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Aquaculture for Income and Nutrition: Final Report

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Contents

List of abbreviations

AIP	Agro Input Project
AIGA	alternative income generating activities
AIN	Aquaculture for Income and Nutrition
BFRF	Bangladesh Fisheries Research Forum
BFRI	Bangladesh Fisheries Research Institute
BFFEA	Bangladesh Frozen Foods Exporters Association
BSFF	Bangladesh Shrimp and Fish Foundation
CGIP	carp genetic improvement program
COP	chief of party
CF	community facilitator
CFC	community feed centers
DOF	Department of Fisheries
DCOP	deputy chief of party
DO2	Development Objective 2
DDI	Dietary Diversity Index
EMS	Early Mortality Syndrome
FCR	feed cost ratio
FTE	full time equivalent
FTF	Feed the Future
GIFT	Genetically Improved Farmed Tilapia
GIS	geographical information system
GPS	global positioning system
GAP	good aquaculture practice
HKI	Helen Keller International
IR	intermediate results
KU	Khulna University
KYP	Krishi Yellow Page
MIS	management information system
M&E	monitoring and evaluation
OSP	orange sweet potato
PIT	passive integrated transponder
PCR	polymerase chain reaction
PSF	private sector facilitator
SHAB	Shrimp Hatchery Association of Bangladesh
SIS	small indigenous species
SC	solidarity center
SWAAN	South West Aquaculture Advisory Network
SPF	specific pathogen free
SIP	super intensive pangas
TBN	tilapia breeding nucleus
TS	technical specialists
TSH	tilapia satellite hatchery
TOT	Training of Trainers
UNIDO	United Nations Industrial Development Organization
USAID	United States Agency for International Development
USG	United States government
WSSV	White Spot Syndrome Virus
ZOI	zone of influence

Executive summary

Bangladesh's Poverty Reduction Strategy Papers prominently feature aquaculture as a national policy priority. It is also a key element in the nation's Country Investment Plan and Sixth Five-Year Plan for agriculture, food security and nutrition. Diversification in higher value, nutritious agricultural production such as aquaculture is one of the areas selected for intervention identified in the Feed the Future (FTF) 2011–2015 Multi-Year Strategy. The United States Agency for International Development-Aquaculture for Income and Nutrition (USAID-AIN) project, implemented by WorldFish, emphasized technology development for improved fish strains, and capacity building in hatcheries and nurseries for wider dissemination and uptake among small- and medium-scale household and commercial producers. Improving nutritional benefits from household aquaculture investment was also an important activity of the project.

AIN directly contributed to the FTF goal of "sustainably reducing poverty and hunger by tackling their root causes and employing proven strategies for achieving large-scale and lasting impact." The main goal of the project was to increase income and nutrition through higher productivity of fish and shrimp in 18 of 20 FTF districts (85 *Upazilas*) in southwest Bangladesh (Dhaka, Khulna and Barisal divisions). Due to public demand, it was necessary to extend the project's activities, especially the sale of improved seed, somewhat beyond the FTF zone of influence (ZOI). Consequently, about 40%–50% of project impacts also occurred outside the FTF ZOI.

Specifically, AIN aimed to increase aquaculture production by developing hatcheries and nurseries, disseminating improved fish and shrimp seed, enhancing farm management skills of smallholder farmers, promoting new technologies to expand commercial aquaculture, developing backward and forward market linkages, supporting policy reform and building capacity of the public and private sectors, which resulted in increased productivity and revenue for farmers. Increased productivity at the household level was anticipated to result in more food for consumption and more produce for sale. This would contribute to a further adoption of these improved technologies and management practices and would result in an overall increase in income for rural households. The project contributed to achieving the FTF goal of sustainably reducing poverty and hunger through four objectives, each linked to one of four project components (Table 1).

No.	Components	Objectives
1	Disseminating quality fish and shrimp seed	Disseminating improved-quality lines of fish and shrimp seed
2	Improving household aquaculture	Improving the nutrition and income status of farm households
3	Strengthening commercial aquaculture	Increasing investment, employment and fish production through commercial aquaculture
4	Supporting institutions and policies	Supporting policy and regulatory reform and institutional capacity building for sustainable aquaculture growth

Table 1. Components and objectives of the AIN project.

Major achievements

The following are the major achievements of the AIN project between 2011 and 2016:

- The project supported an estimated 800,000 households, which included 55% of women, on improved aquaculture technologies for increasing production of both fish and shrimp.

- Fish consumption of the households receiving AIN support, advice and training was higher in 2016 (19.5 kg/capita) compared to that in non-AIN activity households (16.8 kg/capita). Technology, advice and material provided by the project, along with behavioral change communication interventions have made the project's beneficiaries better understand the importance of having a nutritionally balanced diet for mothers and small children, including the nutritional value of eating whole fish, especially small indigenous species (SIS), in combination with orange sweet potato (OSP).

- Provision of technology, equipment, training and capacity development among shrimp hatcheries in the project area has resulted in increased supply of postlarvae in the region that have been tested using the polymerase chain reaction (PCR) technique and found to be free of White Spot Syndrome Virus (WSSV). Although the supply of PCR-tested shrimp postlarvae is far from adequate, their use has shown significant increase in survival rates in ponds and increased production and income.

- Carp nursery and pond operators have improved productivity in their systems using wild broodstock supplied by the project. AIN-supported hatcheries disseminated better carp seed from wild broodstock to many hatcheries in the region. Providing wild broodstock with appropriate training and scientific advice has helped them improve their management practices and productivity.

- Many tilapia hatcheries in the FTF ZOI are now using genetically improved broodfish provided through the project-supported tilapia breeding nucleus (TBN) and disseminating monosex (male) tilapia seed to farmers in the area at a premium price.

- The Rohu Genetic Improvement Program has produced an improved first filial (F1) generation, and agreement has been made with the Department of Fisheries (DOF) for the continuation of the program as a joint WorldFish-DOF carp breeding venture, including possible further technical assistance from the Bangladesh Fisheries Research Institute (BFRI), with the view to produce an improved third filial (F3) generation by 2020.

- At the household level, training and access to improved seed provided by AIN-supported hatcheries have resulted in improved productivity in ponds for carp and SIS, and commercial ponds for carp, tilapia and shrimp.

- The polyculture production model for household ponds, which was introduced and promoted by AIN, consisting of large fish (carps), SIS and dike cropping of vegetables, has increased the availability of nutrient-rich foods that are easy to harvest in small portions for household consumption, with surplus sold to supplement household income.

- AIN training and advice on SIS have created opportunities for women to generate income from aquaculture by providing mola broodfish, gill nets to facilitate pond harvesting and training in pond management.

- The Training of Trainers (TOT) approach adopted by AIN has been effective in maximizing outreach. The trained partner staff, government fisheries officers and local service providers (nursery pond operators, seed traders and feed traders) continue to provide advice and training beyond the project's lifetime.

- Several IT interventions have been developed, field tested and implemented in support of better achieving AIN's goals and objectives. They include (a) expanding the private sector-based agriculture call center to include aquaculture, (b) developing a searchable online database in collaboration with two other USAID projects, which is now accessible through a Google Play App called "Krishi Yellow Page," (c) preliminary development of an e-traceability system for shrimp producers and service providers, which is currently being popularized, and (d) several IT solutions for improving the project's implementation efficiency.

- The emphasis placed on improving fish and shrimp seed quality, coupled with farmer training on improved management practices, resulted in a substantial increase in aquaculture production in the FTF ZOI. Except for shrimp production, all project targets have been reached or exceeded. (The reasons for lower shrimp production will be discussed later.)

Introduction

In Bangladesh, almost 80% of the population lives in rural areas and more than half are employed in agriculture. About one-third of the rural population can be considered poor, though the poverty rate may be higher.

Fish is the second-most important food commodity (after rice) in Bangladesh. It represents 60% of animal protein consumption and the main source of micronutrients. Fish is critical to the food security of the country. Per capita consumption is close to the global average, but in rural households it is lower than in urban households. The demand for fish is expected to grow due to population growth and increasing affluence.

Aquaculture and fisheries together contribute about 25% of agricultural GDP. Aquaculture production has grown rapidly in recent years in response to rising national demand for fish, but even with annual 5% growth in supply, demand is still projected to exceed supply by 450,000 metric tons in 2030.

Bangladesh is the fifth-largest aquaculture producer in the world. In 2014, production from aquaculture contributed 55% of the total fish production of 3.55 million metric tons, recently surpassing inland and marine capture fisheries. There are more than 3 million fish farmers in the country, most with a small household pond of about 600 m^2. About one-third of farmed fish in Bangladesh are produced by smallholders.

Although fish is widely eaten, "hidden hunger" (micronutrient deficiency), is widespread throughout Bangladesh, where more than 20 million people, particularly women and children, suffer from chronic deficiencies of vitamin A, iron and zinc. Micronutrient deficiencies cause irreversible damage in children, stunting growth and inhibiting brain development and cognition, which make it difficult to learn at school and perform at work later in life. Introducing micronutrient-rich vegetables and SIS of fish into the homesteads and diets of rural Bangladeshis would be an affordable strategy to help families increase their income, food security and micronutrient intake.

Background

The AIN project was a key intervention under Development Objective 2 (DO2) of USAID/Bangladesh's Country Development Cooperation Strategy. DO2, Food Security Improved, seeks to increase the volume of food produced by Bangladesh's small-scale farmers and the purchasing power of the food-insecure poor. DO2 is the flagship development objective for the FTF Strategy of the United States government (USG), and its objective in Bangladesh is to make "availability, access and utilization of domestically produced and nutritious foods increased." AIN directly contributes to the achievement of DO2 level intermediate results (IRs) 2.1: Sustainably increase aquaculture productivity and sub-IRs: Enabling environment for policy dialogue at the national and local level; strengthen select value chains. The project has been contracted with WorldFish under number EEM-G-00-04-00013-00.

