts of different climatic events, so it was necessary for the organization to introduce the participants to the climate of Bangladesh as well as the BMD's data generation process, information channel and the use of this information.

Weather data is essential for weather-sensitive sectors, like aquaculture. Bangladesh lost meteorological data in 1974 and 1988 because of severe flooding of the ground floor of the BMD's building. Bangladesh also lost the records of weather data as a result of the war for independence in 1971. Since then, the BMD has worked on improving observational facilities to increase data collection. It has increased the number of surface weather observation stations to 47, pilot balloon observation stations to 10, radio sonde observation stations to four and radar observation stations to five. These stations have good coverage over Bangladesh to collect weather data and information.

Based on this data and information - as well as observation from neighboring countries and satellite observation from the Himawari Satellite (Japan), FY-2 Series Satellite (China) and numerical simulation of the Weather Research and Forecasting (WRF) model through the BMD's high performance computing system - the BMD has provided short-, medium- and long-range forecasts to users, stakeholders, the general public and others. The BMD has also been collecting data and information through international collaboration. Weather data, information, forecasts and products are sent to users through various communication channels, including fax, email, the BMD website, telephone and interactive voice recorder (IVR).

Through the Bangladesh Weather and Climate Services Regional Project, with the support of the World Bank, the BMD is installing 200 more automatic weather stations over the next 2 years. In addition, the BMD has developed a disaster calendar that can help users make sound decisions for their respective sectors. The accuracy of the BMD's forecasts has gradually increased, so people in various sectors are relying more on its forecasts. Accordingly, aquaculture management activities can benefit from using more weather and climate information and forecasts provided by the BMD.

Day 2: October 28, 2019

The second day of the training dialogue focused on the different aspects of climate information that users need to know to use it effectively. Participants were introduced to concepts like uncertainty in weather forecasts, forecasting skill, and probability, all of which are essential to use climate information effectively. The communication processes necessary to deliver and support rural climate services were also discussed. Examples of effective use of climate information in agriculture climate services were presented, and the challenges and characteristics of climate services for agriculture were discussed as useful lessons that the aquaculture sector can learn from.

Session: Timescales of information

Facilitator: Dr. Colin Kelley, associate research scientist, IRI, Columbia University

To use climate information effectively, it is important to understand different aspects of weather and climate information, such as timescales, sources of uncertainty in forecasting, types of forecasts and forecasting skill.

To explore these concepts, Dr. Colin Kelley held a session on weather and climate forecasts and data products, beginning with the concept of timescales: weather (hours to 10 days), sub-seasonal (2 weeks to 3 months), seasonal (3 months to 1 year), interannual to decadal (1 year to 10 years) and multidecadal (10 years to 1 century). Climate data is collected from different sources, such as surface stations, upper air stations, weather buoys (which collect weather and ocean data within the world's oceans), weather ships, aircraft, polar orbiting and geostationary satellites and weather radar. Data is then sent to meteorological services, which process the raw data.

There are two main types of observations: (1) station data, which is more accurate but often has uneven spatial coverage, and (2) gridded data, which is often less accurate but has global coverage. Gridded remotely sensed data quality depends on clouds. As such, gridded datasets should always be compared with local observation data. Merging these two types of data offers the best of both local and gridded data. Forecasting weather, because it is necessary to know both the current state (initial conditions) and how it will evolve. In the atmosphere, even small errors in measurement can grow quickly, which may cause the consequent forecast to deviate by a large margin.

There are two types of forecasts: (1) deterministic forecasts, which do not provide any information about the associated uncertainty, and (2) probabilistic forecasts, which reveal the probability of one or more discrete events. Current weather works as a source of predictability for days, sea-surface temperatures for months, sub-surface temperatures for years and atmospheric composition for decades. We measure whether a forecast is good or not using forecasting skill. There is a tradeoff between lead time and skill, which is important to take into account in decision-making: the shorter the lead time, the higher the skill is, and vice versa. Weather forecasts beyond 10 days are less accurate, and the accuracy of seasonal forecasts greatly varies across regions around the world.

Besides weather and seasonal forecasts, research is focusing on improving sub-seasonal forecasts, which are useful for 1–2 weeks and sometimes 3–4 weeks. Because of poor quality data, however, weather forecasts in the Southern Hemisphere are less accurate than those for the Northern Hemisphere. Generally, forecasts work better in the mid-latitudes than in the tropics. Weather predictions for temperature vary over different countries, ranging from weak to excellent. Bangladesh has moderate accuracy in 3-day weather forecasts for hot spells and weak to moderate seasonal accuracy for rainfall. The BMD is working with the IRI under the ACToday project and other partners to improve sub-seasonal and seasonal forecasting in Bangladesh. For decision-making processes, understanding the uncertainty and the limitations of forecasts is critical. Sometimes, understanding climate risks in the recent past provides more valuable information than less accurate forecasts.

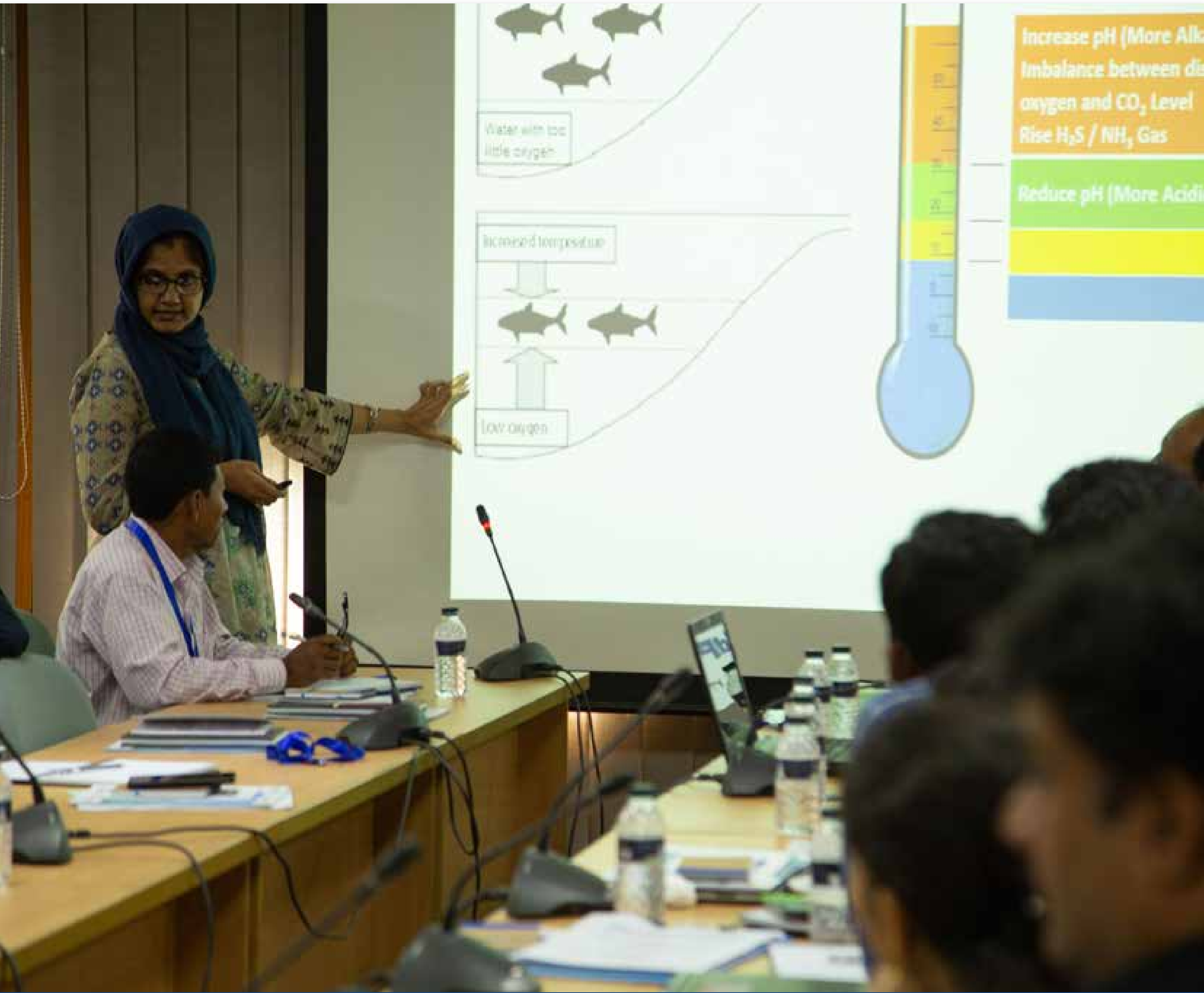
Session: Climate impacts on aquaculture and food security

Facilitator: Dr. Peerzadi Rumana Hossain, climate change research scientist, WorldFish

To identify and tailor the right climate variables to develop climate services for aquaculture, understanding how exactly climate variability does impact fish and aquaculture activities is very important. Dr. Rumana, climate change research scientist at WorldFish, talked about climate variability and climate change along with impacts of climate variability on aquaculture activities. Climate variability directly affects fish physiological activities like breeding, spawning and growth and also indirectly affects fish affecting water quality and quantity. Water temperature between 24ºC and 32ºC is more likely the optimum level for fish. Similarly there are different optimum levels for other water quality parameters, such as water depth, pH, ammonia (NH_3), hydrogen sulfide (H_2S) and dissolved oxygen (DO). Heavy rainfall reduces DO level, pH level and suddenly imbalances water temperature. These changes in water quality lead to less feed intake and physiological stress resulting in fish mortality. Conversely, due to low rainfall and/or dry spells (~less than 1 mm rainfall per day), available surface water decreases and water temperature increases. This leads to a number of problems, including delayed stocking, less production and disease outbreak. Similarly, during high temperature periods, disease outbreak, reduced water quality and lower feed intake in addition to hampered breeding and spawning are more likely to happen. Lower temperatures or cold spells also lead to lower feed intake and disease outbreak.

