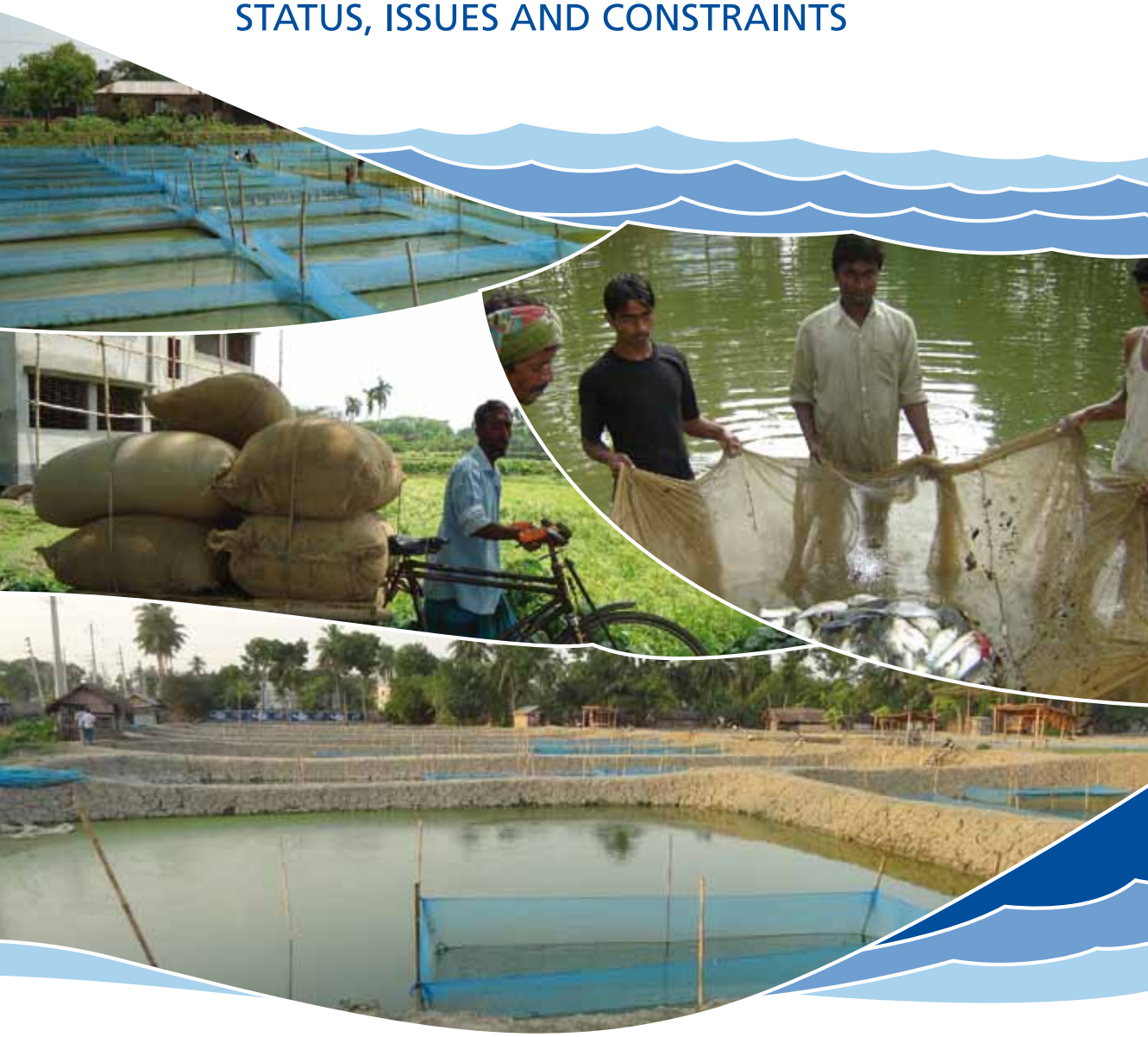
Food and Agriculture Organization of the United Nations

AQUACULTURE SEED AND FEED PRODUCTION AND MANAGEMENT IN BANGLADESH -

STATUS, ISSUES AND CONSTRAINTS



Cover photographs:

Front cover
Top: Rearing of hormonal sex reversed Nile tilapia (*Oreochromis niloticus*) fry in hapas, Trishal, Bangladesh (Courtesy of FAO/Nesar Ahmed). *Middle left:* Transport of feed ingredients in a rickshaw van, Mymensingh, Bangladesh (Courtesy of FAO/Nesar Ahmed). *Middle right:* Harvest of Indian major (rohu, catla and mrigal) and exotic carps (silver, grass and common) from a semi-intensive ploysculture pond in Mymensingh, Bangladesh (Courtesy of FAO/Mohammad R. Hasan). *Bottom:* Indian major carp fry are kept in hapas for conditioning for 1-2 days before being sold and transported, Jessore, Bangladesh (Courtesy of FAO/ Mohammad R. Hasan).

Back cover
Top to bottom: A woman farmer showing her harvested shrimp, Khulna, Bangladesh (Courtesy of FAO/Begum Nurun Naher). Farm-made/semi-commercial feed are being packed after sun drying, Bagerhat, Bangladesh (Courtesy of FAO/Nesar Ahmed). A farmer feeding his fish in a pangas (*Pangasianodon hypophthalmus*) farm in Trishal, Bangladesh (Courtesy of FAO/Mohammad R. Hasan).

Cover design:
Mohammad R. Hasan and Koen Ivens

AQUACULTURE SEED AND FEED PRODUCTION AND MANAGEMENT IN BANGLADESH - STATUS, ISSUES AND CONSTRAINTS

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Preparation of this document

This document presents the findings of the Food and Agriculture Organization of the United Nations (FAO) Technical Cooperation Programme Facility (TCPF) Project (TCP/BGD/3301) "Identification and understanding of key technical, economic and social constraints to seed and feed production and management in Bangladesh", which was implemented between January and August 2012. The project was initiated with two national field surveys on the status and constraints of (i) the aquaculture seed subsector and (ii) aquafeed subsector. These field surveys were conducted from January to March 2012 by two national consultants, and followed by an FAO country field mission (April 2012) and a verification mission by two international consultants (August 2012) for these two subsectors.