Considering the importance of investing in research and development of aquaculture in Bangladesh, toward reducing poverty and improving food and nutrition security among rural communities, USAID awarded WorldFish a task order to implement the AIN project. With funding of $25 million, AIN was implemented between September 2011 and December 2016 by WorldFish.

Goals and objectives

The AIN project was formulated with the aim of achieving

- systemic improvements to the hatchery sector that will increase seed quality and ultimately raise the productivity and profitability of existing farming systems;
- better training for smallholder and marginalized female farmers on improved pond management and horticulture, combined with use of improved seed, to increase farm productivity, household incomes and household nutrition;
- higher seed quality, coupled with improved management practices and stronger linkages to value chain actors, to increase the profitability and output of commercial aquaculture and stimulate employment on farms and in associated value chains;

- support for regulatory reform in the hatchery and feed sectors to provide an enabling environment for the growth of commercial aquaculture enterprises.

The project aimed to intervene in the aquaculture sector among fish and shrimp value chain actors
- to build capacity for sourcing inputs, such as quality broodfish at the hatchery level;
- to improve hatchery management practices;
- to work with forward linkage steps in the value chain to create an enabling environment for nursery operators and farmers to obtain quality seed and facilitate improved farm management practices, which will lead them toward sustainable income and fulfill the nutritional needs of the target actors.

AIN implemented many activities between 2011 and 2016 to achieve the project's goals and objectives. (These activities are outlined in the preceding chapters.) AIN's activities were successful in stimulating aquaculture production in the FTF areas. The main goal of the project was to increase income and nutrition through higher production of fish and shrimp in 18 of 20 FTF ZOI districts in Barisal, Khulna and Dhaka divisions in southwest Bangladesh. This goal was addressed through four components that met four specific objectives (see Table 1).

Project area

AIN activities were conducted in 68 *Upazilas* in 18 selected districts. Project implementation was operationalized through four regional hub offices located in four cities: Khulna, Jessore, Barisal and Faridpur. The main office was in Khulna. The project area is shown in Figure 1.

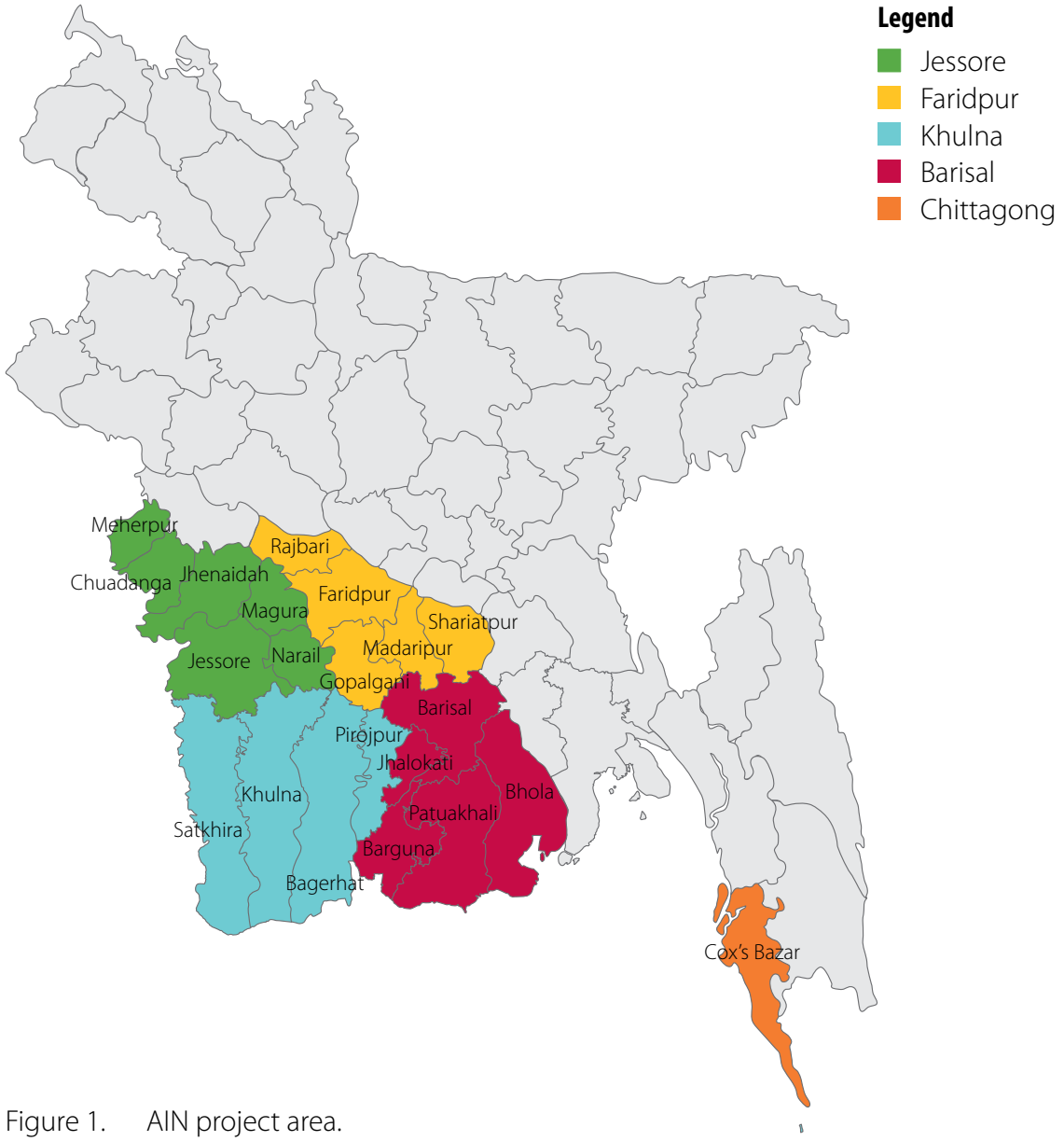

Figure 1. AIN project area.

Project management

Administration and coordination

The AIN project team was led by a chief of party (COP), who was assisted by a deputy chief of party (DCOP). The DCOP also functioned as the technical advisor for the project. The DCOP provided technical guidance to the four project managers, who coordinated the work of the four regional hub offices. The project managers oversaw the technical implementation of activities and capacity development, while full-time aquaculture specialists as technical specialists (TS) provided direct supervision to people who carried out field activities.

Farmer group training programs were implemented by extension facilitators (EF), who were supervised by field supervisors (FS). EFs and FSs were employed by NGOs or private sector partners and were supervised by their peers and the AIN TSs. Additional technical support was provided by WorldFish staff in Dhaka, who contributed part of their time to the project. WorldFish HQ scientists provided additional expertise on planning, research and monitoring, and evaluation. The project COP and DCOP were in regular communication with the USAID Economic Growth Office through an assigned contact person.

Project implementation partners

The project was implemented through strong partnerships with several state, non-governmental and academic agencies, as well as several other USAID FTF projects. These partners helped with efficient implementation and effective outreach. Some of the key partners and their contributions to the project are stated below.

Department of Fisheries of the Ministry of Fisheries and Livestock

AIN partnered with the DOF in various ways. AIN staff assisted in building capacity of DOF staff, especially in PCR testing of shrimp postlarvae in Cox's Bazar. AIN also cooperated with the DOF on the introduction of specific pathogen free (SPF) shrimp and with the implementation of the Feed Act and Rules 2010 and the Hatchery Act and Rules 2010. Similarly, DOF field staff worked closely with AIN field staff in training various target groups. DOF staff were intensively involved in training local business people to become private sector facilitators (PSF).

Bangladesh Fisheries Research Institute

The BFRI was an important source of national knowledge and capacity building for the research objectives of the project. It assisted in setting up both the live feed lab and crab breeding trial, and also helped in building capacity in PCR lab operation and management.

Khulna University

Khulna University (KU) collaborated in setting up PCR testing and also a bacteriology laboratory for disease diagnosis of aquatic animals, which was used mainly for shrimp postlarvae due to its close proximity to the main shrimp production zone. Cooperation with KU was formalized in January 2015 with the signing of a Memorandum of Understanding between WorldFish and the university for research collaboration. KU intends to continue the disease lab on a commercial basis, which will make it sustainable to operate in the future.

Bangladesh Fisheries Research Forum

Three PhD studies have been completed with support from the project and technical and institutional assistance from the BFRF. Linkage has also been made with the Jessore University of Science and Technology, Patuakhali Science and Technology University and KU to form a consulting group, together with the DOF and the BFRI and some private sector members, to provide technical assistance to the private sector.

NGOs

Farmer training at field level was done by EFs, who were supervised by FSs. These staff categories were employed through two NGOs, CODEC and SpeedTrust, in areas where these two NGOs were operational. Where no suitable NGO could be identified, the EF and FS were employed for training using private sector depots and hatcheries. At the peak of the farmer training, AIN employed over 350 EFs and 50 FSs.

AIN collaborated with the Bangladesh Frozen Foods Exporters Association (BFFEA) to improve the quality of shrimp for export. A MoA was signed to establish five collection centers linked to specific processing factories. However, with the sudden decline in the international shrimp price, the processors lost interest and this was not implemented. Instead, AIN set up one collection center in cooperation with the Bangladesh Shrimp and Fish Foundation (BSFF). Over the duration

of the project, the BSFF implemented various activities, mainly on the capacity building of DOF staff.

Helen Keller International (HKI) provided technical assistance with the preparation of the farmer training materials on nutrition awareness. HKI staff trained AIN staff on household nutrition.

Universities

Denmark Technical University and Flinders University (Adelaide) were contracted to provide nutrition analysis of about 100 different fish samples, mainly indigenous.

Other projects

The Strengthening Partnerships, Results and Innovations in Nutrition Globally (SPRING) project collaborated in nutrition interventions with the AIN project's beneficiaries. Agricultural Cooperative Development International and Volunteers in Overseas Cooperative Assistance (ACDI VOCA) exchanged training materials and provided TOT for the AIN staff. The Agro Input Project (AIP), implemented by Cultivating New Frontiers in Agriculture (CNFA), helped in developing a geographical information system (GIS) and collecting data on aquaculture input suppliers. AIN trained 180 input retailers of the Agro Input Retailors Network (AIRN) network developed by AIP on aquaculture management practices. The Improving Knowledge and Practice of Infant and Child Feeding and Maternal Nutrition (SHIKHA) project, which was implemented by the Science Of Improving Lives (FHI360), exchanged training and communication materials on nutrition.