To reduce the risks of these varied impacts of climate variability, different management decisions can be modified. For instance, fish farmers can adjust feed management during periods of high temperature and heavy rainfall, can apply input materials like aerator and pumps or restrict aqua medicines to maintain water quality during high and low temperatures to avoid disease outbreak and heighten the banks of the pond or take protective measures, such as using nets to avoid loss of feed stock and so on.

To anchor the discussion about the personal experience of participants, participants took part in a group exercise to identify the problems farmers faced in their farming practices as a result of climate variability during 2018. They also identified what measures they would take to cope with the problem if they were provided with climate information (temperature and rainfall variability) in advance. The results are provided in Table 7 of the Annex.



Dr. Rumana, climate change research scientist at WorldFish, leads a session on climate variability, aquaculture and food security.

Session: Agro-meteorological and early warning tools

Facilitator: Dr. T. S Amjath Babu, agricultural economist, CIMMYT, and Dr. P Sujatha, ICRISAT

Equipped with the basic concepts of climate science, weather and climate forecasts, and the impacts of climate on aquaculture from previous sessions, participants were given examples of different agro-meteorological and early warning tools used in agriculture. They discussed the successes and challenges of climate services for agriculture, the characteristics of effective climate services and common problems faced in climate services for agriculture. Dr. Amjath Babu and Dr. Sujatha from ICRISAT highlighted their activities on climate service and explained in the following how they could be useful for Bangladesh:

- crop advisories using short-term forecasts, disease modeling and early warning systems
- crop damage warning using short-term forecasts
- crop advisories using seasonal forecasts and monsoon onset information
- common problems in agricultural climate service design
- delivery and conditions on effective climate information use.

Showing the temperature and annual rainfall, it was revealed how receiving information beforehand helps in taking different decisions regarding planting, irrigation, fertilizing and harvesting. Based on this data, crop advisories on rainfall and planting date could be provided, while disease forecasting and early warning systems could save harvest-ready crops from adverse weather.

Dr. Amjath Babu showed an example of a climate service that provided a crop advisory using short-term forecasting. The CSRD is one such initiative, which works through applied science partnerships. The CSRD provides demand-driven climate services, such as climate-informed irrigation scheduling, improved weather and long-range forecasting, disease forecasting and early warning systems, and support to help farmers make better decisions. There is also a web interface where farmers can get relevant advisories to act upon for specific crops, in addition to specific climate stresses by location (Bangladesh) and crop season. Disease modeling and early warning systems were also developed under the CSRD in collaboration with the University of Passo Fundo in Brazil. Under this initiative, a warning system was developed for wheat blast, which appeared in South Asia in 2016 and affected wheat - the second-most widely grown and consumed cereal crop in Bangladesh. BMD data drives the blast warning system and the Bangladesh Agricultural Research Institute (BARI) and the DAE validates it. Right now, the blast warning system is under evaluation and refinement and is positioned for partner deployment. Using a web map, browsers can show the blast risk.

Dr. Amjath Babu then gave another example of agricultural climate service issuing a crop damage warning using short-term forecasting. Right now, in Patuakhali, mung bean advisories are provided using an IVR system, where different voice messages (either male or female, as chosen by the user) are sent to users. Farmers listen to these advisories. Many act on this climate service, which could save up to USD 100 per farmer. This method of climate service delivery can also be adapted for aquaculture.

Dr. Sujatha Peethani then shared another agricultural climate service developed by ICRISAT. ISAT uses the El Niño–Southern Oscillation (ENSO), which is a coupled ocean-atmosphere cycle, in a decision tree system. For delivering pre-monsoon advisories based on seasonal climate forecasts, pre-monsoon planning meetings are organized and SMS advisories are sent to farmers' mobile phones, if needed. These messages can also be edited before being sent. It is possible to replicate this system design of agriculture climate service delivery for aquaculture after accounting for different parameters and thresholds sensitive for the sector.

The following are some of the problems in climate service design and delivery:

- Climatologists or agronomists designed these services without economists.
- It is assumed that the information provided is beneficial.
- Users are not being sensitized on the use of information.
- Users are unaware of the reliability of the information considering timescale.
- The focus is on technology or advisories without addressing institutions.
- Pilot initiatives ignore the cost of service delivery or sustainability of the service.

Different institutions and both the public and private sectors also play an important role in translating climate research into tools for action. To ensure effective climate services, the following factors need to be taken into account: seed markets, irrigation systems, labor market innovations, mechanization, postharvest storage, marketing facilities and insurance.

Session: Communication processes to deliver and support rural climate service

Facilitator: Dr. James Hansen, research scientist, IRI, Columbia University

Up to this point, the training dialogue covered the first two pillars of climate services: generation and translation. Dr. James Hansen introduce the third pillar: transfer.

Transfer refers to communicating climate information to the intended user group. Through presentation and hands-on exercises, the session threw light on different communication functions needed and the available channels to support them. It also aimed at understanding how communication needs differ for information at weather versus climate time-scales, and how group participatory communication processes support understanding and use of complex probabilistic climate information. Climate service requires a number of communication functions to exist, such as climate literacy, adapting management to the local climate, forecast-based seasonal management planning, weather monitoring and forecasts, and customized information, advisories and decision support.

There are four main communication modalities in Bangladesh: media, basic mobile phones, internet (including smartphones) and group processes. Participants identified specific communication channels in each of these categories (Figure 1).

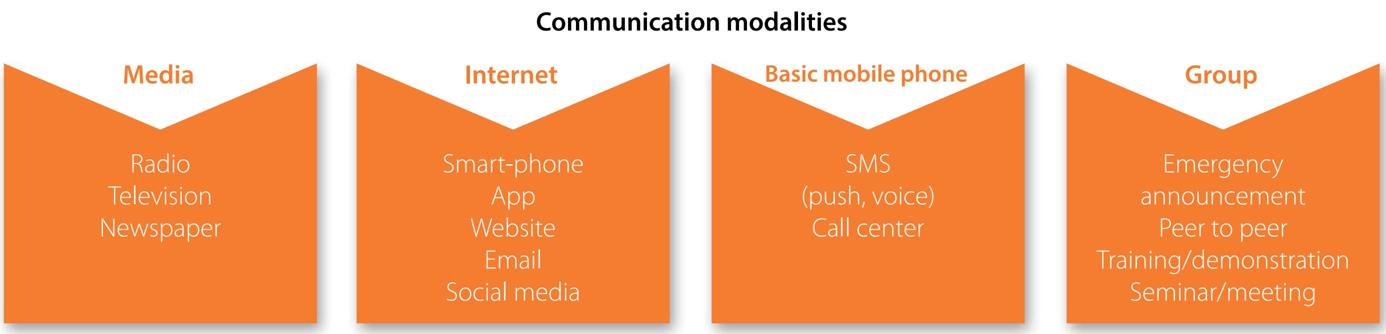


Figure 1. Communication modalities.

In another exercise, each group was asked to score communication modalities for different climate functions according to their usefulness. Table 3 shows which communication modalities are best suited for different communication functions. (For more details, see Table 8 in the Annex.) This information could help in the co-development of aquaculture climate services by considering these different mediums accordingly.

It is important to note that this exercise, like all others, is representative of the participants involved in the training. Considering the large majority of male participants, and despite questions aiming at considering women's perceptions and preferences, the preferred modalities may not adequately reflect all population groups. Complementary efforts are needed for a more comprehensive and socially inclusive understanding of preferred communication modalities.

Functions	Preferred communication modalities
Awareness	Group meeting, broadcast media
Climate literacy	Group meeting, broadcast media
Adapting to current local climate (historical)	Group meeting
Forecast-based seasonal planning	Group meeting, broadcast media
Weather forecasts, day-to-day operations	Broadcast media
Extreme weather alerts	Broadcast media
Customized information advisories	Group meeting, broadcast media, basic mobile phone
User feedback	Group meeting and internet
Support for extension, other intermediaries	Group meeting and internet

Table 3. Communication modalities.

The goal is not to identify the best communication channel but rather to combine channels strategically. Although the timing and content of climate information fit mobile phones and broadcast media, complex and probabilistic climate information requires group participatory processes along with training and support.

Interestingly, the way we absorb and understand weather and climate information is linked to the two decision processing systems of our brains. Experiential processing refers to gaining information from repeated experience in which we match different climate information against our expectation about weather in a particular area as taken from experience. Experiential processing has a strong influence on decision-making, because our past experiences are often associated with strong positive or negative emotions. Analytical processing relates to processing statistical information, but it is prone to widespread biases and decision errors. Well-designed participatory communication processes can help users combine analytical and experiential processing, by connecting statistical climate information to personal experience. Group participatory communication also provides an opportunity for training and social learning for building users' capacity to understand new types of information. Participatory climate communication processes involve discussing whether climate information presented in a graph or a table is consistent with participants' collective memory of recent years. Discussing hazards, opportunities, decision options, and games that simulate decision-making also help participants relate climate information to their experience. To enable participatory communication at scale, an effective intermediary institutions, such as an agricultural or aquaculture extension service, must connect the government with end-users in a cordial manner. It also includes training programs, training of trainers, well-structured processes and good training materials supported by video materials, and effective climate information products for intermediaries and end-users, with ready access to relevant climate information products. PICSA is one such approach developed by the University of Reading in collaboration with CCAFS, which is scaling out a similar approach to support smallholder farmers in several countries.