The printed publication contains the main report synthesizing major findings of the project. Its conclusions and recommendations were drawn from the reports that have been made available on the accompanying CD–ROM: (i) the reports of the field survey on technical, economic and social constraints to aquaculture seed and feed production and management; and (ii) the reports of the verification mission on aquaculture seed and feed production and management. The reports on the CD–ROM have been reproduced as submitted with minor editing.

Although modestly funded, this TCPF project was implemented and completed in a short period on schedule and within budget. It accomplished all its objectives. Much of this success is owed to the full support of Syed Arif Azad, Director General of the Department of Fisheries (DoF), Government of Bangladesh, and the assistance and generous information shared openly by the officers of the DoF headquarters and field offices. The smooth execution of the project activities was a result of the timely assistance and good counsel from the staff of the Office of the FAO Representation in Bangladesh, in particular, Dominique Burgeon and Michael Robson, former and present FAO Representatives, and Begum Nurun Naher, National Operations Officer. Weimin Miao, Regional Aquaculture Officer, FAORAP, provided technical support and guidelines for the project.

The manuscripts in this report were reviewed for technical content, FAO house style and language quality by Mohammad R. Hasan and J. Richard Arthur. For consistency and conformity, scientific and English common names of fish species are from FishBase (www.fishbase.org/search.php). Marianne Guyonnet is acknowledged for her assistance in quality control and FAO house style. Koen Ivens prepared the layout design for printing. Publication and distribution of the report were undertaken by FAO, Rome.

Abstract

This document presents the findings of the Food and Agriculture Organization of the United Nations (FAO) Technical Cooperation Programme Facility (TCPF) Project (TCP/BGD/3301) "Identification and understanding of key technical, economic and social constraints to seed and feed production and management in Bangladesh", implemented between January and August 2012. The project was initiated by national field surveys conducted between January and March 2012 by two national consultants who investigated the status and constraints of the aquaculture seed and aquafeed subsectors. These field surveys were then followed by an FAO country field mission undertaken in April 2012 and by a verification mission by two international consultants in August 2012. These missions collected further evidence and verified the information revealed by the two field surveys through in-depth unstructured interviews and focus-group discussions with the different players in the seed and feed supply chain, by site visits to projects, facilities and farms in several aquaculture-rich districts of the country and through the holding of a stakeholders' workshop. Together, these activities identified the key technical, economic and social constraints hindering the development of the aquaculture seed and feed production and management subsectors in Bangladesh. They also provided recommendations related to improving the four key areas of improved seed quality, improved aquafeed quality, strengthened capacities of farmers to utilize feed efficiently, and increased technical efficiencies of small-scale aquafeed producers. This publication and the accompanying CD–ROM present (i) a synthesis of the project's major findings, including the conclusions and recommendations of the field surveys, FAO country field mission and the verification mission (including the stakeholders' workshop); (ii) reports of the field surveys and (iii) the reports of the verification mission. The recommendations contained in this document should lead to a sustained improvement in the technical and economic efficiencies of the main players in the aquaculture seed and aquafeed subsectors in Bangladesh, from the raw material suppliers to the farmers. This is expected to improve their productivity and economic returns and assure the sustainable growth of the country's aquaculture sector.

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Abbreviations and acronyms

BARC	Bangladesh Agricultural Research Council
BAU	Bangladesh Agricultural University
BFRI	Bangladesh Fisheries Research Institute
BMP	better management practice
BSFF	Bangladesh Shrimp and Fish Foundation
DoF	Department of Fisheries
FAO	Food and Agriculture Organization of the United Nations
FCR	feed conversion ratio
FIRA	Aquaculture Branch, Fisheries and Aquaculture Department of FAO
FSMP	Fish Seed Multiplication Programme
GMP	good management practice
HACCP	Hazard Analysis and Critical Control Point (system)
IM	intra-muscular
IMC	Indian major carp
IP	intra-peritoneal
NACA	Network of Aquaculture Centres in Asia-Pacific
NGO	non-governmental organization
PPP	public–private partnership
R&D	research and development
TCP	Technical Cooperation Programme
TCPF	Technical Cooperation Programme Facility

Executive summary

Bangladesh's rapidly expanding aquaculture sector has put an increasing strain on the production resources, and the demand for quality inputs, especially seed and feed, is rising. This is happening even as the genetic quality of major cultured species is believed to be in need of maintenance or improvement and the cost of good-quality feed ingredients is increasing.

This technical report presents the findings of the Food and Agriculture Organization of the United Nations (FAO) Technical Cooperation Programme Facility (TCPF) Project (TCP/BGD/3301) "Identification and understanding of key technical, economic and social constraints to seed and feed production and management in Bangladesh", implemented between January and August 2012. The project was initiated by national field surveys conducted between January and March 2012 on the status and constraints of the aquaculture seed and aquafeed subsectors that were undertaken by two national consultants. These surveys were then followed by an FAO country field mission undertaken in April 2012 and by a verification mission in August 2012 by two international consultants with expertise in broodstock management and seed production and in aquafeeds. These two missions collected further evidence and verified the information revealed by the field surveys through in-depth unstructured interviews and focus-group discussions with the different players in the seed and feed supply chain, by site visits to projects, facilities and farms in several aquaculture-rich districts of the country, and through the holding of a stakeholders' workshop.

Together, these activities identified the key technical, economic and social constraints hindering the development of the aquaculture seed and feed production and management subsectors in Bangladesh. They also provided recommendations related to improving the four key areas of improved seed quality, improved aquafeed quality, strengthened capacities of farmers to utilize feed efficiently, and increased technical efficiencies of small-scale aquafeed producers. This publication and the accompanying CD–ROM present a synthesis of the results of the field surveys, country field mission and verification mission (including the stakeholders' workshop).