Win Miaki, a private sector company, was supported by AIN with aquaculture training and materials to improve the operation of its agri call center, which provides advice to farmers on agriculture and related topics like aquaculture and nutrition. The solidarity center (SC) provided training to employees of shrimp processing plants to increase awareness on the International Labour Organization(ILO) Core Labour standards and Bangladesh Labour Act with support from AIN. This activity was part of an agreement between the BFFEA, BSFF and SC, and received funding from the Bangladesh government.

Project implementation strategy

During the first 18 months of the project, the main implementation strategy was to dedicate significant resources for the delivery of improved fish and shrimp seed to farmers to lay a foundation for future improvements in commercial and household aquaculture. During the second phase, greater emphasis was placed on delivering impacts on fish productivity and household income by working directly with commercial and homestead producers, through the four components.

Concerning the quality of shrimp seed, the project first started PCR testing for WSSV of seed from regular shrimp hatcheries that followed a mass spawning system (holding a large number of broodstock in one tank for spawning). To improve shrimp seed quality, as well as to produce virus-free postlarvae, the project started supporting the design of the "one mother, one tank system" with PCR testing. In addition, AIN worked with the DOF and the private sector to introduce SPF shrimp. If SPF shrimp are kept in a highly biosecure environment and produce postlarvae, the resulting postlarvae could be considered as very healthy seed and require only occasional testing to confirm their high health status.

To improve the quality of carp seed, AIN distributed river-sourced quality carp broodstock to many hatcheries in the project area. A genetic improvement program for three carp species was initiated, and the project provided technical advice and training to hatcheries in the region to improve the quality of their produce. Improvements in seed supply were implemented in collaboration with key aquaculture value chain actors, such as hatcheries (prawn, shrimp, carp and tilapia), nurseries (fish and shrimp), traders (shrimp and fish seed), feed millers and feed traders.

WorldFish started genetic improvement of tilapia more than 25 years ago, which resulted in the production of the Genetically Improved Farmed Tilapia (GIFT) strain. AIN imported GIFT seed from Malaysia in 2012 and disseminated them to hatcheries in the region for breeding and further dissemination to hatcheries and farmers.

Through training by project staff, AIN created a large population of farmer households with knowledge on aquaculture best practices to increase production through better management methods. To have a sustainable source of information in rural areas, the project increased the technical and facilitation skills of existing local entrepreneurs so that they would be able to provide embedded services as PSFs.

AIN supported increasing the availability and quality of feed at farm and national levels by supporting the institutional capacity of the DOF to implement the

Quality Feed Act and Rules 2010. AIN also helped increase the availability of fish on homesteads and in the market, and it also raised awareness among farmers and households on the nutritional benefits of fish consumption. AIN assisted female household members to more conveniently harvest fish for home consumption by introducing a novel gillnet technique.

To empower women, gender issues were discussed in the aquaculture farmer training. Of more than 130,000 farmers that were directly trained by project staff, 55% were women.

To make the project operation more efficient and to reach more farmers, modern information and communication technology was used. The main applications were for e-traceability, in shrimp marketing and for access to a database of PSFs, as well as for the use of mobile money for project and target group use.

Project monitoring and evaluation

The monitoring and evaluation (M&E) unit has been responsible for monitoring the project's activities, and analysis of results and evaluation. A result-based monitoring system was used to track results against 22 predefined indicators, of which 11 were USAID standard indicators and the remaining 11 were custom indicators. The data for the indicators was collected through monthly, quarterly and annual performance surveys. Four annual performance surveys were conducted during the project period. The annual surveys were supplemented by three complementary surveys, including training beneficiary registration, tested shrimp seed user tracking and quality carp seed user listing. The training beneficiary registration was completed in the first three years of the project during the selection of fish and shrimp farmers for training groups.

Basic information like address, age, education, pond area, production and annual household income were registered. A pair of consulting farms conducted baseline and final annual performance surveys, while project staff collected data for other surveys. Data quality assurance was embedded in all surveys, as stated earlier, following USAID's data quality standard, which is called the Data Quality Assessment process. The M&E unit analyzed the data and drafted quarterly and annual reports on the project's progress considering the reporting requirements of USAID and WorldFish. To visualize the data, the GIS was integrated with the M&E system, which also helped in planning and decision-making. The GIS was used mainly for locating the global positioning systems (GPS) of key stakeholders of project—hatcheries, nurseries, community feed centers (CFC) and demos—in the map. The GIS was also used in management decision-making. For example, PSF approach implementation clustering was done using geo-spatial analysis. During the cluster design of different surveys, GIS maps were also used.

Photo credit: Foto Agency

Local service provider conducting training.

Objective 1: Dissemination of higher-quality lines of fish and shrimp seed

High quality and accessible seed is necessary for sustainable production in aquaculture. The purpose of this component of the project was to make better quality fish and shrimp seed available to farmers in the Khulna, Barisal and Dhaka divisions. The expectation was to provide the basis for at least a 15% increase in fish and shrimp yield in the southern delta, benefiting around 1.1 million farm households by the end of 2016.

AIN implemented activities to improve the quality, availability and accessibility of both shrimp postlarvae and carp fry in the project area, and beyond, by providing technical assistance to better manage fish and shrimp hatcheries and supplying genetically improved or better quality fish and shrimp broodstock. The project also helped build human capacity through targeted training to improve the quality and quantity of seed produced.

Improved aquatic farming systems were expected to provide an additional 125,500 metric tons of fish and shrimp by the end of 2016. Government brood centers and private hatchery operators will be assisted with sourcing quality brood stock, establishing management systems to maintain and develop seed quality and accelerating the distribution of improved quality of fish, shrimp and prawn to farmers.

Carps

Freshwater finfish species such as carp, catfish, pangas and tilapia are the backbone of aquaculture in Bangladesh. They are produced for local consumption, while shrimp and prawn are produced mainly for export. About 60% of the 1.85 million metric tons of freshwater aquaculture production consists of carp. Availability of hatchery-produced seed is the main driver for this level of production.

Over 900 carp hatcheries produce about 500 metric tons of spawn annually. However, broodstock management in these hatcheries is poor, and inbreeding has become a problem, which has deteriorated the quality of carp seed over time. AIN assisted hatcheries and other seed value chain operators to improve methods of carp broodstock management, maintenance and seed production. Better quality seed would lead to increased production at the farmer level without additional cost.

AIN used three different approaches to assist carp hatcheries: (1) a supply of new male and female broodfish from three natural river sources on a cost-sharing basis, (2) a technical package to upgrade hatchery infrastructure and operation, and (3) training in broodfish pond management practices. The technical package included the provision of a tiered aeration screen (called an oxygen tower) and a dissolved oxygen meter to 76 hatcheries. Implementation of this simple technology had an immediate and profound impact on improving the survival of sensitive yolk sac larvae.

The project assisted 85 hatcheries to source broodstock from wild sources to replace the part of their broodstock that was of poor quality. Between 2012 and 2015, 71,250 kg of quality broodstock was distributed, which replaced about 50% of overall broodstock among the partner hatcheries. To ensure that the seed from good quality broodstock will reach farmers in good condition, AIN trained seed value chain operators in all stages of the chain. AIN also trained the hatcheries on improved management. The adoption of better groundwater aeration through an oxygen tower was introduced, and it is now standard in nearly all carp hatcheries in the project area. Use of the tower has improved water quality and increased the survival of the spawn (hatched eggs).

As part of an awareness campaign, messages on the benefits of quality fish seed were delivered through billboards and signboards. Overall, the hatcheries produced 90,000 kg of quality carp spawn over the four production seasons. AIN trained 560 nursery operators, who raised spawn up to fingerlings, as well as about 1200 seed traders, who carry the fingerlings to farmers. The seed traders delivered over 6.3 billion quality carp fingerlings to nearly 659,000 farmers covering about 93,000 ha of pond area, and the overall increase of fish production due to improved quality seed was about 200,000 metric tons from 2012 to 2016. This production contributed to an incremental sales value of USD 240 million of fish within the FTF ZOI. The fingerlings produced in the project area were also used by about 63,500 trained farmers, who subsequently managed to increase fish production.

AIN also advised hatcheries to reduce the stocking density of broodstock almost to 50% (from 20–25 kg/decimal to 12–15 kg/decimal), which resulted in much higher production and survival of spawn. The project

supplied microscopes to evaluate the suitability of eggs for fertilization (ripeness), tested hatchery water pH to maintain it between 7.5 and 8.5, and used quality feed to enhance broodfish nutrition and egg quality and quantity. The project also arranged study tours of hatcheries in Mymensingh and elsewhere in Bangladesh for some carp and tilapia hatchery owners. On a cost-sharing basis with a private company, Innovision, hatchery owners visited Thailand and Vietnam to observe improved hatchery management and commercial aquaculture.

Two carp hatcheries in Jessore have installed a biofiltration system to allow water recirculation, which reduced water pumping costs and improved water quality. One hatchery installed solar panels to generate renewable green energy to operate generators. Interventions of the AIN activity to improve carp hatchery technology and management practices have resulted in increased output of quality seed from project-associated hatcheries.

Carp genetic improvement program

The government of Bangladesh has placed great importance on the use of improved quality fish seed to achieve a target fish production of 4.5 million metric tons by 2020–2021. However, hatcheries countrywide are having difficulties producing quality seed due to a lack of scientific broodstock management programs in place as well as continued use of broodstock of deteriorated genetic quality. Although many hatcheries try to improve their broodstock by introducing wild broodstock, the process has been very irregular and disorganized due to high cost and poor organization and has yielded little or no impacts.