Session: Climate services for agriculture

Facilitator: Dr. Tufa Dinku and Dr. James Hansen, research scientists, IRI, Columbia University

This presentation gave the basic ideas behind climate data versus climate information, climate services and climate services for agriculture. It started by clarifying the difference between the concepts of data and information. Data is a collection of values or measurements of the variable of interest, whereas information is analyzed or interpreted data with a specific goal.

There are three types of climate data: station, gridded and model. Likewise, there are three types of climate information: historical information, real time/monitoring/early warning systems and forecasts/projections. According to the Global Framework for Climate Services (GFCS), climate service is a decision aid derived from climate information for improving decision-making.

According to the Climate Services Partnership, climate services also involve the production, translation, transfer and use of climate knowledge and information for climate-informed decision-making and climate-smart policy and planning. The different actors involved in the aquaculture value chain will be playing different roles across the four pillars (generate, translate, transfer and use) to develop sustainable climate services, and it is important to identify the roles, mandates, needs and complementarity of stakeholders to ensure a functional flow of information. The objective of the GFCS is to develop and apply science-based climate information and services. Similarly, the National Framework for Climate Services is an institutional mechanism for improving the co-production, tailoring, delivery and use of climate predictions and services. In designing climate services, all timescales are relevant to agriculture, and information needed depends on decisions. With increasing lead time, information becomes more uncertain and complex, and farmers need more help to understand and use it.

There are five challenges for climate services to impact agriculture at scale:

1. **Gaps in the capacity to access, understand and act on information**
   Group participatory communication processes can help address this challenge. They combine communication and capacity building and use local historic and forecast information through graphs and participatory planning activities.

2. **Agricultural extension capacity to deliver services at scale**
   Scaling up participatory communication can tackle this challenge by combining participatory broadcast media and ICT channels. In Rwanda, for example, 1800 agricultural extension personnel and other intermediaries were trained. In turn, these then trained and facilitated 130,000 smallholder farmers. There were also radio listener groups that combined the reach of media with the depth of group interaction.

3. **Capacity of national meteorological services (NMSs) to routinely provide tailored local information**

4. **Gaps in historical data**
   These two challenges can be addressed by supporting the NMSs to provide useful local climate information. One such support is the ENACTS approach, which provides reliable and readily accessible climate data at high resolution. It is necessary also to translate climate information into decision support by establishing agro-climatic forecasts and advisories using seasonal climate prediction models and crop simulation models.

5. **Governance processes to bring the voice of farmers into services**
   Bringing farmers into co-production can address this challenge through institutional arrangements for co-production and repetitive processes to collect, combine and prioritize farmer feedback. For that to happen, institutions must represent farmers' voices and NMSs must prepare to respond to farmers' needs.

Exercise: Daily takeaways and discussion

Facilitator: Ms. Mélody Braun, IRI, Columbia University

In the concluding session, Ms. Braun and Ms. Ashley Curtis used an activity where participants were asked to provide their opinion on the biggest challenges to the development of climate services in Bangladesh across the four pillars.

Ashley Curtis (IRI) facilitates an activity on challenges for climate services in Bangladesh.

Pillars	Institution	Activity	Challenges
1st pillar (generation)	BMD	Data generation and data archive, data management and programming	Data analysis, missing data, data quality, lack of service system for data storage and time frame
	DOF	Check quality of fish products	Data to assist quality check of fish and fish products
	WorldFish	Fish spawning, breeding and development	Seasonal climate information that focuses on aquaculture
	Coast Trust	Transferring technology, training, meetings, school sessions	Lack of seasonal climate data on aquaculture
	WorldFish	Training, meetings, seminars	Unaware of the existence or use of aquaculture apps
2nd pillar (translation)	Agro-met Division, BMD	Data generation, data management	Forecast generation for fish farmers and agro-met data storage
	Mantaf Agro Ltd, fish farmers	Fish breeding, production	Information not tailored for the aquaculture sector
3rd pillar (transfer)	Bangladesh Institute of Maritime Research and Development	Research, capacity development, policy advocacy	Absence of proper transfer modalities of climate information to users
	Fish farmers	Fish production, fruit gardening	Lack of knowledge of the focal institutions that provide climate information
	Fish manager, DOF	Produce fry, fingerlings and fish	Fish farmers do not get daily weather information to make sound decisions
	BFRI	Shrimp/prawn breeding	Current transfer modalities often fail to reach end-users
4th pillar (use)	Pranti Aquaculture Ltd	Fish breeding, production	Fish production falls because of sudden temperature fluctuations and infection breakout from a lack of rainfall
	Assistant director, DOF	Deals with fish seed farms, innovation with extension	Lack of awareness among farmers regarding the use of climate information in fish farming
	Glorious fisheries, Savar, Dhaka	Pond preparedness, fingerlings, supply of fish feed, fish health, harvest, sales	Water scarcity is a big problem and farmers often cannot apply the information

Table 4. Challenges with the four pillars of climate services.

Discussion

Participants highlighted the need for time, location and season-specific data to make sound decisions. They also identified the need to translate the information for field-level farmers and the need for a proper transfer channel of the translated information. Farmers often do not know where and who to go to collect the information. Bangladesh's geographical location and lack of institutional collaboration are the major reasons behind inadequate and unsuitable data generation. Appointing a focal point in different departments was recommended to help send information to farmers. In total, there are many challenges along different levels of the value chain to make it an efficient and functioning service.

Day 3: October 29, 2019

The presentations and exercises designed for this day aimed at identifying and addressing hurdles to implementing climate services, and exploring different tools available to support climate services for aquaculture and agriculture.

Exercise: Stakeholder mapping for climate services in aquaculture

Facilitators: Ms. Mélody Braun and Ms. Ashley Curtis, IRI, Columbia University

In the first session, participants were asked to identify the different aquaculture stakeholders at various levels of the value chain and then map out how they relate to and communicate with each other. Stakeholders were divided based on their role along the four pillars of climate services, and their relationships were identified as unidirectional or bidirectional based on the flow of information. The stakeholders who were relevant but thought to be not included have been flagged with a red box, as shown in Figure 2.

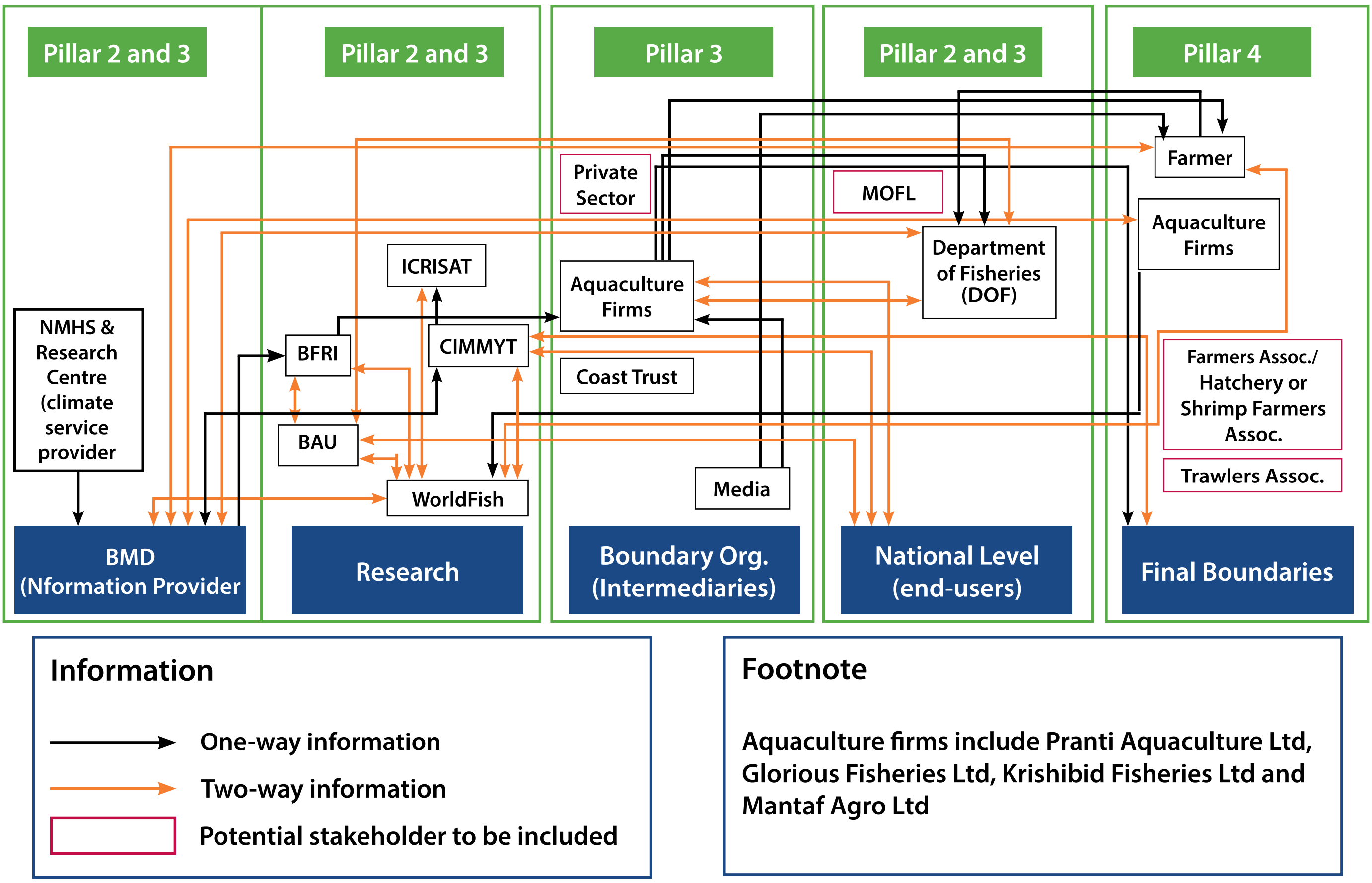


Figure 2. Stakeholder mapping.