The findings of the various project activities outlined above support the following conclusions:

- The Brood Banking Programme through fish seed multiplication farms (FSMFs) has had some impact on improving the quality of carp broodstocks. It would have achieved more if the farms had had better resources, expertise and physical facilities, and their efforts had been more strongly focused on broodstock development and providing technical advice and training to hatcheries. Private hatcheries produce almost all of the seed required by fish farmers (as well as by shrimp and prawn farmers), and there seem to be no shortfalls that government seed multiplication farms and hatcheries need to fill. This argues for eliminating the production and sale of seed by the FSMFs (which is usually sold at below production cost) in order for them to concentrate on genetic improvement.

- A number of strategies have been adopted by freshwater fish farmers to optimize the utilization of feed by the fish. The polyculture of Indian major, Chinese and common carps is a common and proven practice to utilize feed efficiently. Other innovative practices include the stocking of other high-value species, as well as carps, with the main species, usually striped catfish (*Pangasianodon hypophthalmus*), and their feeding with a specific feed formulation. Interviews have revealed that farmers barely make a profit from the culture of striped catfish, but are able to compensate for this with the sale of high-value species such as local and Thai varieties of climbing perch (*Anabas testudineus*), stinging catfish (*Heteropneustes fossilis*) and walking catfish (*Clarias batrachus*). Similarly, tilapia farmers stock other fish species, including Indian major carps (*catla [Catla catla*], mrigal [*Cirrhinus cirrhosus*] and rohu [*Labeo rohita]*), Chinese carps (bighead carp *[Hypophthalmichthys nobilis]*, silver carp *[H. molitrix]*, black carp *[Mylopharyngodon piceus]*, and grass carp *[Ctenopharyngodon idella]*); and common carp (*Cyprinus carpio*). These are feed-optimizing strategies.
- The key constraints to producing quality feed include rising production costs, which are driven mainly by the higher cost of ingredients (most of which are imported), and the lack of means to enforce compliance of quality standards for feed ingredients and finished products. The latter is firstly a policy constraint and secondly a capacity-building issue; i.e. a lack of farmers' capacity to assess and demand quality feed, but also their lack of capital to purchase higher-priced quality feed. This is compounded by poor-quality inputs (seed and feed) and abetted by suboptimal farm management practices. The structure of the feed industry, which consists of small farm-made feed formulators, small- and medium-scale commercial feed manufacturers, and large livestock feed manufacturers producing well-known brands of poultry feed (the bulk their output) and fish and shrimp feed, presents a difficult policy issue and capacity-building task. The small producers tend to produce lower-quality feeds (in terms of nutritive value and structure), and the sector itself is only operating at 45 percent capacity. The small producers suffer from the use of low-quality raw materials and an unreliable power supply. Feed quality standards, manufacturing equipment and associated processes also need upgrading.
- Encouraging developments in the shrimp sector include farmers being assisted by the feed companies to take up better management practices (BMPs), to move from extensive to semi-intensive culture, and to use quality seed and feed. Extension materials and technical advice are usually provided to freshwater fish farmers through the feed dealers. Although feed dealers sometimes provide credit to loyal customers, not many farmers are extended this facility.
- The use of additives is fairly common (and could intensify with increasing problems of water quality and disease), and an assessment of their efficacy would provide the farmers with a scientific basis for deciding whether or not to continue using these supplements. The Fish Feed and Animal Feed Act (2010) includes provisions on their sale and use, and might have to be

expanded if some additives are found to have adverse effects on human health and the environment.

- There are four key areas that could boost the technical and economic efficiencies of farm-made feed and small commercial feed producers: (i) assurance of the quality of ingredients; (ii) upgrading of equipment; (ii) provision of technical advice and training on good manufacturing practice; and (iv) stabilizing the cost of the ingredients. A reliable power supply from the grid would raise technical efficiency considerably, as well as reduce downtime or the need for an alternative power generator, which adds to production costs.

The project has proposed a number of recommendations that address the issues crystallized in the conclusions. These include:

- **Improve seed quality by developing and implementing selective breeding programmes for the important species-groups.** To support this programme, the capacities of government FSMFs and the focusing of their efforts on broodstock development needs to be strengthened. While the Fish Hatchery Act (2010) provides for hatchery registration and certification, this should be accompanied by a certification standard process and hatchery better management practice (HBMP) guidelines.
- **Improving aquafeed quality by developing the guidelines and technical support to implement the Fish Feed and Animal Feed Act (2010).** The guidelines could be developed through a national consultation process led by the Department of Fisheries (DoF).
- **Improving the capacity of farmers to utilize feed efficiently.** To accomplish this, the government should develop and promote the adoption of BMPs. Farmers should be encouraged to organize themselves into clusters or associations for better uptake of BMPs.
- **Improving the technical efficiencies of small aquafeed producers.** To accomplish this goal, farmers need to be assured of a reliable supply of quality key ingredients at a stabilized cost, assistance with the upgrading of equipment and processes, training in good manufacturing practice, and encouragement to organize themselves to achieve better economies of scale in buying raw materials and for other transactions.

A semi-intensive shrimp (black tiger shrimp Penaeus monodon*) farm in Bagerhat, Bangladesh. Electricity operated aerator is generally used to maintain the optimum level of oxygen in the water.*

COURTESY OF FAO/MOHAMMAD R. HASAN

A synthesis of key technical, economic and social constraints to seed and feed production and management in Bangladesh

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1. Introduction

The growth of Bangladesh's aquaculture sector has been facilitated by the use of hatchery-bred seed and the application of prepared feeds. The supply of fish seed of common aquaculture species has been sufficient to satisfy demand. With the intensification of aquaculture, commercially produced aquafeeds have been made available by feed manufacturers, which vary in scale from small farm-made feed formulators operating in rural population centres, to small- to medium-scale commercial operations, to the large national and multinational feed millers that produce poultry and aquaculture feeds. The quality of both inputs (seed and feed) has been seen as a problem that is generally expressed at the farm level as poor yield performance and higher cost of production. As this publication describes, this creates a cycle of inefficiency in the seed and feed supply chains.