In other culture species, such as poultry and livestock, animals have been domesticated for hundreds of years. Modern chicken breeds grow much faster than their wild ancestors. The same is also possible for fish. It has already been done with, for example, salmon and tilapia, but many culture species, including carp, still rely on wild-sourced broodstock. The carp genetic improvement program (CGIP) was therefore initiated to improve the genetic performance of three carp species, initially focusing on improving the growth rate. It is expected that faster growing fish will lead to higher production for farmers and increase fish availability and accessibility. By implementing such a program, the expectation is that three generations of selective breeding will add 30% to the average growth rate. Other characteristics will also be monitored, especially egg production and survival, since these are important economic indicators for hatcheries.

The CGIP includes three species of carp that are important to fish farmers and consumers in Bangladesh and elsewhere in South Asia: rohu (*Labeo rohita*), catla (*Catla catla*) and silver carp (*Hypophthalmichthys molitrix*). The first two species are native to Bangladesh while silver carp is native to China. All three species are popular and widely used in polyculture systems in Bangladesh. The objective has been to develop genetically improved strains of these species through a program of selective breeding over at least three generations.

Fertilized eggs and spawn of wild rohu were collected from the natural spawning sites of the Halda, Jamuna and Padma rivers during the breeding season in 2012 and reared in selected private farmers' ponds. After one year, 900 rohu (300 each from the Halda, Jamuna and Padma rivers) were collected from this stock and reared for another year until sexual maturity. To identify the stocks, they were tagged before stocking with digital passive integrated transponder (PIT) tags, which are injected into the abdomen. The PIT tags are readable from around a 20 cm distance with a digital scanner. All tagged fish were genetically analyzed (DNA analysis), and 210 pairs were randomly selected from the 900 tagged broodstocks. These 210 pairs produced 210 full sib families through single pair mating by using a mating scheme that made hybrids in all possible combinations between the three river stocks for maximum genetic diversity.

DNA sampling results were used to construct a genomic relationship matrix between all fish to avoid the mating between related rohu. Between August 2014 and January 2015, these 210 full sib families were reared in 210 separate enclosures. When the fish reached around 6 g, they were PIT tagged. A total of 50 tagged fingerlings from each of the 210 families were stocked in ponds in Jessore. These fish (10,500) were considered the base population of rohu. From these 210 families, the largest two fish (one male and one female) from 160 families were selected and mated in 2016 to form the F1 generation for genetic improvement. Another 50 families were raised as control to determine the response to selection. In early 2017, when they were large enough to be tagged, 50 individuals of each family in the F1 generation were tagged for further rearing. The tagged F1 generation fish are now being grown in ponds in Jessore. Once these fish have matured, the same procedure will be adopted and F2 and F3 generations will be produced by 2022.

Currently, negotiations are underway to transfer the rohu F1 generation to a government hatchery/broodstock facility maintained by the DOF. The agreement would be for the DOF to house fish in its facility while WorldFish staff provide technical assistance and manage the fish until they reach the sexually matured F3 level.

In the second year of the third generation (possibly in 2022), the rohu broodstock will be ready for mass reproduction and distribution to other regular hatcheries. The regular hatcheries will get a mixed batch of small fish from all improved families to use as broodstock. This broodstock will produce good quality fish seed to be sold for grow-out. It is envisioned that every three to four years, hatcheries will have their broodstocks replenished by the DOF with a batch of improved seed from a further improved generation. It is still too early to present the outcomes of AIN's rohu improvement program, since only the first generation had been developed by the end of the project in December 2016. Each successive generation is expected to add 10% in average growth, with the aim being 30% after three generations of selective breeding.

Based on the methods developed through the CGIP with rohu, WorldFish, with support from USAID-AIN, has started a similar selection process for catla and silver carp, two other popular carp species. Samples of silver carp broodstock gathered from various locations have been subjected to DNA analysis to assess the level of crossbreeding with bighead carp. A satisfactorily genetically pure population of silver carp that can efficiently digest algae is expected from the intended three generations of selective breeding. A batch of 900 catla broodstock have been conditioned and bred in 2017, and over 700 silver carp are being bred in the second half of 2017. The tagged stocks (generations) of catla and silver carp will be treated in the same way as rohu. Additional agreements between WorldFish and the DOF will be developed to house catla and silver carp stocks in DOF facilities. The CGIP initiated by USAID-AIN will continue as a joint WorldFish-DOF program, under an agreement between the two agencies, for years to come in selected DOF facilities.

Tilapia

Tilapia was first introduced to Bangladesh from Thailand in 1954 followed by several other import initiatives. Tilapia has since become increasingly popular in Bangladesh, particularly among the poor because of its low cost, taste and nutrient quality. It can be grown under subsistence conditions, as well as in commercial intensive culture, and it is a freshwater fish that can tolerate brackish water in coastal areas. Tilapia production has taken off recently, increasing from 20,000 metric tons in 2000 to 250,000 in 2014. Bangladesh now produces over 4 billion tilapia fry every year from over 400 tilapia hatcheries. This increase in production could have been even higher if the broodstock had been of substantial quality. The country's tilapia broodstock had seriously deteriorated over years due to a lack of good management, which resulted in inbreeding. Inbreeding, the mating of closely related fish, leads to poor growth and higher susceptibility to disease outbreaks.

To address this shortfall, AIN imported GIFT from Jitra Research Station in Malaysia. These fish were bred from 56 families and divided into eight cohorts. AIN helped set up four TBNs from the project area. In the TBN, the eight cohorts were stocked in eight separate ponds. Every year the required number of males and females are selected from each of the eight cohorts for next year's broodstock. Every year, the males and females are rotated to create eight new combinations that make up the eight cohorts for that generation. This method, which is called rotational cohort breeding, is how genetic diversity is maintained.

The four TBNs sell a mixture of offspring of the eight cohorts to four tilapia satellite hatcheries (TSH) that specialize in multiplying and selling broodstock to regular hatcheries. (TBNs also sell directly to regular hatcheries.) Regular hatcheries use this improved broodstock to produce quality monosex tilapia fry for grow-out farmers.

Tilapia hatcheries in the region intensively practice hormonal sex reversal to produce monosex male tilapia seeds. Project-provided inputs such as microscopes are now used to evaluate the extent of sex reversal through visualization of gonads. The project provided feed mixing machines to the Tilapia Hatchery Owners Association for producing fry feed for sex reversal. The project supported small-scale hatcheries by providing GIFT, and they are now able to compete with large-scale commercial hatcheries.

In 2016, the four TBNs produced 760,000 fry to be raised as improved broodstock, and the four TSHs supplied 1.2 million fry to be raised as improved broodstock. In 2015, 37 regular hatcheries (29 tilapia hatcheries and eight carp cum tilapia hatcheries), which make up 65% of all active hatcheries in the project area, produced 83 million tilapia fry for grow-

out culture, which is about 55% of total tilapia fry demand in the project area.

Based on AIN's tilapia impact study conducted in 2016, the introduction of GIFT increased production to an additional 15,000 metric tons of tilapia in the 2015–2016 season. Overall, it is estimated that GIFT grows about 30% faster than other tilapia strains available in the project area.

Shrimp

AIN assisted black tiger shrimp (*Penaeus monodon*) hatcheries to improve their postlarval quality by testing their broodstock and postlarvae against WSSV, one of the most dangerous viral pathogens/diseases, using PCR methodology. AIN also implemented several new concepts toward producing better quality and biosecure shrimp seed to hatcheries in the project area. As the number of PCR-tested better quality postlarvae increased and farmers began to recognize the benefits of stocking PCR-tested WSSV-free postlarvae, demand for quality postlarvae increased while incidents of disease decreased.

AIN has invested in analytical equipment for a PCR testing laboratory operated by the DOF to provide hatcheries with the means to comply with the PCR Act, which mandates PCR testing of all seed sold. The project has provided similar support to a laboratory at the BFRI in Cox's Bazar that has PCR testing equipment and other disease diagnostic (e.g. histopathology) capability. More than 1 billion WSSV-free, PCR-tested postlarvae were sold by the cooperating hatcheries to farmers over the four production seasons in the project period. This led to an increased production of nearly 3,000 metric tons of shrimp with a total value of USD 39.75 million, based on AIN's annual performance surveys.

AIN and the DOF also assisted a private hatchery in Cox's Bazar to produce healthier postlarvae originating from SPF broodstock. However, the current supply of PCR-tested postlarvae and healthier postlarvae are far from sufficient to meet national demand.

AIN has also established a live foods laboratory at the BFRI in Cox's Bazar that produces phytoplankton (algae) species that can be used by hatcheries as live

Packaging shrimp for the market.

food for larval shrimp. Such a facility has the potential to serve as a reference lab and a source for pure cultures of algae that can be used as hatcheries start their annual operation cycle. Hatcheries do not have adequate facilities to maintain uncontaminated algal stock cultures during the several months when they are not in operation.

Research done by WorldFish, with support from USAID-AIN, confirmed the relation between increased production and stocking of WSSV-free postlarvae. The small farmers that stocked PCR-tested postlarvae had an average survival of 27% compared to 15% in ponds of farmers who stocked non-tested postlarvae. Production with tested postlarvae was 49% higher than with non-tested postlarvae. The profit per ha was 82% higher when tested postlarvae were used.

Freshwater prawn

Freshwater prawn (*Macrobrachium rosenbergii*) has significant economic importance in Bangladesh aquaculture. Since 2011, however, an unknown larval mortality syndrome has been causing major production loss in the country's freshwater prawn hatcheries. According to the DOF, there are 72 functional prawn hatcheries in Bangladesh that have been producing postlarvae since 2004. From a peak of 70 hatcheries producing over 150 million postlarvae in 2010, only 22 attempted prawn postlarval production during 2016, and these managed to produce fewer than 15 million postlarvae. This problem has caused a severe shortage of postlarvae, resulting in very high postlarval prices and collection of postlarvae from the wild, which is banned. There have been many illegal importations/introductions from neighboring countries as well.