Session: Current opportunities for climate services for aquaculture

This session featured three apps for aquaculture and agriculture. They were developed by the BMD, ACI (WorldFish app) and CIMMYT. Presenters demonstrated the functionalities of their respective apps and how they provide climate information and advisories, after which a discussion followed on different aspects of these different tools.

BMD App

The BMD has developed an aquaculture app that can be accessed from the website (www.bmd.gov.bd/p/Aquaculture-App/) and downloaded onto mobile phones. The objective of the app is to help fish farmers with BMD information and guidelines. As most farmers use mobile phones, the BMD can easily send its forecasts directly to them. The app can also reach farmers in districts (zilla) and subdistricts (upazilla).

Participants provided recommendations for the app, such as requests for an emergency number for queries. They also mentioned that the BMD website is not user friendly. It requires high speed internet, which is not always available at the local level, and the interpretation of data is a complicated task. As such, experts and scientists in climate change and aquaculture fields must work together for sector-specific translations.

CIMMYT Tools

The presentation on CIMMYT tools displayed how it has brought benefits to agriculture and the potential to replicate it in the aquaculture sector. Also shown was the mechanism of ISAT, an advisory tool that builds on decision trees for sending seasonal crop advisories and short-term crop advisories to farmers on their phones. Using data analytics, key farm decisions and drivers are identified. The decision trees are developed with appropriate triggers or thresholds for several crops. Right now, ISAT is expanding to more areas.

Training participants identify opportunities for climate services in aquaculture during a group exercise.

The following are aquaculture practice examples relevant to climate services:

- freshwater pumping to cool down the temperature of the ponds
- use of bore well water in low rainfall conditions
- early harvesting in case of drought
- pumping out water because of drought
- identifying thresholds and developing decision trees for each identified action.

Decision trees are behind short-term forecast-based advisories. One such example is decision trees for mungbeans and lentils. In the PICSA project, the decision-making process are divided into four stages.

1. Long before the season: Here historical climate data along with crop, livestock and livelihood options are considered, and planning is done in a participatory way.
2. Just before the season: Plan is revised.
3. During the season: Short-term forecasts and warnings as well as advisories are provided.
4. Shortly after the season: Weather, production, forecasts and process are reviewed.

The following are some of the factors for consideration in deriving a decision tree for aquaculture activities:

- identifying the species-specific decision points
- determining the required lead time
- identifying species-specific rainfall and temperature thresholds
- detailing key interventions
- detailing the decision trees, depending on short-term and seasonal forecasts
- using a separate exercise for hatcheries.

Rupali App by WorldFish

The ACI, one of the leading agro service providers in Bangladesh, developed the Rupali App in collaboration with WorldFish. The ACI works with around 8 million farmers yearly, the majority of whom work in the aquaculture sector. The rationale behind developing this app was to provide post-farming services, instant information and also to spread the reach to the native corners of Bangladesh. Currently, 500 lead farmers use the app, and each transfers the information to another 14 farmers. The app is available on smartphones and features broadcast messages and automated voice calls. Using sensors, the ACI is planning to measure different parameters of a pond.

Session: Overview of ENACTS

Facilitator: Dr. Md. Abdul Mannan, meteorologist, BMD

BMD weather stations provide data at specific locations where they are installed. The availability of data for a specific area depends on its distance to the closest weather station. To address this and to provide additional functionality (custom tailored data, maps, forecasts) to users from different interest groups (researchers, practitioners, agriculture and now aquaculture), the BMD launched ENACTS on June 27, 2019, with the help of the IRI and ACToday, as part of the BACS initiative. Dr. Mannan explained the functions of ENACTS data and Maproom, the associated tool. Maproom is a web interface used to generate maps from the data. The Data Library (DL) is used to access and download ENACTS data. ENACTS provides climate information for making decisions by improving the availability, access and use of climate information. Bangladesh is the first country in Asia to implement ENACTS, which harnesses the best available local and global climate data for informing decision-making in climate-sensitive sectors, such as agriculture and aquaculture. The data provides more spatial coverage than the weather data observed from 47 weather stations, because it combines the BMD's station data with proxies such as satellite and re-analysis data. For rainfall, 35 years of satellite rainfall data is available, and for temperature 50 years of re-analysis data is available. ENACTS data now has a spatial resolution of 5 km. Using the DL, users can install this data for different times and locations according to their needs.

Inside Maproom, there are two main sections: (1) Climate and (2) Agriculture and Climate. (In the near future, an Aquaculture and Climate section will also be added.) Under Climate, there are three main sections or tabs: (1) Climate Analysis for past data, (2) Climate Monitoring for present data, and (3) Climate Forecast for future data. NextGen forecasts are now being tested experimentally and will be added under Climate Forecast. BMD scientists have already received training on the DL, Maproom, CDT software for ENACTS data generation, network troubleshooting and Ingrid programming language for working with the data library. Maproom products will be updated based on user requirements and partly from the training dialogue.

Demonstration of ENACTS Maproom

Facilitator: Dr. James Hansen, research scientist, IRI, Columbia University

To reinforce what had been taught so far, participants were introduced to the basic concepts needed to use seasonal forecasts. Dr. Hansen led a session called Understanding and Using the Flexible Forecast Maproom. Through hands-on exercises he explained the concepts of probability and how to use it. Using a case study from Rwanda, he explained some of the gaps between the tercile convention that many national meteorological services use, and farmer needs. Providing full forecast probability distribution can overcome the arbitrary categories and ambiguous uncertainty in tercile-based forecasts. Using a flexible forecast format that provides full probability distribution, along with the probability distribution from historical data, can remove this confusion to a great extent. Using a time series graph, Dr. Hansen showed how to calculate the probability of a particular climatic event (above or below some threshold). He then showed how to transition from a time series to a probability graph. To reinforce this concept of probability and probability graphs, there was also a group activity to calculate probabilities from historical probability graphs. Using graphs, he also showed how a seasonal forecast can shift the probabilities that users can expect in the next agricultural season.

For successful use of seasonal forecasts, key concepts such as variability, frequency, uncertainty, probability and forecasting must be explained in the native language of farmers and fishers. Second, using time series graphs, users need to verify whether their group memory of agricultural seasons agree with it. They then need to understand their risks using time series. The next step is to introduce users to probability-of-exceedance graphs. Users then need to understand seasonal forecasts and how they influence risks that are important for making seasonal decisions. Finally, after weighing in on the forecasts, risks and their influence on seasonal decisions, users need to discuss and select a management option. Dr. Hansen noted that these steps have been used successfully with smallholder farmers in several locations.

Exercise: ENACTS Maproom

Facilitator: Dr. Tufa Dinku, IRI, Columbia University

In this session, Dr. Dinku conducted group work with the participants on the basics and use of Maproom. ENACTS already has an agricultural Maproom, and the development of an aquaculture Maproom could be further explored as an outcome of the training dialogue.

Maproom has two components: (1) climate components and (2) application components. The analysis tools of the climate part of the app have three components: (1) climate analysis, representing the past, (2) climate monitoring, representing the present, and (3) climate forecasts, representing the future.

Day 4: October 30, 2019

Day 4 focused on reinforcing what participants had learned through practical applications of Maproom. Participants were introduced to different functionalities and options available in the app and how to use and interpret them. They also took part in a hands-on exercise where they completed a project work using Maproom that reinforced the basics ideas covered earlier.

Session: ENACTS Maproom hands-on training

Facilitators: Dr. Tufa Dinku, IRI, Columbia University and Dr. Md. Abdul Mannan, BMD

In the Maproom session, Dr. Dinku explained how to navigate and use the app and understand the terminology used in it. First, he explained the climate analysis section. The following are some of the highlights from the discussion:

- In **Monthly Analysis**, the data shows the monthly average of the minimum or maximum temperature or amount of rainfall. This helps to analyze the seasonal climate of a region.

- The **Daily Analysis** is more complicated, because it considers many parameters that have to be fixed beforehand. It helps to analyze how many rainy or dry days and dry or wet spells occur in an area according to the parameters set by the user.

- In **Seasonal Climate Analysis**, different seasonal characteristics can be calculated, and the significance of trends or other statistics can be measured using p-value. Calculating extreme temperature or rainfall analysis helps to understand threats and expectations related to seasonality.

Remarks

These introductory sessions on Maproom gave participants an overview of its potential to support decision-making. However, a full grasp of all its functionalities would require more time and follow-up training for participants to interpret and analyze them. Participants emphasized not having much exposure to statistical terms, so they suggested integrating some statistical explanations into Maproom to help them without leaving the webpage they are in.