For aquaculture seed, the generally accepted causes of low quality are the deteriorating genetic quality of broodstocks and their improper management. These apply particularly to Indian major and Chinese carps, which together are the most important cultured species group by volume. Feed quality, on the other hand, has been largely a problem faced by the small farm-made feed producers and the small commercial feed millers. A variety of reasons for this have been put forward: the lack of quality standards for ingredients and finished products and, where these exist, the lack of ability of the government to enforce them; and the increasing cost of producing feed and, therefore, the higher cost of the feed produced, to which farmers adapt by opting for cheaper but lower-quality feeds that, in turn, the feed producers are obliged to place in the market to maintain their customer base. While these may not necessarily apply to the large manufacturers producing popular brands, they also have to cope with increasing production costs that are particularly driven by the increasing cost of feed ingredients, almost all of which are imported. The coping mechanism is to increase the price of their product and, positively, to adopt a business strategy that consists of providing advice and technical assistance to dealers and farmers on better feed management and, for some companies, improved culture practices and systems.

There is also a third issue, which is linked to the desire to boost performance with supplements. Small- and medium-scale farmers use various feed additives to improve fish or shrimp growth and protect them from pathogens. The efficacy of these compounds is largely anecdotal and needs to be scientifically assessed, as do their impacts on human health and the environment. Many of the issues related

to seed and feed quality can be addressed by existing legislation; i.e. the Fish Hatchery Act (2010), and the Fish Feed and Animal Feed Act (2010). These laws need implementing guidelines and the institutional and human capacity for their implementation, as well as robust mechanisms to enforce them. Finally, there is a widely felt need to build the capacity of farmers to demand and assess standard-quality seed and feed and to utilize these two inputs more efficiently.

1.1 Background

In 2012, aquaculture contributed some 1.73 million tonnes to the country's total fish production of 3.26 million tonnes (FAO, 2014). This is an almost 19-fold increase from the 1980 aquaculture production of 91 030 tonnes.

More farms have been established, and 22 freshwater finfish species,[1] nine of which are exotic,[2] are now being cultured. Coastal aquaculture is confined to marine shrimp (primarily giant tiger prawn, *Penaeus monodon;* local name: bagda) and freshwater prawns (primarily giant river prawn, *Macrobrachium rosenbergii*; local name: golda) and the fattening of crab (giant mud crab, *Scylla serrata*). The country's rapidly expanding aquaculture sector has put an increasing strain on the production resources - demand for quality inputs, especially seed and feed, is rising. This is happening even as the genetic quality of the major cultured species is felt to be deteriorating and the cost of good-quality feed ingredients is increasing. This broad description of the status of these two subsectors can manifest itself in the economic phenomenon called "cost-price squeeze", which prompts coping strategies on the part of the players in the seed and feed supply chains. These coping strategies and their implications were among the factors that the project sought to identify and describe.

A set of scientifically collected and analysed technical information provided the project with a useful reference. These were the reports of two field surveys conducted by two national experts on the status and constraints of the aquaculture seed and aquafeed subsectors. These reports provided the subsequent missions with technically robust information for the discussions that ensued with the major players in the seed and feed supply chains, namely, the broodstock producers, hatchery operators, fry nursery operators and traders, feed manufacturers, traders, retailers and farmers.

[1] There are 13 indigenous species of finfish cultured in Bangladesh. These include 3 Indian major carps: catla (*Catla catla*), mrigal (*Cirrhinus cirrhosus*) and rohu (*Labeo rohita*); 5 other carps or barbs: bata (*Labeo bata*), kuria labeo (*L. gonius*), orangefin labeo (*L. calbasu*), olive barb (*Systomus sarana*) and putitor mahseer (*Tor putitora)*; 4 catfishes: Gangetic mystus (*Mystus cavasius*), pabdah catfish (*Ompok pabda*), stinging catfish (*Heteropneustes fossilis*) and walking catfish (*Clarias batrachus*); and climbing perch (Anabas testudineus).

[2] The 9 introduced (*exotic*) species of finfish being farmed include 4 Chinese carps: bighead carp (*Hypophthalmichthys nobilis*), silver carp (*H. molitrix)*, black carp (*Mylopharyngodon piceus*), and grass carp (*Ctenopharyngodon idella*); and common carp (including mirror carp) (*Cyprinus carpio*), silver barb (*Barbonymus gonionotus*), striped catfish (*Pangasianodon hypophthalmus*), Nile tilapia (*Oreochromis niloticus*) and a Thai variety of climbing perch (*Anabas testudineus*).

2. Objectives

FAO implemented the Technical Cooperation Programme Facility (TCPF) Project (TCP/BGD/3301) "Identification and understanding of key technical, economic and social constraints to seed and feed production and management in Bangladesh" from January to August 2012.
The main objectives of this TCPF project were to:

- assess the implementation of the programme to improve fish seed quality, recommend improvements and identify future needs;
- investigate the technical, economic and policy constraints related to the production of quality aquafeeds;
- identify the major issues that need to be addressed to build the capacity of aquafarmers to optimize the use of feed and feed additives;
- identify the support services that are needed to build the capacity of small-scale aquafeed producers to enable them to improve the technical efficiency of their production processes.

3. Materials and methods

As part of this project, two national field surveys on the status and constraints of the aquaculture seed and aquafeed subsectors were conducted by two national consultants[3] between January and March 2012. These field surveys were followed by an FAO country field mission that was undertaken (16–29 April 2012)[4] and a verification mission on seed and feed conducted by two international consultants, on seed and feed (9–19 August 2012).[5] These two missions collected further evidence and verified the information revealed by the two field surveys through in-depth unstructured interviews and focus group discussions with the different players in the seed and feed supply chain, and through site visits to projects, facilities and farms in several aquaculture-rich districts of Mymensingh, Jessore, Khulna, Bagerhat, Comilla and Bogra. The field visit activities included on-site interviews and focus group discussions with:

- government seed multiplication (brood and hatchery) farm managers and technicians;
- private hatchery operators and technicians;
- private hatchery operators cum grow-out farmers;

[3] The field surveys were conducted by Dr Mohammad Rafiqul Islam Sarder (National Consultant on Aquaculture Seed and Broodstock Management) and Dr Nesar Ahmed (National Consultant on Aquaculture Feed).
[4] The FAO mission team consisted of Dr Mohammad R. Hasan (Aquaculture Officer, Aquaculture Service, FAO Rome) as Mission Leader, Mr Weimin Miao (Regional Aquaculture Officer, FAO Regional Office for Asia and the Pacific, Bangkok), and Mr Pedro B. Bueno (FAO Consultant on Socio-economics of Feed and Seed Production, Distribution and Utilization).
[5] The verification missions were undertaken by Dr Padmanav Routray (FAO Consultant on Aquaculture Seed and Broodstock Management) and Dr Thomas Ashley Shipton (FAO Consultant on Aquaculture Feed).