AIN has attempted different experiments to determine the reasons for the precipitous decline of postlarval production in prawn hatcheries with suggestions on different critical issues of prawn hatchery operation from various experts during 2013–2015. The project supplied some inputs and equipment to some hatcheries and brought in experts to study the situation. In 2013, project-assisted hatcheries produced 6.7 million postlarvae. In 2014, production increased to 9.5 million from a single cycle.

By 2016, however, freshwater prawn postlarval production declined due to uncontrollable mortalities. A viral infection, transmitted vertically and horizontally from broodstock to postlarvae, was suspected to be the cause. By 2016, postlarval production was down to fewer than 400,000. WorldFish recently identified MrNV (*macrobrachium rosenbergii noda virus*) as the underlying cause of infection.

Objective 2: Improving the nutrition and income status of farm households

Improving production

There are many homestead ponds in the AIN project area. The average pond size is about 1200 m^2 (28 decimals). The average pond size of an AIN homestead farmer is about 800 m^2 (20 decimals). Fish production in these small ponds is low. Baseline investigations confirmed that the average annual production of AIN farmer ponds is about 1700 kg/ha, based on water area alone, or 136 kg for an average pond. The culture conditions in these household ponds are not optimal. Rainwater is the only water source. After five months without rain during the dry season, water depth is reduced due to evaporation and the use of pond water for vegetable irrigation and household uses.

AIN worked with 65,600 farmers, of which 88% were female, involving 113,000 farmer ponds, amounting to little over 9000 ha. During the project, AIN provided some inputs, and farmers were trained on how to improve homestead pond production and the nutritional benefits of increased fish consumption. From 2012 to 2014, farmers were trained in sustainable and productive household aquaculture. Each received 24 hours of training. Selected CFs received additional training by project staff and eventually became community trainers. The overall attendance rate of all farmers was 80%–90%, and the adoption rate of at least one of the training messages was 99%. About 75% of the training was spent on aquaculture technology and the remaining time on nutrition and gender awareness messages.

AIN training on improved pond management resulted in 2865 kg/ha of production in the 2015–2016 season based on water area, a 69% increase over the baseline. The average production per household pond was 230 kg, a 70% increase from the baseline. AIN achieved this increase through two main activities: (1) providing training on improving pond management methods and (2) improving the quality of carp seed.

Improving nutrition and hygiene

Current average fish consumption in Bangladesh is 15.4 kg/person/year. The government's target for consumption is about 20 kg/person/year (56 g/person/day). Although the average annual per capita consumption is 15.4 kg, there are some who consume

much less and others who consume much more. However, 36% of children under 5 are stunted, 14% are wasted and 33% of children are underweight, in large part due to a lack of essential micronutrients. Fish, especially small fish, which are eaten whole, are a rich source of micronutrients, including calcium, vitamin A, iron and zinc, as well as essential fatty acids needed for good health, especially in women and children. This was confirmed by an analysis of micronutrients in about 100 fish species. An advantage of meat as a source of micronutrients is that iron and zinc are more bioavailable in combination with animal protein.

Two benefits of fish compared to livestock or poultry meat is that it can be killed in smaller portions and it is also easier to store. Comparing fish to poultry, a homestead pond will usually be able to maintain more kg of fish than a comparable surface of land can maintain free-range chickens.

From interviews, it was discovered that some years ago poor people would capture fish from open water bodies to supplement their diet. Now, however, due to overfishing and habitat deterioration, fish from open water has become scarce and the price is high. Aquaculture has become the main source of fish, especially for poorer households.

In the FTF ZOI, fish is the dominant source of animal protein for most households. Nutrition problems can also be caused by disease attributed to inadequate water, sanitation and hygiene facilities and practices. Improved hand washing has been shown to reduce diarrheal and respiratory diseases. In 2012, the National Hygiene Promotion Strategy for Water Supply and Sanitation in Bangladesh was launched, which incorporates five behavioral domains, including sanitation hygiene, personal hygiene, food hygiene and environmental hygiene promotion.

To improve nutrition and hygiene in the project area, AIN trained about 130,000 farmer households on nutritional and hygienic topics, such as the importance of consuming adequate micronutrients like vitamin A and iron, complementary feeding, safe food preparation and preservation and hygiene promotion. Further training was conducted on the production of nutrient-dense mola (*Amblypharyngodon mola*) and OSP, as well as better preparation methods of each, in combination or separately. About 43,000 children under 5 were included in the training. Trained farmers could answer an average of 82% of nutrition-related questions correctly compared to 44% of control farmers during AIN's performance survey conducted in 2016.

The project encouraged farmers to grow vegetables, including OSP, the roots and leaves of which are high in vitamin A, at their pond dikes and homestead area. Between 2012 and 2015, the project distributed more than 840,000 OSP vines to 7500 farmers. Of these, about half the farmers distributed an additional 2 million vines to a further 27,000 farmers. Average per household OSP root and leaf production was 16 kg, of which almost 70% was consumed and the rest sold.

Another key nutrition-focused initiative of AIN was the introduction of mola into homestead ponds, initiating a polyculture system with higher productivity. Between 2012 and 2015, the project distributed 4700 kg of mola to 9,100 household farmers to be cultured along with other fish in household ponds. AIN encouraged farmers to share their mola broodfish with other farmers once they had reproduced in their ponds. This resulted in the transfer of a further 5600 kg of mola broods to an additional 37,500 farmers. At least 46,600 farmers significantly increased their homestead pond production of mola and other fish between 2012 and 2015. Through training, farmers and household members learned not to remove the heads of mola, as well as other small fish like chela, darkina and puti, originating from the ponds during cleaning, because the head is the most nutritious part of many small fish.

As part of sanitation and personal hygiene, the project introduced a small hand-washing device called the "steppy tap," which is a modification of the "tippy tap." The devices were distributed among 650 households. This initiative appeared to have helped change hygiene behaviors and practices. The steppy tap can reduce the time spent bringing water from the pond or tube well, increasing hand washing frequency and reducing misuse of water.

Empowering the private sector

Over nearly four years, with the help of staff from several partners, AIN provided farmers and households with knowledge and training on aquaculture management. Toward the end of the project, concern grew as to how to continue the flow of information to the farmers after the end of the project. In response, AIN developed training material and trained several PSFs, who in turn trained and educated farmers on aquaculture management. AIN's use of PSFs became very popular among farmers and has proven successful.

AIN trained 1275 PSFs on technical and facilitation skills during the fifth year (2015–2016) of the project. Their business is mainly related to the production and sale of quality fish and shrimp seed and quality feed. PSFs have various seasonal businesses, and their training skills also benefit other activities. These PSFs include 419 fish nurserers and 55 shrimp seed nurserers, 245 fish fry hawkers (*patilwala*), 39 fish input traders, 31 shrimp input traders, 50 CFCs, 147 local feed traders, 167 fish-related commission agents, 51 shrimp-related commission agents, 43 shrimp depots, 43 shrimp postlarvae traders and 23 tilapia hatchery owners.

The effectiveness of the training was in large part due to the quality of training materials that were developed by the AIN. Each PSF was trained to use a set of seven festoons/posters that described all the important topics and illustrate them with pictures. Several real materials like fertilizer and feed were also part of the training package. Farmers not only learned about aquaculture but also about vegetable cultivation around the pond, as well as dike cropping and the importance of a balanced diet and regular fish consumption by all members of the family.

During 2016, the PSFs trained about 76,000 farmers. The facilitation skills became a permanent asset to the community because a PSF can continue training long after the project has ended and transfer the skills to others. Based on monitoring of the training provided by the PSFs, it was estimated that 37% of PSFs have excellent and 57% have good facilitation skills. Based on knowledge surveys of participants, they could answer 73% of questions related to aquaculture and nutrition correctly compared to 34% of non-trained farmers.

To facilitate continued access to knowledge for PSFs and commercial fish and shrimp farmers, AIN has initiated the South West Aquaculture Advisory Network (SWAAN). It is a cooperation made up of three universities, the DOF, the BFRI and private sector representatives, which will meet regularly to answer questions from the field and identify the need for additional research wherever an answer is not available. WorldFish, which is intending to set up a permanent technology hub in the region, is planning to convene meetings of SWAAN for some time after the phase-out of AIN. It is envisioned that SWAAN will form the linkage between the member organizations and the field level, especially with DOF members, who have a linkage to the field via the *Upazila* fisheries officers. In turn, these officers can link with individual PSFs and support the formation of *Upazila* level associations of quality fish seed groups.

Objective 3: Commercial aquaculture

Commercial aquaculture, which is usually done in larger ponds instead of homestead ponds, has two main differences in pond management compared to household aquaculture: (1) stocking fingerlings at a higher density per unit pond area, and (2) mandatory supplementary feeding. These factors result in higher per unit production. Commercial aquaculture is market-oriented, with only a small portion of production used for home consumption. The aim of AIN is to promote commercial aquaculture as it will increase availability of fish in markets in rural and sub-urban areas.

Fish culture

AIN provided training on better aquaculture management, including some novel techniques. In the commercial aquaculture practices that received training from AIN, culture techniques visibly improved. Nearly 14,500 commercial fish farmers were trained using the same modules as those used for household fish farmers, but customized for commercial aquaculture. The project demonstrated improved technologies with increased inputs through 86 commercial fish demonstration ponds, of which the average annual production was about 6000 kg per ha. These ponds helped farmers to better understand the benefits of certain modern technologies. In addition, AIN arranged cross visits for project farmers and organized 25 farmers' field days at the village level to disseminate advanced fish culture technologies.

Following training, about 14,300 commercial farmers applied their knowledge and training in their fish farms. This led to an increase in production above the baseline (1320 kg/ha) to between 73% and 267% (4849 kg/ha in 2013, 2522 kg/ha in 2014, 2286 kg/ha in 2015 and 2338 kg/ha in 2016). The pond area was calculated based on the water surface and dike. Therefore, production per hectare will be higher when only water surface area is considered. The profits increased to USD 5737/ha in 2013, USD 2023/ha in 2014, USD 1662/ha in 2015 and USD 1951/ha in 2016, compared to the baseline of USD 805/ha. Over the five years of the project, increased production by trained commercial farmers was 15,371 metric tons of fish, with a sales value of USD 28.96 million. The fluctuation of production volume and income has been attributed to suboptimal climate conditions and the prevailing market price of shrimp at the time of production.