Later on, Dr. Mannan explained the climate monitoring for current forecasts. He described how the analysis of certain scales of a map can help farmers understand various parameters, like moisture content or rainfall pattern. It can also help them predict rainfall and plan their harvests accordingly. In this way, it helps them formulate better and cost-effective decision-making.

Finally, Dr. Dinku showed the climate forecasting section for future forecasts. Forecasting has been done based on observed data. He explained the impact of El Niño and La Niña and the probable rainfall/temperature conditions in the future. He also explained probability of seasonal rainfall and temperature conditions on ENSO. Mr. Shammunul Islam translated the session into Bangla for the participants.

Participants were then divided into three groups and asked to work on some exercises that would require them to use the basic knowledge of probability, trends, etc., to solve problems. Participants were asked to present their group work using Maproom. The objective was to familiarize them with the app so that they could identify the information they need and formulate sound decisions for their working areas. The group members worked hard to answer all the questions given in the exercise and used Maproom to come up with answers. Facilitators also helped the participants with further questions and queries they had regarding the app. The exercise reinforced the basic concepts of probability and probability distribution, and how to use them for making climate-sensitive decisions.

Day 5: October 31, 2019

The last day of the training dialogue started with a presentation from three groups on the exercise completed using Maproom. Based on what they had learned from the first four days, participants identified needs and provided recommendations for climate services. They also shared how they planned to use this new knowledge and apply the tools they were introduced to.

Group work: Presentation on Maproom

Facilitator: Dr. Tufa Dinku and Ms. Mélody Braun, IRI, Columbia University

All three groups presented their work and explained how they answered all the questions. Each group was able to answer many of the problems in the exercise using what they had learned over the previous four days. Dr. Dinku addressed any confusion or unanswered questions.

Group work: Identifying needs and recommendations for aquaculture climate services

Facilitator: Dr. Peerzadi Rumana Hossain, climate change research scientist, WorldFish

Following these presentations, participants gave another presentation on identifying needs and recommendations for climate services for different stakeholders in the aquaculture sector.

BMD

Pillars: Generation, translation, transfer

Role: Climate forecasting, transfer

Things to do to better support climate services: Tailoring climate information and then sending to media; aquaculture specific forecasting; collaboration with the DOF, BFRI, universities and NGOs

Challenges/concerns: Lack of aquaculture experts; institutional barrier

Recommendations: Strong collaboration with the MOFL, DOF and BFRI; arrange training for end users.

DoF

Pillars: Translation, transfer

Role: Using climate information for aquaculture production

Things to do to better support climate services: Tailoring climate information for aquaculture services; collect information from the BMD and then disseminate to beneficiaries

Challenges/concerns: In-house capacity development

Recommendations: Collaboration with the BMD, BFRI and DAE; connecting lead farmer with small farmers; arrange training for end-users.

BFRI

Pillars: Translation, transfer, use

Role: Research, training and advice

Things to do to better support climate services: More need-based and intensive research; awareness building

Challenges/concerns: Capacity development for transfer of climate information

Recommendations: Introduce climate smart technology, introduce saline and drought tolerant species, and establish a dedicated team for climate services.

WorldFish, Coast Trust, BRAC Fisheries

Pillars: Translation, transfer, use

Role: Capacity building, generate advisory, communicate with farmers

Things to do to better support climate services: Tailoring climate information, trainings and advisories, group meetings

Challenges/concerns: Covering all agro-ecological zones of Bangladesh and collaboration with the BMD

Recommendations: Collaborate with the BMD, MoFL, NGOs and private sector.

Pranti Aquaculture Ltd.

Pillars: Translation, transfer, use

Role: Started building capacity

Things to do to better support climate services: Integrate climate into training; translate and disseminate into groups

Challenges/concerns: Collect information before dissemination and follow up with groups

Recommendations: Information from the BMD to the DoF and finally to them; follow-up training.

Farmers and entrepreneurs

Pillars: Use

Role: Aquaculture activities

Things to do to better support climate services: More intensive research

Challenges/concerns: Building awareness and better understanding

Recommendations: Train farmers at the community level.

Universities

Pillars: Translation, transfer, use

Role: Aquaculture research

Things to do to better support climate services: More intensive research

Challenges/concerns: Lack of research collaboration with the DOF, BFRI and other stakeholders

Recommendations: Carry out collaborative research.

NGOs

Pillars: Transfer

Role: Extension activities, awareness buildup

Things to do to better support climate services: More intensive research

Challenges/concerns: Lack of sustainability of the project outcome

Recommendations: Focus on sustainable outcome of the projects.

Figure 3. Needs and recommendations for aquaculture climate services.

Recommendations

- Create **capacity development** initiatives covering different segments of the value chain - from farmers to government officials, to ICT officials and extension officers - to implement the climate services.

- The ICT Division of the DOF should integrate climate services into their existing system and explore innovative mechanisms to expand the services up to the household level.

- **Include the DAE** in the training so that the DOF can benefit from the DAE's experience in delivering aquaculture services to fishers and fisheries.

- **Identify the intervening area** in the existing value chain system to inform the wider population about climate services.

- Create a **dedicated department** within a ministry or institution to promote climate services.

- **Increase collaboration between the universities** that focuses on climate change and fisheries. It is a common practice for experts in these two sectors to work in silo, but collaboration between academics from these two disciplines can complement their knowledge and skill. Some of the country's specialized universities with fisheries departments include the Bangladesh Agricultural University (BAU), Dhaka University, Rajshahi University, Khulna University, Chittagong University and the Patuakhali Science and Technology University. These universities also need to explore the opportunities to develop modules on climate services and integrate this topic into the curriculum.

- The BMD needs to make people aware of Maproom and arrange training for users of climate data.

Feedbacks from the participants.

Feedback

Facilitator: Ms. Mélody Braun, IRI, Columbia University

Table 5 provides a summary of the information gathered in the final session before the closing session. Participants expressed their opinions on what they liked about the training dialogue, suggestions for improvement and what they would do with the knowledge gained over the previous 5 days.

What did you like about the course?	Where can we improve?	What will you do next with what you learned?
• The BMD database is robust. • Participants gained knowledge on climate information for farmers. • Participants learned to translate climate information for better decision-making. • The content was very helpful. • Participants learned to explore BMD data and use it in making decisions. • The training was beneficial for the aquaculture sector in Bangladesh. • The trainers were extremely efficient in helping to understand the material. • Participants learned a lot about the weather and climate forecasting for making decisions. • Facilitators learned from the participants as well. • Maproom was one of the best parts of the training.	• Increase the amount of time for training. • Add regular follow-ups. • Develop an expert team in the DOF for improving knowledge on climate services. • Train aquaculture personnel, extension workers, researchers and trainers. Enhance knowledge among extension workers, because they are always in touch with farmers and trusted by them. • Have the DOF form a group to sit together regularly to increase knowledge exchange. • Request more training for experts at the DLS and DAE. • Seek opportunities to intervene into the current forecasting modules . • Arrange refresher training before the onset of climate events. • Conduct research on additional economic returns with the use of climatological data and show the benefits to farmers. • Provide online courses for the aquaculture sector. • Request to build a communication network to regularly update information. • Develop an online forum to share experiences and communication.	• Share knowledge with people in the community to help them make better decisions. • Begin implementing climate services at the local level. • As the climate of Bangladesh is favorable for the aquaculture sector, explore this area further. • Use BMD information and Maproom to help with research activities and breeding schedules to improve fisheries. • Use knowledge learned to help formulate better decisions in fisheries management. • Develop a course for a climate-related curriculum to conduct training for farmers. • Meet with the DOF's director general to incorporate climate services into the system. • Conduct awareness raising and education programs for farmers. • Plan for breeding and spawning according to climate information. • Prepare a brief report and develop a tool or map to reflect the impact of climate change on fisheries. • Help develop strategies for farmers.

Table 5. Course feedback.

Concluding remarks

In the concluding session, Ms. Braun said that, rather than a one-way exercise, the training was a dialogue that provided a platform for two-way knowledge. Climate services for aquaculture is a new sector, so there is a lot of knowledge to be exchanged among different actors along the value chain. The training helped to understand the needs of the aquaculture sector. It also helped with designing a decision-making flowchart (DMF), specific climate decisions and finally recommendations for promoting climate information. She expressed her interest in taking this further and said follow-ups would be held in the future. Further opportunities would also be sought to provide training, including training for trainers and both the DOF and BFRI, and also to explore how developing an app can bring benefits to farmers in accordance with climate information.

Dr. Dinku highlighted two things about Maproom. One is that Bangladesh requires aquaculture mapping on the ENACTS website and extensive training on Maproom for optimal use of climate information. This training provided a demonstration of Maproom only to make people aware of its existence. However, in future, opportunities will be sought to have more training for trainers and other relevant stakeholders of the fisheries sector.

Later on, Dr. Saleemul Huq, director at the ICCCAD, added his own concluding remarks. He briefly discussed the role of the ICCCAD in terms of research on climate change and capacity development activities. He also explained the difference between a workshop and a short course: a workshop would last 2–3 days and provide information and raise awareness, whereas a short course would run for 5 days to get acquainted with the needs of participants and the modalities needed to use the available information in their respective sectors. The last day of training would begin implementing the knowledge that participants learned during the training to help enhance the social capital of Bangladesh. He thanked the BMD for its continuous support and data availability. He also urged that future training be organized for trainers and other actors to help the sector guard against the negative impacts of climate change. He encouraged everyone to remain focused and use what they had learned to bring fruitful and innovative actions in the future.