- nursery operators;
- eed traders;
- freshwater fish farmers;
- feed manufacturing plant managers and technical personnel;
- feed depot managers and feed retailers;
- feed company field managers/technical advisers;
- freshwater fish and shrimp farmers.

As part of the FAO field mission, a workshop attended by representatives of different stakeholder groups (government extension unit, government seed multiplication farms, feed manufacturers, academic institutions, non-governmental organizations [NGOs] and FAO) was organized on 26 April at the FAO Bangladesh Office. The workshop discussed the findings of the field visits and provided advice on making the study more relevant to the issues of Bangladesh aquaculture, as well as economic development in general, and made suggestions on follow-up actions.

The outcomes of the consultations and the stakeholders' workshop appear as Annex 1.

4. Findings of the project

The project outlined a supply chain-based analytical framework in identifying key inefficiencies in the seed and the feed industries. The supply chains for seed (one type) and feed (two types) were modelled, and constraints were identified along each chain, which tended to intensify by their interactions through the supply chain. For example, poor-quality feed has an impact at the farm level in terms of poorer growth and therefore lower productivity and lower revenue, which makes farmers less able to afford better-quality and higher-priced feed. Annex 2 presents an indicative national programme to improve efficiencies along the aquafeed supply chain is presented. The same applies to broodstock of poor genetic quality, which produces lower-quality and less-healthy seed that grow more slowly and are more prone to disease at the farm. The lower farm productivity results in both lower revenue and lower capacity to buy quality inputs. This cycle of inefficiency is perpetuated, and will grow worse in the supply chain unless the causes are addressed. The project provided some examples of ways to address the inefficiencies and also developed an indicative framework for both the seed and the feed sectors as an example of a template for a national research and development (R&D) programme to identify, prioritize and develop projects that address key constraints or inefficiency factors. The framework provides an indication of institutional collaboration. Annexes 3 and 4 present the illustrative examples of the R&D frameworks on seed and feed, respectively. Annex 5 presents the socio-economic elements pertaining to best practices for feed production and marketing and seed distribution.

4.1 Aquaculture seed

4.1.1. Status of aquaculture seed production in Bangladesh

The seed supply chain starts with the government fish seed multiplication farms (FSMFs), which produce broodfish that they sell to hatcheries, as well as fish seed that is directly sold to fish farmers. The next players in the chain are the hatcheries, some of which maintain broodstock and usually produce several species, although some have one or two preferred species such as Nile tilapia and striped catfish. The next players along the chain are the nursery operators, which buy fry from hatcheries and raise them to fingerling or juvenile size depending on the demand of their clients. A few hatcheries have nurseries, and some farms have an integrated operation that includes a hatchery, a nursery (which is in fact a stunting pond), and grow-out ponds. A striped catfish farm in Mymensingh also produces feed for its operation and sale. The last player is the grow-out farmer.[6]

A large number of hatcheries have been established in the country to provide the required quantity of seed, but maintenance of seed quality is seldom given the proper attention and effort. There are about 70 government FSMFs and an estimated 1 000 private hatcheries. Eleven native freshwater species and nine exotic species, as well as penaeid shrimp and freshwater prawns (*Macrobrachium* spp.), make up the entirety of cultured species. There is as yet no significant marine fish cage-culture subsector in Bangladesh. The predominant species groups are the Indian major carps and the Chinese carps, including common carp. Table 1 shows aquaculture production by species group for the period 2010–2012.

TABLE 1
Aquaculture production by species group, 2010–2012

Species group	Production (tonnes)		
	2010	2011	2012
Indian major carps	600 003	650 207	679 877
Exotic carps including silver barb	280 752	268 959	306 140
Striped catfish	125 724	156 375	258 137
Nile tilapia	24 823	104 716	123 712
Other species	189 229	216 163	221 026
Marine shrimp and freshwater prawns	87 984	127 339	137 174
Total	**1 308 515**	**1 523 759**	**1 726 066**

Source: FAO (2014).

[6] For the purpose of analysing the inefficiencies in the supply chain in line with the objectives of this TCPF Project, the last player in the chain is the farmer. For the follow-up activity, the project suggests extending the analysis to the product (i.e. fish) market and conducting a market chain analysis.

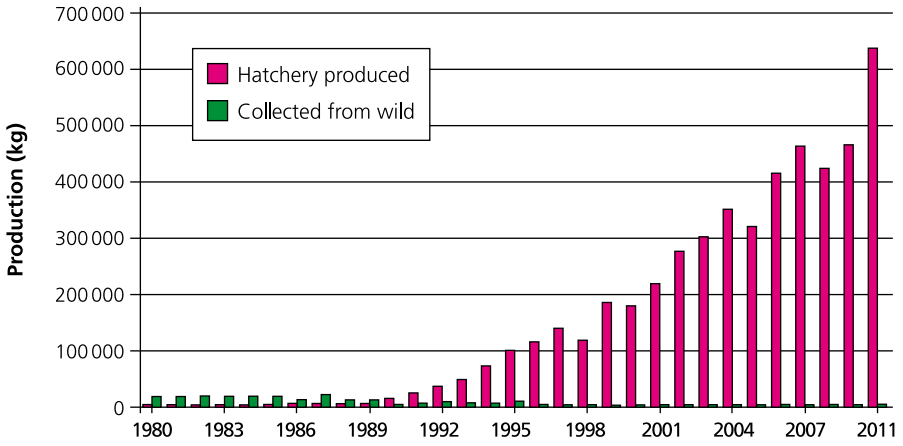
In 2010, the production of seed, expressed in kilograms of seed, by source was:

- government hatcheries (119 hatcheries): 5 600 kg, or 1.2 percent of total production;
- private hatcheries (931 hatcheries): 460 000 kg, or 98.3 percent of total production; wild/natural sources: 2 200 kg, or 0.5 percent of the total.