To disseminate the potential for more intensive high value fish production technologies, the project supported establishing four demonstration production units of Vietnamese climbing perch (koi). Considering the high productivity, pangasius and tilapia were also demonstrated in two ponds. Vietnamese koi farming (in polyculture with silver carp, mhing and magur) created a profit of USD 5280/ha of pond area. Profit from pangasius farming (in polyculture with silver carp, common carp and Thai puti) was USD 3962/ha. From tilapia farming (in polyculture with silver carp, mrigel, catla and rohu), the profit was USD 3754/ha.

Shrimp culture

Shrimp and prawn are the second-largest source of export earnings after the garment industry in Bangladesh. Out of 275,000 total ha of shrimp and prawn culture area in the country's coastal zone, about 90% are used by small farmers, who produced on an annual average of 230 kg/ha in 2012, based on AIN's baseline data.

To increase the production of small-scale shrimp farmers, the project provided technical training to 50,000 shrimp farmers using similar modules as those used for fish farmers, but customized for commercial shrimp aquaculture. A total of 140 farmers were supported to set up shrimp culture demonstration ponds. This was a practical learning tool for farmers to observe the effects of improved practices in their farms.

After training, the shrimp farmers applied what they learned about improved management practices in their farms, which led to an increase in production above the baseline (230 kg/ha) between 20% and 65% (380 kg/ha in 2013, 309 kg/ha in 2014, 280 kg/ha in 2015 and 275 kg/ha in 2016), with an annual average shrimp production of 311 kg/ha. The farmers also cultured fish in their shrimp ponds and production was 460 kg/ha in 2013, 571 kg/ha in 2014, 563 kg/ha in 2015 and 553 kg/ha in 2016 compared to the baseline 245 kg/ha. Their profit was USD 1928/ha in 2013, USD 2121/ha in 2014, USD 1952/ha in 2015 and USD 1333/ha in 2016, compared to USD 564/ha in the baseline year. Over the four production seasons, trained shrimp farmers increased their production with 8014 metric tons of shrimp and 34,225 metric tons of fish grown in polyculture with the shrimp, for a total sales value of USD 177.08 million. The evident fluctuation of production volume and income could be attributed to suboptimal climate conditions and the prevailing market price of fish/shrimp at the time of production.

Community feed center development

Most small-scale farmers with household ponds possess some knowledge and experience in basic aquaculture. Some may have used agricultural by-products to feed their fish. A small number of farmers also use fertilizer to boost natural feed in the pond. However, these interventions provide only limited outcomes in fish production. To optimize fish growth, a balanced diet with better nutritious feed is essential.

AIN's research on fish feed indicates that there has been a strong growth in the fish feed business between 2008 and 2013, with an estimated annual commercial feed production of 1 million metric tons, originating from about 100 commercial feed mills. Additionally, small enterprises produce about 300,000–400,000 million metric tons of pelleted feed. Although nearly 1.4 million metric tons of feed are produced in Bangladesh, efficient distribution is an issue. Many farmers in the project area claim that fish feed does not reach them in sufficient quantities. Available feed becomes expensive due to the high cost of long transportation and the involvement of many supply chain actors. The quality of feed is also low due to poor quality control and storage conditions along the value chain. AIN thus endeavored to increase the availability of quality feed to farmers in remote areas at a reasonable price.

To improve feed availability and quality, the project assisted the private sector to establish 62 CFCs, which are semi-auto feed production facilities. CFC staff have been trained on how to operate and maintain the machines, feed formulation and production of quality feed. The CFCs subsequently trained about another 2500 farmers, who are potential customers, and sold feed to 2000 of them.

The CFCs produced over 1300 metric tons of feed from 2013 to 2016. The CFCs' arrangement provided choices for farmers to make feed based on the formulae provided by the project, using available ingredients such as rice bran, mustard oil cake, dry fish, maize and wheat flour. This gave farmers even more control over achieving better feed quality.

The CFCs are mainly operated by large farmers who produce feed for their own fish ponds; however the CFC is a community resource because neighbors can rent it to produce their own feed and can observe and verify how it is made. Women also have easy access to CFCs, which have created part-time job opportunities for several women.

AIN assisted CFC operators to improve their operation by providing support with accessories like weighing scales, crusher nets, water pumps, silencers, sewing machines, mixer hoppers, feeder screws, feed dryers and health safety equipment. The project also linked the CFC owners to ingredient wholesalers so that they can buy at lower prices. Farmers in the project area increased their feed use from 30% in 2012 to 46% in 2015.

Objective 4: Policy and regulatory reform and institutional capacity building

Support for the Hatchery Act 2010 and Hatchery Rules 2011

Shrimp

In terms of policy support and assistance toward regulatory enforcements and institutional capacity development, AIN assisted the DOF in better implementing the Hatchery Act 2010 and Hatchery Rules 2011 (Hatchery Act and Rules). Even though it is explicitly mentioned in the Hatchery Act and Rules that all shrimp seed must be tested by PCR for WSSV before sale, many farmers claim heavy losses due to WSSV outbreaks in shrimp ponds. Available PCR testing facilities were limited and full compliance to the regulatory requirements of the Hatchery Act and Rules has been impossible. The project endeavored to increase the availability of PCR-tested postlarvae in cooperation with the DOF. Since 2014, the project also supported production of postlarvae deriving from SPF stocks.

From September 2011, WorldFish started PCR lab activities through AIN at the DOF lab in Cox's Bazar to support shrimp farmers with quality postlarvae. AIN signed MoAs with 18 shrimp hatcheries to test and distribute WSSV free shrimp postlarvae. During the following years, PCR testing was done in many hatcheries.

In 2014, the Feed the Future Partnering for Innovation program started funding the introduction of SPF shrimp broodstock and postlarvae into Bangladesh from Moana Technologies Inc in Hawaii. This was done in collaboration with the DOF and a private hatchery, MKA Hatchery in Cox's Bazar. AIN provided funds for key hatchery equipment during the 2015–2016 season. It also supported the DOF lab at Cox's Bazar in testing samples from broodstock, nauplii and postlarvae for 11 specific pathogens, especially WSSV, Infectious Hypodermal and haematopoietic necrosis virus, Monodon-type baculovirus, Hepatopancreatic Parvovirus, Yellow Head Virus, Taura Syndrome Virus, Necrotizing Hepatopanceatities Bacteria, Infectious Mionecrosis Virus and Mourilyan Virus in 2012. In 2013, WorldFish introduced a test kit to detect early mortality syndrome (EMS). Subsequently in 2016, another test kit was added to detect the entercytozoon hepatopanaei (EHP) pathogen.

In 2015, the Shrimp Hatchery Association of Bangladesh (SHAB) organized a two-day training session on PCR lab management. The focus was to familiarize participants with hatchery preparations, including cleaning and disinfecting facilities and equipment and maintaining them throughout the production year, which is a requirement for PCR testing. The project also delivered a two-day practical session on PCR lab management to train the participants on PCR lab operation, and 42 participants from the DOF, BFRI, SHAB and ACI Animal Health Limited attended the training.

In 2015, to develop DOF and BFRI personnel capacity on management of diagnostic laboratories, one DOF staff member and one BFRI staff member were sent to the Aquatic Animal Health Research Institute of the Thai Department of Fisheries in Bangkok. They received two weeks of training in basic microbiology, parasitology, mycology, histopathology and lab maintenance and management.

Fish

The objective of the Fish Hatchery Act 2010 and Fish Hatchery Rules 2011 (Fish Hatchery Act and Rules), which have been implemented by the DOF, is to regulate hatchery production of fish by specific schedules mentioned in both legislations. Many hatcheries were unaware of the provisions of and obligations to the Fish Hatchery Act and Rules, thus increasing awareness was necessary.

Several workshops were conducted in 2013, 2014 and 2015 with DOF officials, private hatchery owners and NGO professionals. They were all organized under AIN, which provided advice and guidance on implementing the Fish Hatchery Act and Rules. Recommendations for making relevant amendments to the Fish Hatchery Act and Rules were prepared. The recommendations were validated in a consultation meeting conducted on 15 and 16 August 2016 at the BSFF conference room in Dhaka, and a report was prepared to follow up with the DOF for incorporating the amendments in the existing Fish Hatchery Rules 2011 during a new update. To support

implementation of the Fish Hatcheries Act, AIN has drafted a manual to inspect quality seed production at hatcheries based on a review of the Fish Hatchery Act and Rules.

Support for the Fish Feed and Animal Feed Act 2010 and the Fish Feed Rules 2011

A national study on fish feed commissioned by AIN revealed that the quality of fish feed produced in Bangladesh is poor and needs urgent improvement. The Fish Feed and Animal Feed Act 2010 and the Fish Feed Rules 2011 (Feed Act and Rules) govern the feed quality and are supposed to regulate and control feed production and quality in Bangladesh. A study conducted by the project in 2012 found that only 20% of feed mills are aware of the Feed Act and Rules' restrictions on antibiotic and chemical use, but are unfamiliar with other requirements. The importers and suppliers of raw materials and additives are also often unaware of specific rules, but already comply with some parts of the Feed Act and Rules because of their compliance with customs regulations. Similarly, feed traders comply with some of the requirements in the Feed Act and Rules, which are set by feed companies at the time they apply to set up a dealership. But critical points like storage and transport are being avoided due to a lack of knowledge on feed rules and monitoring.

AIN supported capacity development of DOF staff and technical staff from several large feed mills to better understand the Feed Act and Rules and compliance. The training materials were based on the official protocols for inspection of feed mills, which were developed by the Best-Better Fish Quality project funded by the UN Industrial Development Organization (UNIDO).