On behalf of WorldFish, Dr. Rumana also thanked everyone for participating in the training. What most interested her was the vision of each participant to do something to help the aquaculture sector, which is a climate service unto itself. She also urged participants to work together with other stakeholders to bring climate services forward, and she hoped to develop a platform to share climate information.

Dr. Amjath Babu liked that the event was a dialogue rather than only training. He thanked the participants for making it a successful event. For him, the training revealed the need for developing more climate service products for aquaculture and showed the need to design more tools in the future. However, because the poor, who are highly exposed to climate risks, need climate services the most, the time is right to develop such services and go further with translation and transfer.

Ms. Curtis thanked everyone for joining the training and recommended that they focus on some of their respective decisions. She said that dedication would help to implement these decisions in real life and that others would follow accordingly.

Mr. Ahmed concluded the remarks by saying that big changes start from small ones and that BACS started with a vision for a qualitative change. This meant that gaining knowledge and sharing it with communities are important for adapting to climate changes. It is important to work for the people's benefit. He hoped that this initiative would go a long way and help many people. Finally, he thanked Dr. Huq for his time and interventions, as well as CIMMYT and other partners for working together. He said that the BMD had tried its best to facilitate everything and would try to engage more with different stakeholders in the future.

Certificate distribution ceremony

To wrap up the event, participants received certificates of completion for successfully completing the training dialogue. This was followed by a photo session with all the participants.

Dr. Huq, director of the ICCCAD, delivers the closing remarks at the training.

A participant receives a certificate for the training.

Conclusion and way forward

The event's focus on climate services for aquaculture was the first of its kind in Bangladesh. It highlighted the dire need for climate services in aquaculture because of the lack of use of climate information to anticipate climate shocks, despite the importance of the aquaculture sector for food security and nutrition in Bangladesh and the losses induced by climatic events. Although a strong focus on climate services for agriculture has allowed major progress in the field over the past several years, aquaculture has yet to bring climate information and climate services into its policies, practices and capacity building efforts.

The training dialogue was jointly organized by WorldFish, IRI, ICCCAD, BMD and CIMMYT as part of BACS and CaFFSA, funded by the CCAFS program, with support from the IRI-led ACToday, the first Columbia World Project, and from the CIMMYT-led CSRD project. It brought together users and providers of climate information to discuss climate-sensitive decisions along the aquaculture value chain. It also helped identify climate information needs along the four pillars of climate services to better anticipate losses from climate risks while building the capacity of participants on the basics of climate science and climate services.

Through the various activities of the week, participants identified threats and opportunities and provided recommendations for different stakeholders to enhance the development of climate services for aquaculture. Recommendations strongly suggested strengthening collaboration among different government organizations, such as the BMD, DOF, BFRI and DAE. It also emphasized the importance of capacity building of different stakeholders (such as aquaculture personnel, extension officers and researchers) as well as follow-up training. Training outcomes and recommendations will help inform upcoming activities of CaFFSA and ACToday. Participants identified the need for a separate Map Room to receive tailored CIS for aquaculture and fisheries and recognized that the BMD aquaculture app is very generic, recommending that it be further improved – for example, to provide more context-specific climate information. CaFFSA will build on this momentum, continuing to work with partners in Bangladesh to develop the Decision Support System for fisheries and aquaculture tailored to user-defined needs to provide practical recommendations. Consequently, follow-up activities will include (1) developing a decision tree by identifying the temperature thresholds for mostly cultured fish species and accordingly aquaculture advisories through CaFFSA, (2) exploring the feasibility of water temperature modeling through ACToday, while discussing capacity building needs with relevant departments, (3) develop the context specific decision support system for aquaculture through the combined effort of the CaFFSA partners. Participants are expected to explore and communicate how they can use what they learned from the training in their personal positions and respective organizations through the BACS alumni network.

Notes

1 Biswas JC, Maniruzzaman M, Haque MM, Hossain MB, Rahman MM, Naher UA, Ali MH, Kabir W. 2018. Extreme climate events and fish production in Bangladesh. Environment and Natural Resources Research 09:01. 10.5539/enrr.v9n1p1

2 Rashid S and Zhang X, eds. The making of a blue revolution in Bangladesh: Enablers, impacts, and the path ahead for aquaculture. Intl Food Policy Res Inst.

3 Goosen et al. 2018. Nationwide climate vulnerability assessment in Bangladesh. Bangladesh Ministry of Environment, Forest and Climate Change, Government of the People's Republic of Bangladesh, GIZ.

List of tables

Table 1. Summary of the decision-making flowchart activity. 8
Table 2. Timescale activity. 10
Table 3. Communication modalities. 17
Table 4. Challenges with the four pillars of climate services. 20
Table 5. Course feedback. 28
Table 6. Information extracted from DMFs. 34
Table 7. Effects of climate variability on aquaculture and preventative measures using climate information. 28
Table 8. Communication modalities exercise. 28
Table 9. List of participants. 28

List of figures

Figure 1. Communication modalities 16
Figure 2. Stakeholder mapping 21
Figure 3. Needs and recommendations for aquaculture climate services 26

Annex

Profession	Activity	Impact of climate	Precautions during high temperature	Trust on the forecast	Worst case if risk happens	Tolerance and tradeoffs	Needs
Owner of fish hatchery, Krishibid Fisheries Ltd.	Planning and overall operation of the fish hatchery	Decrease spawn production and growth; high mortality; loss in business turnover	Artificial showering (1 week); reservoir of surface water (1 month); water pump installation (3 months)	Not fully	Additional expenses for risk mitigation; loss of breeding and profit earning	Huge loss and worst situation occurs when there is a lack of preventive measures	Climate information required at household, upazilla and district levels; lead times of 1 week, 3 months and 1 year
Training and extension coordinator, Pranti Aquaculture Ltd.	Training and technical support to the fishers	Water crisis and growth hampered; fish mortality and disease breakout	Table-sized fish harvest and shadow water shelter (1 week); water source exploration (1 month); plantation on dike, late season stocking, etc. (3 months)	Trust it because it impacts fisheries	Early fish catch will hamper the full development of fish; profit loss	Farm income loss is the worst case scenario	Information required at local and district levels; lead time of 1 week
Laboratory analyst, DOF	Conduct laboratory analysis of fish	Load shedding during heavy rain or high temperature damages work	Fuel for generator (1 week); UPS check and maintenance work (1 month); rearrange generation connection for continuing support (3 months)	Yes	Not a problem as fuel can be used later	Instrument loss and reduced sensitivity of the tools	Information required at the household level; lead time of 1 week
Nutrition and aquaculture coordinator, Coast Trust	Transfer technologies; training and courtyard meetings; school sessions; seminars and workshops	Salinity intrusion; disease outbreak	Water shelter for fish (1 week); improve management (1 month); adopt short-cycle aquaculture techniques, dig deeper ponds and select high temperature tolerant species (3 months)	It helps farmers to make decisions beforehand	Damages fish stocks and development; loss of profit	Loss of production	Information required at least at the upazilla level; lead time of 1 week
Fisheries scientists, BFRI	Shrimp/prawn breeding and development of improved culture technique	Affects the health of shrimp	Prepare shades, feed and water pump (1 week); maintain water depth and quality and pond bottom environment (1 month); design stock plan and culture species (3 month)	It helps in designing hatchery operations	Extra expenses	Loss of production and lack of preparation would be the worst case scenario	Information required at the household level; lead time of 10–15 days

Profession	Activity	Impact of climate	Precautions during high temperature	Trust on the forecast	Worst case if risk happens	Tolerance and tradeoffs	Needs
Research assistant	Select breeding to produce improved strains; PIT tagging, sampling, breeding value assessment	Loss of breeding and schedule change is the worst case scenario	Ground water (1 week); pond depth (1 month); ensure backup brood (3 months)	It helps in fish spawning, shifting and stocking	Higher time consumption and breeding schedule change	Temperature fluctuation and heavy rainfall is the worst case scenario	Information required at the national level; lead time is year-round
Manager, fish farm	Rearing major carp species; fish stocking, nursing, rearing	Death of fish species	Supply of groundwater (1 week); alternative water reservoir (1 month); water pump installation (3 months)	It helps to prepare for an alternative water supply	Extra expenses occur	Lack of preventive measures would be the worst case scenario	Information required at the household level; lead time of 1 week
Agriculturist and quality control officer, DOF	Laboratory analysis of fish and fish products	Sudden rain, prolonged rain and lightning	Prepare in advance to face load shedding	Weather forecasts from television and mobile apps are trustworthy	Instruments of laboratory could be damaged permanently	-	Lead time of 1 week
Monitoring and quality control, BRAC Fisheries	Produce fish seed	Temperature fluctuation and drought	Weather forecasts can help in making sound decisions	Trends of weather, local and online weather forecasts	Permanent damage to instruments	-	Requires weather forecast at regional basis; lead time of 15 days
Project coordinator, Coast Trust	Select breeding to produce improved strains; PIT tagging, sampling, breeding value assessment	Extreme hot weather; heavy rainfall; cyclones	Short-cycle species (1 week); dig deeper ponds (1 month); high temperature tolerant species (3 months); introductions to insurance systems, integrated farming systems, improved diseases surveillance systems	Forecasts from TV and radio help farmers to take preventive measures	Damages fish stocks and development; loss of profit	Loss of production	Information required at least at the upazilla level; lead time of 1 week
Senior scientific officer, BFRI	Shrimp/prawn breeding and development of improved culture technique	Sudden rain, prolonged rain; drought or cyclone	Reconsider stocking and harvesting pattern; feed management; arrangement of additional inputs	Currently using weather forecasts for rain	It can collapse the whole production system	Damages the fisheries sector	-

Profession	Activity	Impact of climate	Precautions during high temperature	Trust on the forecast	Worst case if risk happens	Tolerance and tradeoffs	Needs
Research officer, BIMRAD	Study on the impacts of climate change; preparedness to reduce the impacts; collect climate information; disseminate the information	Mass mortality of fish from diseases; impedes fish growth; enhances exposure to certain diseases; fish feed, medicine regime and cost structure	Stock of fish fry, medicine, water pump use and consult with fisheries officer (1 week); co-management by communities, netting arrangement around the pond, water pump arrangement (1 month); change culture pattern, seasonal pond, application of control management, dissemination of climate information, assess infrastructure, long run scenario planning and empowering local entities (3 months)	Through radio and TV and use in fisheries planning	Loss of fish stock	Fish diseases; loss of yield; mass mortality	Information required at the household and district levels lead time of 1 week or 1 month
Lecturer, BAU	Management of open water resources; water quality management support for aquaculture	Rising ocean temperature	Long-term preventive measure; species selection	Through web-based information	Massive fish death and pond dry out	-	-
Fish farmers	Produce fish and pond management	Lack of water creates virus problem; high temperature affects soil fertility; uncertainty of water	Take long preparatory decisions	-	Huge economic loss	-	-

Table 6. Information extracted from DMFs.