This highlights the important role of the private seed producers. The rapidly growing dependence of aquaculture on hatchery-bred seed is exemplified by the development in Indian major carps, illustrated in Figure 1). Wild source had stagnated or declined to almost nil by 2000, as hatchery-produced seed, which began as a supplement in 1985, increased very rapidly to meet the demand.

FIGURE 1

Growth in natural and hatchery-bred seed of indigenous and exotic carps, 1980–2011



Note: 1 kg of seed = about 0.15 million hatchlings.

Source: M.R.I. Sarder, Bangladesh Agricultural University, Mymensingh, Bangladesh, personal communication (2013).

The ongoing brood banking project on Indian major carps is conducted in 20 government FSMFs. The project aims to: overcome inbreeding problems and ensure a supply of quality broodstock as well as fingerlings; improve growth performance through genetic improvement of broodstock; and train fish farmers and hatchery and nursery owners in hatchery, nursery and farm management.

4.1.2 Aquaculture seed issues

Policy and regulations

- There is a lack of needed regulation and the absence of an effective implementation scheme for regulating the fish seed production sector. The Fish Hatchery Act (2010) has been introduced, but it has not been widely promoted, and awareness of it is limited.
- The market price of fish seed has remained stable, while the production cost of hatcheries and grow-out farms has been increasing owing to higher input costs; this has implications for the efforts to improve seed quality at the hatchery level.
- Bangladesh is prone to flooding, so that escapes of hatchery-produced fish from culture facilities can have significant impacts on the genetic quality of natural populations.
- The use of hormones in producing all-male Nile tilapia could be a potential trade issue for aquaculture products.
- There are too many government FSMFs (60–70) and private hatcheries (reportedly more than 1 000); this hinders efforts to upgrade the fish-seed production sector (largely because of too many suppliers competing for what will soon be a saturated seed market).
- There has been no effective measure to address the deteriorated genetic quality of Chinese carps, which are among the important species cultured in the country.
- It is not clear how the national research institutes such as the Bangladesh Fisheries Research Institute (BFRI) are providing technical backstopping to the government hatcheries.

Broodstock development

- Government FSMFs undertake too many other activities. Staff are overextended with too many types of activities, which include supplying not only broodstock but also fry/fingerlings to farmers, and other functions. This weakens their effectiveness in producing good-quality broodfish.
- Government hatcheries/multiplication farms provide broodstock to private hatcheries at a price lower than table fish in the market, which seems to be a disincentive for farm managers and staff to perform better and a waste of opportunity. Moreover, it delivers the wrong message to the private hatchery operators on the value of good broodstock.
- The Brood Bank Project has had some positive impact on improving the genetic quality of the broodstock used in private hatcheries. However, continuous collection of wild fry for rearing broodstock is not "brood banking" in a real sense. It is not a sustainable and effective way to ensure the quality of broodstock.
- The status of the original strains of grass carp, silver carp, bighead carp and black carp obtained by the BFRI from China is not clearly known. For example, how many fish are left and how are they being maintained?

- Broodstock rearing and management need improvement: broodfish are often reared as if they were destined for sale as table fish.
- Individual broodfish are used too soon (i.e. in their early stage of maturation), which is not good for maintaining a good broodstock population and may not result in good-quality seed, as newly matured fish do not always produce high-quality eggs.
- There is a lack of pure strains of exotic carps (Chinese and common), striped catfish, Thai variety of climbing perch and Nile tilapia.
- There is a lack of quality broodstock in government and private hatcheries.
- Natural fry are unavailable or becoming scarce.
- The quality of broodstock is uncertain.
- There is inadequate pond space for brood banking.

Hatchery

- Government hatcheries/multiplication farms do not have adequate capacity (in terms of infrastructure, equipment and personnel) to perform the function of providing quality broodstock for the private hatcheries.
- Private hatcheries vary widely in their capacities and management practices. Some hatcheries do not even have a broodstock pond; individual hatcheries often conduct induced breeding of all cultured fish species, which is beyond their physical and technical capacity of producing quality fish seed.
- The private hatcheries are practicing multispawning of broodfish over very short intervals, i.e. within two to three weeks. This not only results in very high mortality during the second breeding but also affects the quality of the seed produced by these broodfish.
- In the breeding practices, broodfish to be used for induced spawning are not properly selected according to standard procedure; selection is often based only on external observations.
- There is a general lack of technical capacity of the workers performing induced breeding in both private hatcheries and government multiplication farms.
- There are inadequate numbers of personnel (or personnel skills), including those of hatchery technicians. Hatchery staff lack training; many staff learned the techniques by doing the work. While they have developed a good level of skill, they need an understanding of the scientific basis of what they are doing, so that they can further improve and even innovate.
- Unreliable power supply is a major problem for hatchery operators. Operating a backup power generator adds to cost. A sudden outage can wipe out an entire hatchery run.
- The seasonal employment of contractual or casual workers is a social issue. Government broodstock and hatchery centres operate only for some four months of the year, and private hatcheries are busy for only half of the year.

Nursery

- Nursery operations have not been paid adequate attention; no standards are followed in nursery operations and products.
- Probably there are too many nurseries.

- There is also the social issue of seasonal employment of the nursery operators and their workers, as well as the seed retailers.

Grow-out

- Optimizing stocking densities and the stocking of a combination of species in a polyculture system is a good strategy but needs scientific guidance.
- Better management practice (BMP) guidelines that include culture techniques, feed management and health management are not available to farmers.