To address the issues, two national level workshops were conducted in collaboration with the DOF, bringing in representatives from the Feed Industries Association Bangladesh, Animal Health Companies Association of Bangladesh, Department of Livestock, BFRI and several commercial feed millers. The workshops discussed the implementation and appropriate review of the Feed Act and Rules, and helped improve the implementation of it. The project also trained a batch of 29 DOF officials on fish feed nutrition and feed formulation.

The project also trained 90 DOF officials on the use of the inspection protocol for verification of feed mills. DOF officials are now confident in inspecting feed mill operations and formulations as part of their regular monitoring and license issue and reviewing. They have a better understanding of feed acts and rules that ensures production of quality and safe feed. As part of the process, 1000 fish feed inspection protocol manuals have been printed and distributed among officials and feed millers.

The project also trained 101 staff from 53 commercial feed mills on creating awareness of the Feed Act and Rules. Thus, millers now have a better understanding of them both.

As part of the AIN research program toward improving feed quality, 194 local fish feed ingredients samples (such as rice bran, wheat bran, de-oil rice bran, soybean oil cake, mustard oil cake, dry fish, fish meal, meat and bone meal, maize, rape seed oil cake, wheat flour, protein concentrate and sunflower oil cake) and 200 feed samples of the main fish species (tilapia, pangas, koi, shing, magur, prawn, shrimp and carp) were tested for proximate composition (such as moisture, crude protein, crude fat, ash and fiber). The test results of the feeds showed that 15% of crude protein samples were lower than the recommended level as per the Feed Act and Rules. The research is continuing.

Summary of Feed the Future Indicator Report

Table 2 summarizes some of AIN's achievements against FTF indicators. The following are its main achievements:

4.5.2-23: Value of incremental sales (collected at farm level) attributed to FTF implementation

Incremental sale is the difference between the value of baseline sales and the annual performance survey. The value of sales includes the value of the amount of fish, shrimp and vegetables sold only by farmers. The incremental sales were USD 102 million, USD 82 million, USD 111 million and USD 156 million in FY2013, FY2014, FY2015 and FY2016, respectively, for a total of USD 451 million. Fish and shrimp farmers had higher production in FY2013 due to suitable weather conditions for aquaculture. Overall, production gradually increased mainly due to an annual increase in production of quality carp seed and training.

4.5.2-38: Value of new private sector investment in the agriculture sector or food chain leveraged by FTF implementation

Private sector investment reached USD 1.65 million over the project period (USD 292,600 in FY2016). Only capital items were included in calculating the value of new investments. The investment was less than targeted because shrimp farmers reduced new investments in FY2016 due to the low international market price of shrimp.

4.5-2: Number of jobs attributed to FTF implementation

In 2013, trained farmers generated 8170 new jobs (18% for women) in their aquaculture farms. According to the revised FTF guideline in 2014, a new jobs calculation method was used, which increased the number of jobs to 14,911 (25% for women). As per the

Photo credit: Yousuf Tushar/WorldFish

Freshly harvested tilapia in Jessore, Bangladesh.

upcoming revision of the FTF guideline, during the next two years the project reported only the number of hired permanent laborers where paper-based documentation was maintained. The number of new jobs generated by project-supported carp hatcheries in 2016 was 124. Most new jobs in 2016 were generated by eight newly established carp hatcheries.

4.5-16, 17, 18: Gross margin per ha, animal or cage of selected product

In general, the gross margin per ha for fish and shrimp production increased while the same for vegetables decreased. Although the gross margin varied over the project period due to variations in weather conditions, input costs, sales price, etc., the average gross margin per ha was higher each year (USD 1372/year for carp farming and USD 1815/year for shrimp farming) than the baseline (USD 805 and USD 564, respectively).

4.5.2-2: Number of ha under improved technologies or management practices because of assistance from the USG

Nearly 349,000 farmers applied improved technology or management practices in their aquaculture farms in the FTF zone in 2013. The project extended support to farmers in the following years, and the number increased gradually from 616,000 in 2014 to 792,000 in 2016, of which 19% were women.

4.5.2-5: Number of farmers and others who have applied new technologies or management practices because of USG assistance

Nearly 584,000 farmers applied improved technology or management practices in their aquaculture farms in 2013, and 349,000 were in the FTF ZOI. The project extended support to farmers in the following years, and the number increased gradually from 616,000 in 2014 to 792,000 in 2016, of which 19% were women.

4.5.2-7: Number of individuals who have received USG-supported short-term agricultural sector productivity or food security training

The project trained 100,000 individuals (52% women) in 2013. More farmers were trained in the following years, and 132,000 farmers and people from the private sector received training in 2016. Most farmers received continued annual training at least three times. In addition, 1275 project-supported PSFs trained 75,725 farmers in 2016, of which 80% did not receive training from the project before.

4.5.2-13: Number of rural households benefiting directly from USG interventions

Over 793,000 rural households in FTF's 18 districts have benefited from the project. Benefits include receiving training, and quality fish and shrimp seed. Nearly 762,000 of those households were inhabited by families consisting of both adult men and women.

3.1.9-15: Number of children under 5 reached by USG-supported nutrition programs

The 43,000 children under 5 in trained households (50% boys and 50% girls) have benefited from nutrition programs through increased accessibility to and consumption of fish in the household.

4.5.2.8(TBD3): Total quantity of targeted nutrient-rich value chain commodities set aside for home consumption by direct beneficiary producer households

Out of the total of 138,000 metric tons of fish, shrimp and vegetables produced in the project area in 2015, 2650 metric tons of nutrient-rich food have been used by the beneficiary producer households.

In addition to the above FTF indicators, by the end of the project period there was a 39% reduction in the number of people living on less than USD 1.25/day in the project area, and 62% of the farmers in the project area increased their annual income by USD 100.

Indicator Number	Indicator Title	Unit	Disaggregated by	2012 Baseline	Achievements over project period (2012–2016)	Percentage Change
4.5.2-23	Value of incremental sales (collected at farm level) attributed to FTF implementation	USD	Fish	0	242,599,166	
			Shrimp	0	202,926,434	
			Vegetables	0	4,390,842	
			Total	0	449,916,442	
4.5.2-38	Value of new private sector investment in the agriculture sector or food chain leveraged by FTF implementation	USD	None	0	1,645,945	
4.5-2	Number of jobs attributed to FTF implementation	FTEs	Urban	0		
			Rural	0	23,208	
			New	0	16,537	
			Continuing	0	6,671	
			Male	0	18,075	
			Female	0	5,133	
			Total	0	23,208	
4.5-16, 17, 18	Gross margin per ha, animal or cage of selected product	USD/ha (aquaculture in ponds)	Male farmers (carp)	805	1,354	68
			Female farmers (carp)	805	1,626	102
			All farmers (carp)	805	1,372	70
			Male farmers (shrimp)	564	1,800	219
			Female farmers (shrimp)	564	1,968	249
			All farmers (shrimp)	564	1,815	222
		USD/ha	Bottle gourd	2161	1,171	
			Bitter gourd	1266	2,137	
			Cucumber	4413	2,116	

Indicator Number	Indicator Title	Unit	Disaggregated by	2012 Baseline	Achievements over project period (2012–2016)	Percentage Change
4.5.2-2	Number of ha under improved technologies or management practices because of USG assistance	Number	Other aquaculture management	0	146,722	
			Total with one or more improved technology			
			New	0	58,436	
			Continuing	0	88,286	
			Male	0	130,043	
			Female	0	16,679	
			Improved fish (carp) farming technology		105,599	
			Improved shrimp farming technology		41,123	
			Total	0	146,722	
4.5.2-5	Number of farmers and others who have applied new technologies or management practices because of USG assistance	Number	Producers			
			Male	0	642,074	
			Female	0	148,287	
			Aquaculture management		790,361	
			Total with one or more improved technology		790,361	
			New	0	247,398	
			Continuing	0	542,962	
			Others			
			Male		1,870	
			Female		102	
			Aquaculture management		1,972	
			Total with one or more improved technology		1,972	
			New		542	
			Continuing		1,430	
			Total	0	792,333	

Indicator Number	Indicator Title	Unit	Disaggregated by	2012 Baseline	Achievements over project period (2012–2016)	Percentage Change
4.5.2-7	Number of individuals who have received USG supported short-term agricultural sector productivity or food security training	Number	Male	0	59,299	
			Female	0	72,319	
			Producers		129,646	
			People in private sector firms		1,972	
			People in civil society			
			Total	0	131,618	
4.5.2-13	Number of rural households benefiting directly from USG interventions	Number	New	0	222,891	
			Continuing	0	570,603	
			Total	0	793,494	
3.1.9-15	Number of children under 5 reached by USG-supported nutrition programs	Number	Male	0	21,893	
			Female	0	21,112	
			Total	0	43,005	
4.5.2.8(TBD3)	Total quantity of targeted nutrient-rich value chain commodities set aside for home consumption by direct beneficiary producer households	t	Commodity		10,034	
AIN-Custom	Percentage of people living on less than USD 1.25/day (impact)	%		62	37.6	-39
AIN-Custom	Percentage of farmers increased annual income USD 100 (impact)	%		0	62.4	

Indicator Number	Indicator Title	Unit	Disaggregated by	2012 Baseline	Achievements over project period (2012–2016)	Percentage Change
AIN-Custom	Increased supply of quality postlarvae/ fingerlings to the project farmers disaggregated by shrimp and carp	Million	Carp and tilapia	0	6,300	
			Shrimp	0	1079.45	
			Total	0	7379.45	
AIN-Custom	Amount of brood supplied at FTF AIN supported hatcheries	t		0	72,250	
AIN-Custom	Amount of improved spawn produced by FTF AIN supported hatcheries	t		0	90,041	
AIN-Custom	Percentage of farmers who increased food (fish) consumption	%		3.96	3.96	78
AIN-Custom	Amount of production increased	t	Fish	0	254,566	
			Shrimp	0	10,666	
			Vegetables	0	31,655	
N/A	Yields of rice, fish and potatoes	t/ha	Fish	1.32	1.99	51
			Shrimp in fish pond	0.048	0.01	-79
			Shrimp	0.23	0.31	35
			Fish in shrimp gher	0.245	0.53	116
			Bottle gourd	24.7	13.75	-44
			Bitter gourd	7.904	18.77	137
			Cucumber	40	21.68	-46

Table 2. FTF indicators and AIN achievements.