Climate variability	Fish Species	Problem	Month	Preventive measures
High temperature	Shrimp	• Loss of appetite	March–April	• Use cold water
	Shrimp	• Disease outbreaks • High mortality rate • Decreased dissolved oxygen • Damage to pond • Death of larvae	April–June May–September	• Use an irrigation system • Arrange shedding • Apply lime • Increase pond depth • Nesting • Stock fish food • Use canal system • Improve breeding • Add fertilizer
	Gulsha, pabda, shing	• Decreased dissolved oxygen • Increased ammonia and hydrogen sulfide	April–July	• Add groundwater
	Prawn, tilapia	• Disease outbreaks • Poor water quality	April–June	• Reschedule feed management • Increase water depth
	Catla, rohu, carp, silver, mrigel	• Disease outbreaks • Loss of appetite • Decreased dissolved oxygen • Fish mortality	April–June March–July May–July	• Add groundwater • Use aeration system • Increase water depth • Add aquatic vegetables

Climate variability	Fish Species	Problem	Month	Preventive measures
Heavy rainfall	Shrimp	• Fish go away • Damage to pond • Death of larvae • Decreased dissolved oxygen	June–July May–September	• Fishing net • Nesting • Stock fish food • Use canal system • Apply lime • Improve breeding • Add fertilizer
	Gulsha, golda fry	• Decreased dissolved oxygen • Lower pH • Loss of appetite	April–May	• Use paddle wheel • Water shade • Add chemicals
	Shada	• Fish escape from pond	June–July	• Nesting
	Prawn, tilapia	• Decreased dissolved oxygen • Lower pH • Lower salinity • Lower water temperature	June–August	• Use paddle wheel • Nesting • Reduce feed and use of lime
	Catla, rohu, carp, silver carp	• Decreased dissolved oxygen • Lower pH • Damaged dikes • Fingerling mortality and fish death	July–August	• Adjust feed management • Use aeration and zeolite
Cold spell	Shrimp	• Loss of appetite • Fish death	December–January	• Reduce the death toll with water from high and low tides
	Prawn, tilapia	• Decreased dissolved oxygen • Lower pH • Increased salinity • Disease outbreaks		• Adjust feed management • Improve greenhouse facility • Apply chemicals
	Koi, golda, shing, gulsha, catla, rohu, carp, silver carp	• Disease outbreaks • Loss of appetite • Decreased fish growth • Poor water quality • Lower pH • Breeding hampered	November–January	• Replace the water • Use aerator • Apply chemicals • Move fish to another pond • Add groundwater • Decrease feed

Climate variability	Fish Species	Problem	Month	Preventive measures
Dry spell	Shrimp	• Fish death	March–May	• Use irrigation system to increase water level
	Shrimp	• Growth of spawn and larvae is impacted • Decreased dissolved oxygen • Disease outbreaks		• Increase oxygen level • Improve water quality • Conduct polyculture • Remove toxins from water and pumping system
	Gulsha	• Disease outbreaks	April–September	• Add groundwater and aquatic vegetables
	Prawn, tilapia	• Rising water temperatures • Increased salinity, pH, ammonia levels	March–May	• Find an alternative source of water • Improve feed management and fish stock
	Silver, catla, carp	• Disease outbreaks • Rising water temperatures • Lower water depth and pH level	March–April March–August February–May	• Improve management system • Move fish to another pond • Increase water depth using underground water • Add lime and chemicals

Table 7. Effects of climate variability on aquaculture and preventative measures using climate information.

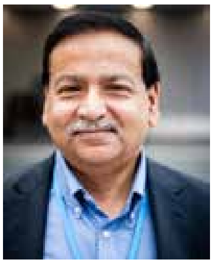
Functions	Group meeting	Broadcast media	Mobile phone	Internet/ smartphone
Awareness of services	Very useful	Very useful	Somewhat useful	Somewhat useful
Climate literacy	Very useful	Very useful	Not useful	Somewhat useful
Adapting to current local climate (historical)	Very useful	Somewhat useful	Not useful	Not useful
Forecast-based seasonal planning	Very useful	Very useful	Not useful	Somewhat useful
Weather forecasts day-to-day operations	Not useful	Very useful	Not useful & somewhat useful	Somewhat useful
Extreme weather alerts	Not useful	Very useful	Somewhat useful	Somewhat useful
Customized information advisories	Not useful & very useful	Very useful	Very useful	Somewhat useful
User feedback	Very useful	Not useful	Somewhat useful	Not useful & very useful
Support for extension, other intermediaries	Very useful	Not useful	Somewhat useful	Not useful & very useful

Table 8. Communication modalities exercise.

Bios of the resource persons and facilitators

Shamsuddin Ahmed is a meteorological scientist who works as a director in the BMD. He is the permanent representative of Bangladesh with the World Meteorological Organization (WMO), where he has served as part of the WMO/The Economic and Social Commission for Asia and the Pacific (ESCAP) panel on tropical cyclones for the Bay of Bengal and the Arabian Sea. He is the focal person for the The South Asian Association for Regional Cooperation (SAARC) STORM program and is the alternate GEO principal of the Bangladesh Government for Group on Earth Observations. He holds BSc and MSc degrees in physics from Chittagong University.

Md. Abdul Mannan is a meteorological scientist at the BMD, where he analyzes meteorological data and information and conducts short-, medium- and long-term weather forecasting and early warning management. He holds BSc and MSc degrees in physics from the University of Chittagong, Bangladesh. He also holds an MPhil in physics from the Bangladesh University of Engineering and Technology. He is a PhD fellow of Jahangirnagar University in Dhaka. He is the author of more than 30 technical papers and reports and is one of the focal persons of the BMD under the CSRD.



Saleemul Huq is the director of the ICCCAD. He serves as a senior fellow at the International Institute for Environment and Development in the United Kingdom and is also an academic visitor at the Huxley School of Environment at Imperial College in London, where he teaches a course on global environmental policies. He holds a BSc and a PhD in plant sciences from Imperial College in London and has published numerous articles in scientific and popular journals. He strives to grow the capacity of Bangladesh stakeholders while enabling people and international organizations to benefit from training in the country.

Mizan R. Khan holds a PhD in environmental policy and management from the University of Maryland's School of Public Policy. Currently, he wears two hats at the ICCCAD as its deputy director and also the program director of the LDC University Consortium on Climate Change. Prior to joining the ICCCAD, he was director of external affairs at North South University. He is a lead author for the The Intergovernmental Panel on Climate Change (IPCC) and has written a wide range of publications in peer-reviewed journals, along with three books on climate change politics published by Routledge and MIT Press.

Mélody Braun is a senior staff Associate at the IRI, with a multidisciplinary background in Earth science and development. Her work focuses on the design of systemic and transdisciplinary approaches to improve integration of climate information into decision-making processes and bridge the gap between decisionmakers, climate scientists and policymakers. She is the Bangladesh country lead for ACToday, which aims at developing climate services to contribute to ending hunger, achieving food security and improved nutrition, and promoting sustainable agriculture.

Tufa Dinku has 25 years of operational and research experience in the field of climate science and its applications. This includes 12 years of operational meteorology at the National Meteorology Agency of Ethiopia and 12 years of research and applications at the IRI. He received a BSc in physics from Addis Ababa University, a post-graduate diploma in meteorology from the Indian Institute of Tropical Meteorology, and MSc and PhD degrees in civil engineering/hydrometeorology from the University of Connecticut in the US. He is the ACToday country lead for Ethiopia, and he leads the ENACTS program, a unique multifaceted initiative designed to bring climate knowledge into national decision-making.

James Hansen is a senior research scientist at the IRI. His research focuses on finding practical, equitable and scalable solutions to the challenges of making smallholder livelihoods more resilient through climate services, climate-related insurance, and climate-informed food security management. From 2010 to 2019, he was part of the leadership team of the CGIAR research program on CCAFS where he led the Flagship on Climate Services and Safety Nets. Past research contributions included applications of agricultural systems methods to the use and valuation of climate information, farm economic risk and sustainability analysis, and land use under conflicting goals; communication of probabilistic climate information; spatial scaling in agro-ecosystem modeling; stochastic weather modeling; climate-based crop production forecasting; and intercrop ecology. He holds a PhD in agricultural and biological engineering from the University of Florida, and an MS in agronomy and soil science from the University of Hawaii.