There are inefficiencies related to the constraints that have been identified at each node of the supply chain. These are summarized into the "inefficiency factors" shown in Table 2. Their interactions in the supply chain are illustrated in Table 3. The impacts of these inefficiency factors invariably result in a lowering of product quality along the entire chain and in poorer growth performance and lower yield, and probably in less revenue at the fish-farm level.

TABLE 2
Inefficiency factors in the seed supply chain

Broodstock farm	Hatchery	Nursery and retailing	Grow-out farm
• Too many objectives per farm and probably too many brood farms • Inadequate technical manpower and physical facilities • Uncertain genetic quality of broodfish • Difficulty of obtaining quality broodfish	• Poor broodstock management • No standard spawning practice • Unreliable power supply	• Poor nursing techniques • Poor infrastructure and logistical facilities • Difficult transport system • Probably too many nurseries	• Inadequate culture techniques • Inability to identify good quality seed • Inability to demand • good quality seed

TABLE 3
Impacts of inefficiency factors on the performance of the players along the seed supply chain

Broodstock farm	Hatchery	Nursery and seed distribution	Grow-out farm
• Low-quality broodstock	• Low-quality spawners • Low-quality seed • Increased cost of operation	• Competing based on factors other than quality, such as volume, delivery and price	• Poor performance • Low yields • Higher operations cost

4.1.3 Findings of the verification mission on seed

The verification mission confirmed the following weaknesses in the country's seed production sector:

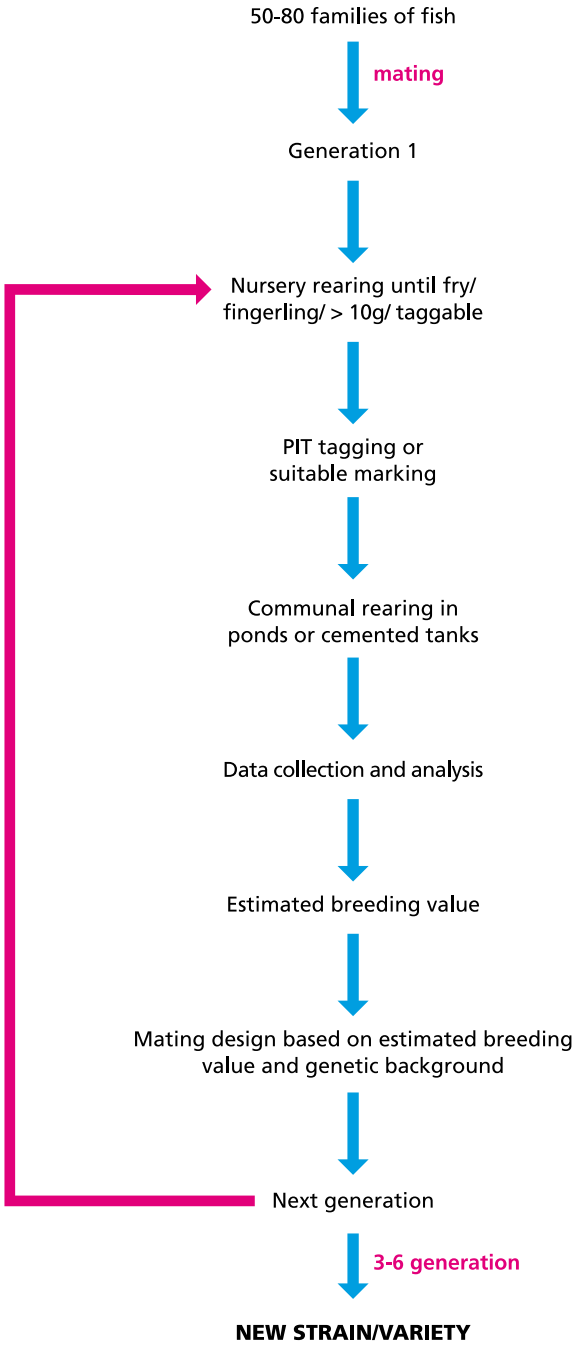
- poor-quality seed, growth retardation in the culture phase, and no broodstock management and genetic norms followed in most of the hatcheries;
- hatcheries exchanged their stock with riverine stocks from brood banks without assessing their genetic status;
- no use of preserved milt for stock up-gradation;
- very few fish (low population size) were used for breeding purposes every year;
- poor knowledge on quality seed;
- genetic introgression of silver carp with bighead carp;
- no proper enforcement of seed certification and hatchery act.

The mission identified the following key areas essential for the development of seed quality:

1. **Brood banking:** At present, there are 21 seed hatcheries declared as brood banks in Bangladesh under the management of the Department of Fisheries (DoF) (20) and (Brac)[7] (1). In a true sense, these centres are not working as brood banks, as separate stocks representing different genetic strains (e.g. Padma stock, Jamuna stock, Halda stock, local stock) are not properly maintained owing to space constraints. The mission is of the view that four brood banks (one being the nucleus centre and others as satellite centres) with all facilities and procedures should be established to maintain breeding plans and genetically improved stocks. One of these centres could be the hatchery located at Kotchandpur, Nimgachi, Parbatipur or Raipur. These hatcheries have physical facilities that can be renovated, and additional facilities can be created for activities such as soil and water analysis and semen banking. Once selected, the centre may be adequately staffed to work as a centre of excellence and can be an international centre for germplasm conservation. Once one hatchery is selected as a nucleus brood bank, other hatcheries may be developed later for the setting up of the satellite brood banks to cater to the needs of specific regions.
2. **Selective breeding programmes:** A national-level selective breeding programme for selected fish species should be undertaken to overcome inbreeding problems in fish hatcheries (Figures 2 and 3). The improved stock developed at these centres would be supplied to the brood banks for dissemination purpose (Figure 4). The brood banks would be required to implement breeding plans to maintain the status of the supplied stock. One of the brood banks may be especially designed to undertake selective breeding programmes.

[7] A non-governmental organization (NGO).