Lessons learned and recommendations for the future

Production of clean and healthy shrimp postlarvae

The aim was to increase production of PCR-tested postlarvae so that farmers will have better access to healthy postlarvae and the risk of disease will be reduced, leading to increased production. However, in practice only a few hatcheries cooperated with the testing, and only a small percentage of shrimp postlarvae was tested. The majority of shrimp postlarvae in the market was not PCR tested. Thus, the risk of disease, particularly through contamination by non-tested postlarvae, remained high. Consequently, farmers were not willing to pay a higher price for tested postlarvae, and hatcheries had no incentive to go for more testing. Under these circumstances, it is unlikely that hatcheries in future will take up 100% PCR testing using their own resources, though this is a requirement under the Hatchery Act and Rules.

On the other hand, advanced farmers have invested in purchasing simple and easy PCR test kits (micro-pockit), showing their interest in stocking disease-free postlarvae. Now that hatcheries know that some farmers have access to this technology, the likelihood that their postlarvae will be checked before stocking will be greater.

Although many farmers still use wild-caught postlarvae, in 2016 the demand for postlarvae derived from SPF broodstocks was higher than what MKA Hatchery could supply. Unless MKA Hatchery increases its capacity, it will not be able to produce the envisaged 500 million postlarvae per year. Although semi-intensive farmers might continue to increase the use of postlarvae derived from SPF broodstocks coming from MKA Hatchery, the demand for these postlarvae will increase in the coming years, and it is unlikely that this demand can be met, as existing facilities cannot produce enough to bridge the gap.

Multiple-stocking practice, the availability of wild-caught postlarvae, inadequate timely supply of PCR-tested postlarvae and a lack of capital investment make many farmers stock a combination of PCR-tested and non-tested postlarvae or totally non-tested postlarvae. Unless the production practice elevates from extensive to improved-extensive with better management practice and some engineering improvements to ponds, it will be a long time before most farmers will use PCR-tested postlarvae or postlarve deriving from SPF broodstock. This makes full enforcement of the Hatchery Act and Rules difficult, and, as of today, almost impossible.

It is essential that the DOF has a PCR lab to provide an independent control mechanism to check hatchery efficiency and compliance in disease testing. It should be able to test for all eight viruses and two bacteria included in the SPF status, if this procedure is going to continue in future. At this moment, the DOF does not have a full-time skilled staff member to operate the PCR lab and monitor the SPF program. This shortfall needs urgent rectification.

It is envisioned that in future more SPF hatcheries will produce nauplii. The nauplii will be reared to the postlarvae stage by less specialized but biosecure hatcheries. This way, all hatcheries can benefit from this new SPF technology, which is not dependent on the supply of broodstock from the sea, does not affect the natural population of black tiger shrimp in the sea and does not carry WSSV. Gradually, more hatcheries could apply for a license to import SPF postlarvae to start their own SPF hatchery. However, one should not be so complaisant to think that SPF technology is simple. It is very complex, complicated and costly, and requires highly skilled and trained personnel.

It is essential to develop science-based guidelines, standards and an audit system for establishing, licensing and operating SPF hatcheries in Bangladesh. The DOF and SHAB should ensure that compliance to guidelines and standards are met by hatcheries and that they comply with the government's Hatchery Act and Rules. If not, these hatcheries will only claim that they are SPF, without producing real SPF postlarvae.

The domestic shrimp market has gradually been expanding in Bangladesh. This may in part be due to the lower world market price, and in part due to increased purchasing power in Bangladesh. There are rumors that the shrimp on the national market are from rejected international consignments. AIN attempted a more in-depth study of the local market but could not find enough information to estimate the total volume of the national market. More study is needed to assess the national market for shrimp.

The success of quality seed production and their use in Bangladesh's shrimp sector will largely depend on how better technology is used to produce healthy postlarvae and how many improvements to shrimp

production facilities and their management practices are made to reduce the risks of disease and improve biosecurity.

Carp genetic improvement program

Although the process has been complex, difficult and lengthy, the CGIP has progressed well and foresees success in the coming years. Based on previous experience, nursing is now done only in hapas, which has reduced the cost compared to the previous cycle when seed was nursed in net enclosures as well as hapas. Stocking density in hapas has also been reduced, which has resulted in faster growth. This experience with the rohu genetic improvement program has been applied to the selection procedures of catla and silver carp. Hatchery owners are interested in receiving genetically improved fingerlings when they are ready, likely to be between 2020 and 2022. An agreement between WorldFish and the DOF will facilitate continuation of the CGIP program beyond the lifetime of the AIN project. Necessary financial resources should be found to continue the program, as many stakeholders are waiting with high expectations to receive genetically improved carp in the coming years. Once they are adequately available, the Hatchery Act and Rules may be amended to capture the mandatory use of genetically improved broodstock.

The tagged fish will be gradually moved to DOF facilities beginning in 2017 and eventually become a part of the national carp broodstock program. Dissemination of improved fish will be done by the DOF, thus recognizing the CGIP as a national success.

Tilapia breeding nucleus (TBN) program

It is expected that the TBN system will continue in the future and that most hatcheries will replace their broodstock with GIFT broodstock. Farmers are experiencing better growth rates, and the demand for GIFT fry and broodstock is increasing. However, TBNs are experiencing continued difficulty in selling fry, particularly the mix-sex fry destined to become broodstock. This is mainly due to the long distance between TBN hatcheries and major production areas in the country. There is a need for improving awareness on the benefits of using TBN produced GIFT seed for hatchery production among tilapia hatcheries and farmers countrywide.

Photo credit: Din M Shibly/WorldFish

Harvesting fish and prawn from a gher.

The program should be continued, and the genetic quality of GIFT stock should be maintained through science-based broodstock management. Regular introduction of new GIFT broodstock might be necessary to maintain the genetic quality. Necessary amendments to the Hatchery Act and Rules may be necessary to further promote the use of GIFT broodstock in tilapia hatcheries.

Freshwater prawn hatcheries

Freshwater prawn hatcheries in FTF's ZOI have been experiencing serious postlarval mortalities over the past several years, and many hatcheries are now shut down. No systematic investigation has been done, though some evidence suggests that several viral pathogens are the primary course of mortality. It is necessary to better understand the disease situation and causative agents in Bangladesh's freshwater prawn sector. A medium- to long-term solution could be to develop a disease-resistant strain of freshwater prawn in Bangladesh. The immediate solution would be to allow the private sector to import certified and guaranteed SPF prawn broodstock to be used for seed production in the country. Improving biosecurity in hatcheries would be an important prerequisite.

Small fish, nutrition and gender

Together, these nutrition-focused activities have helped households increase their consumption of fish and vegetables and diversify their diets, providing families with a greater intake of vital micronutrients. The Dietary Diversity Index (DDI) indicates the ability of a household to access a variety of foods. In the coastal zone, raising the DDI through increased fish consumption is nearly impossible as fish represents 80% of their daily meals. For increased DDI, there is a need to focus more on the consumption of milk and eggs. However, the amount of fish and the variety of fish in the diet can be increased. Fish is also an important source of cash, which can be utilized to purchase milk and eggs. Calcium from fish bones is bioavailable comparable to milk. Since milk is in short supply in rural areas, only 20% of people on average drink milk, so small fish can be an important source of calcium. Furthermore, additional work is needed to increase fish consumption by children.

More study is needed on the preparation methods of fish. If nutrients are concentrated in the head or organs of small fish, then there may be scope to increase nutrient intake by increasing the utilization of those fish parts also from larger cultured fish.

Initiatives are necessary to increase breeding of different fish species, particularly indigenous species. Indigenous species have a high value in the market. A variety of fish in the market will motivate people to eat more fish. Also, different fish contain different nutrients, so by eating a variety of fish, the overall range of consumption of micronutrients will increase.

Legislation and the development of state capacity

Developing technical capacity, increasing scientific knowledge and improving management is necessary for all aspects of aquaculture, among both the state and private sector. Improved technical capacity will allow the DOF to better enforce both the Hatchery and Feed Acts and Rules. As genetically improved carps and more broodstock and fingerlings of GIFT become available, it might be necessary to amend the Hatchery Act and Rules to ensure these new developments are fully reflected in the legislation.

The Feed Act and Rules do not have a provision for small feed mills and feed that is made at the farm and for sale. However, the Fish Act and Rules are now in practice not applied to small-scale feed production. Since those small feed mills mainly produce for their own use, the exact composition as per proximate analysis of the feed is less concerning. However, it should be assured that small feed mills use safe ingredients, because the feed may influence food safety. Since it is difficult to stop small-scale feed production for person use, more emphasis should be placed on the quality control of available feed ingredients.

Besides feed labs for proximate analysis, there should be good capacity for the analysis of feed for heavy metals, pesticides and antibiotics. Even though some labs are available, access is variable and the results of tests were found to vary for the same sample. Since feed samples can be easily couriered, it is recommended to provide close support to one key lab, which can handle samples to test for heavy metals, pesticides and antibiotics across Bangladesh.

Conclusion

The AIN project, financed by USAID and implemented by WorldFish in partnership with an array of local stakeholders, proved beyond doubt that there is great potential for the aquaculture sector in Bangladesh to increase production, both for income generation through commercial aquaculture and supporting food and nutrition security through homestead/household aquaculture. Key to this growth will be the availability of good quality healthy seed, feeds with high nutritional quality, adequate health and production management advice. Improving research capacity at both state and private levels is needed to develop technology applicable to the conditions and requirements of Bangladesh. Besides helping boost fish production, household income and nutrition, and employment opportunities in the aquaculture sector, the successes and education achieved through the AIN project can be used to improve national policies in support of further strengthening and improving poor and nutrition targeted aquaculture in Bangladesh. This will ensure that fish farmers and their families—many of whom are poor and live in rural areas—have sustainable livelihoods and happy, healthy lives.

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