Colin Kelley is an associate research scientist at the IRI. His research focuses on better characterizing and predicting extreme rainfall events with the context of existing vulnerability, across multiple timescales such as seasonal to decadal. His work thus far in Bangladesh has related to using climate models to improve seasonal forecasts of wet and dry spells during the monsoon season. He will also be working on an exploration of the feasibility of using climate information for aquaculture, and a literature review of flooding in Bangladesh. He holds a PhD in hydroclimate from Columbia University.

Jacquelyn Turner is a visual storyteller specialist at the IRI where she works on creative storytelling surrounding climate services and related research. Jackie received a dual degree in the environment and screen arts and cultures from the University of Michigan. She then spent four years in Los Angeles editing reality television and online media before going back to school to obtain her MSc in applied ecology. She graduated at the top of her class with distinction from Imperial College London in 2017. As a result, she has one foot in science and research and another in creative video and media and believes the two can actually work quite well together. She has produced short paper-to-video documentaries for Nature, as well as a feature-length documentary about the future of bananas (currently in post-production and set to premiere in late 2019).

Ashely Curtis joined the IRI in 2008 after completing her MA in environmental science and policy at Clark University. At the IRI, Curtis coordinates the Climate Program and contributes to research, education and outreach efforts. She is also actively involved with the IRI’s partnership with the International Federation of the Red Cross and Red Crescent Societies (IFRC). Staffing the IFRC Helpdesk at the IRI, she communicates and contextualizes climate and forecast information that humanitarian decisionmakers can then use to improve preparedness for weather and climate-related disasters.

Dr. T. S Amjath Babu works as an agricultural economist at CIMMYT in Dhaka. He does research in the fields of sustainable intensification, climate smart agriculture, climate service evaluation, climate policy, food security assessments, technology scaling, land use policy, water resource modeling, indicator based analysis and choice modeling in Asia, sub-Saharan Africa, Europe and at global scales. He has published about 40 international journal articles and holds a PhD and postdoc from Justus Liebig University in Germany.

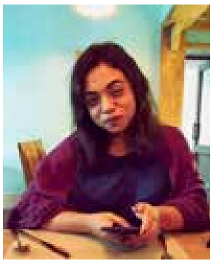
Dr. P Sujatha is a postdoctoral researcher in innovation systems for the drylands at ICRISAT in Hyderabad, India. She holds a PhD from the Andhra University in Meteorology and Oceanography and an M. Tech in atmospheric science. She worked as a research fellow at the National Remote Sensing Centre in the Indian Space Research Organization's department of space and has also worked as a professor in the department of physics at the Avanthi Institute of Engineering and Technology. She has published in national and international journals related to climate science.

Dr. Peerzadi Rumana Hossain is a climate change research scientist with WorldFish's Bangladesh and South Asia Office. She leads a project entitled Capacitating Farmers and Fishers to Manage Climate Risks in South Asia, which focuses on climate information and advisory services for fishers and farmers in Bangladesh and India. She holds a PhD in environmental sciences and an MSc in Forestry and has 10 years of professional experience in multidisciplinary research environments from the ecological, social and economic dimensions of ecosystem-based natural resource management. She loves to explore the ability of nature to improve the quality of life on earth.

Shammunul Islam is as in-country liaison for ACToday, where he coordinates different activities under the project in Bangladesh. Islam holds an MA in climate and society from Columbia University, a master's in development studies from the University of Dhaka and a BSc in statistics from the Shahjalal University of Science and Technology. He is an author of two books on GIS and remote sensing.

Tasfia Tasnim is a research associate at the ICCCAD. Her expertise is mainly centered around climate finance, climate services, livelihood resilience and natural resource management. On behalf of the ICCCAD, she has been assigned as the focal point for BACS in formulating the initiative and designing both the technical and financial aspects of the program. As a climate activist, Tasnim has considerable experience in facilitating sessions on gender dimensions, sociocultural aspects and the political dynamics of climate change in various workshops. Tasnim holds a bachelor's degree in urban and regional planning from the Bangladesh University of Engineering and Technology.

Farah Anzum works as a junior research associate at the ICCCAD while pursuing her bachelor's degree in environmental management from North South University in Bangladesh. She is interested in the fields of climate finance and accounting, climate adaptation, natural resource management and environmental economics. Previously, she worked with BRAC and the Capacity Development Unit of Access to Information Program with the Government of Bangladesh. She has also been involved in research projects with the National University of Singapore and Western Sydney University in Australia. She loves to travel and aspires to be a natural resource economist and contribute in the field of natural resource management.



Hafizur Rahman is a project officer at the ICCCAD. He has been involved with its Gobeshona Program, the European Climate Foundation project and the Policy Support Program, as well as in learning hub events with the Planning Commission in the Government of Bangladesh's Department of Environment and other related government officials. He holds a BSc in environmental science and an MSc on climate change and development from Independent University in Bangladesh.

Ashraful Haque is a system analyst who works as research officer at the ICCCAD. His research areas are climate-induced migration, shock-responsive social protection, capacity building, and transformation labs for action research. He holds an MSc in environmental sciences from Jahangirnagar University in Bangladesh, an MS in disaster management from BRAC University in Bangladesh and an MSc in sustainable development from Uppsala University in Sweden. He also holds an MPhil in system dynamics from the University of Bergen in Norway. His passion is to introduce sustainable practices within organizations and to incorporate outside the box thinking to solve dynamic problems using a systems approach.

Harun Or Rashid is working as a project officer for the CaFFSA project of WorldFish. He has been working with WorldFish in the CCAFS program since 2013. He has a wide range of field level work experience on climate resilience fisheries and aquaculture.

Mr. Shamim Murad is a general manager of digital strategy at ACI Agribusiness.

Faiyead Ahmedul Hye is a senior manager of digital strategy at ACI Agribusiness.

Sl No.	Name	Organization and Address	Contact	Email	Role in aquaculture value chain
1	Sahzada Hasibur Rahman	COAST Trust 75, Light House Road, Kolatoli, Cox's Bazar	01708120394	rahman.hasib.coast@gmail.com	NGO
2	Md. Al Emran	Department of Fisheries Management, Bangladesh Agricultural University, Mymensingh	01740063954	alemranfm@bau.edu.bd	Academics (research on aquaculture value chain analysis)
3	Md. Mizanur Rahman	Pranti Aquaculture Ltd, Khulna	01712012472	mizanmedha@yahoo.com	Aquaculture extension
4	Md. Ashraf Uddin Ahmed	Glorious Fisheries Savar, Dhaka	01989250082	auahmmed@yahoo.com	Technical consultation service on carp breeding and supply chain of carp seed
5	Md. Noor Khan	Mantaf Agro Limited, Trishal, Mymens-ingh	01750119614	Noor.khan.swapon@gmail.com	Fish biologist
6	MHM Mostafa Rahman	WorldFish, Dhaka	01711462255	MHM.Rahman@cgiar.org	BACS alumni
7	Harun Or Roshid	WorldFish, Jhalokathi	01749730905	H.Rashid@worldfishcenter.org	CCAF
8	Faridul Islam	BRAC Fisheries Enterprises, Kaderia Tower, Mohakhali, Dhaka	01704121086	faridul.i@brac.net	Deputy manager
9	Hosnay Nasrin	BIMRAD, Dhaka	01737173221	hn_nahin@yahoo.com	Research officer
10	HM Rakibul Islam	BFRI, Mymensing	01711450500	rakib.bfri@gmail.com	Senior scientific officer

Sl No.	Name	Organization and Address	Contact	Email	Role in aquaculture value chain
11	Md. Barkatul Alam	Quality Control Laboratory, DOF, Dhaka	01717410538	barkatbau@gmail.com	Fish inspection and quality control officer
12	Muhammad Abdullah Al Bari	Rajapur Polytechnic Institute, Jhalokathi	01611262248	bari2nd@gmail.com	Pangas aquaculture and sorjan crop production
13	Md. Sultan Mohmud	Carp GIP Team, Jashore	01717799512	M.Mohmud@cgiar.org	Carp GIP team member
14	Chittaranjan Hawlader	Morelganj, Bagerhat	01743562780	–	Gher farmer
15	Biprodas Shikder	Morelganj, Bagerhat	01721428887	–	Gher farmer
16	Md. Alamgir	Krishibid Fisheries Ltd. Bahadurpur, Trishal, Mymensingh	01700-729150	alamgirdhbd@gmail.com	Planning and overall operation of fish hatchery and grow-out farm, guide on marketing and total business
17	Md. Ishaque Ali	DOF	01722468093	Ishaq.alifm@gmail.com	Fish seed production and aquaculture extension
18	Bichitra Kumar Sarker	DOF	01711236163	bichitrakumarsarker@gmail.com	Aquaculture extension service as farm management

Table 9. List of participants.

WorldFish

About WorldFish

WorldFish is an international, not-for-profit research organization that works to reduce hunger and poverty by improving fisheries and aquaculture. It collaborates with numerous international, regional and national partners to deliver transformational impacts to millions of people who depend on fish for food, nutrition and income in the developing world. Headquartered in Penang, Malaysia and with regional offices across Africa, Asia and the Pacific, WorldFish is a member of CGIAR, the world's largest global partnership on agriculture research and innovation for a food secure future.

For more information, please visit www.worldfishcenter.org