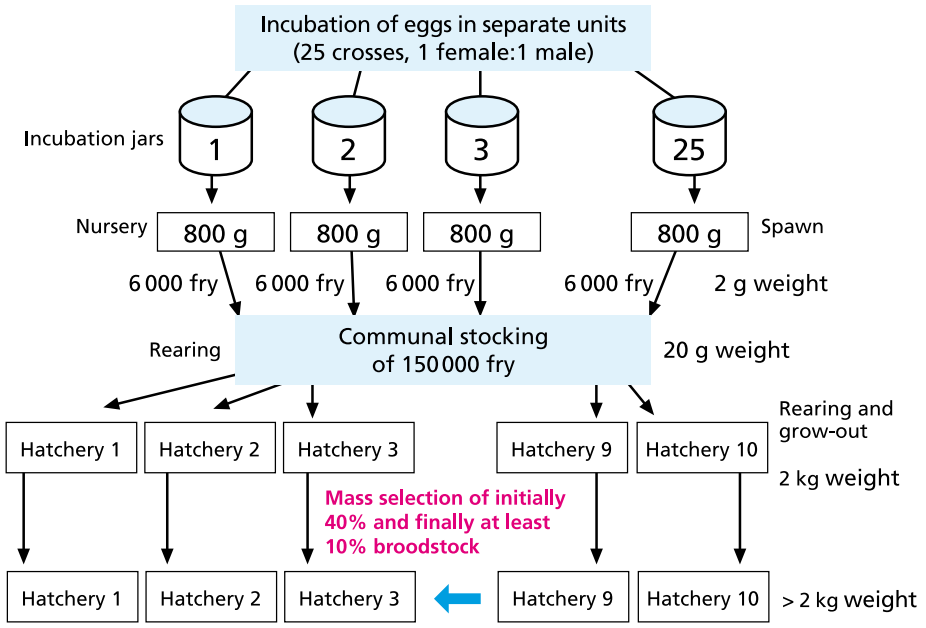
FIGURE 2
A typical protocol that may be adapted for selective breeding for genetic improvement in fish in Bangladesh



Source: P. Routray, Central Institute of Freshwater Aquaculture, Bhubaneshwar, India, personal communication (2013).

FIGURE 3

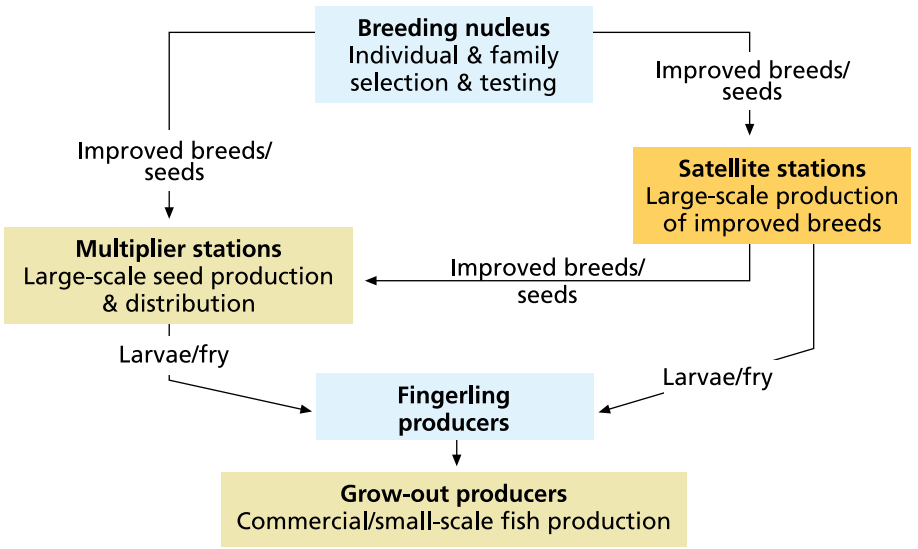
Breeding plan and mass selection protocol for Indian major carps



Source: M.R.I. Sarder, Bangladesh Agricultural University, Mymensingh, Bangladesh, personal communication (2013).

FIGURE 4

A schematic dissemination layout for improved quality seeds of Indian major carps[1]



Source: M.R.I. Sarder, Bangladesh Agricultural University, Mymensingh, Bangladesh, personal communication (2013).

3. **Upgrading of stock:** To overcome the present level of inbreeding (almost 30 percent) in many hatcheries and improve the quality of seed, it is imperative to undertake the upgrading of stock. The use of cryomilt or temporarily preserved milt as an immediate measure would be less cumbersome and easy for the DoF to implement with its current personnel.
4. **National guideline on good management practice (GMP) / Hazard Analysis and Critical Control Point (HACCP) system in hatcheries:** There is no uniform hatchery infrastructure and procedure, and many of them use more water than required. Many of the technical problems, such as faulty water pipe connections and improper slope in the spawning tank, lead to egg breakage during breeding programmes. In this regard, a GMP / HACCP guideline for hatcheries would help hatchery users, beginners and more experienced hatchery operators to improve their facilities and processes. It could also improve the creditworthiness of hatcheries.
5. **Enforcement of Fish Hatchery Rules (2011):** The enactment of the Fish Hatchery Act (2010) is a unique and significant step towards ensuring quality assurance in fish seed. This act is believed to one of a kind and the first in Southeast Asia. The Fish Hatchery Rules is exhaustive, and there are several clauses for ensuring quality. The process of hatchery registration has already started. However, hatchery owners have to comply with several technical points that may be very difficult to enforce. For example, they are asked to provide breeding plans for each year, broodfish development process, etc. However, once the registration process has been completed, it will be easy for the DoF to monitor and enforce the act effectively. It was felt that a rider in the regulation such as "a hatchery owner has to exchange his/her stock (5–10 percent) each year from a government-recognized brood bank" may bring a great difference.

4.2 Aquafeed

4.2.1 Status of aquafeed production in Bangladesh

There are about 100 commercial fish-feed manufacturers in Bangladesh, most producing both aquafeed and poultry feed. Poultry feed is generally more profitable than aquafeed because it is required year round, while aquafeed is only required in the 6–8 month fish culture period. The peak season for aquafeed production is March–October.

The three types of nutritional source for farmed fish are: supplementary feed; farm-made/semi-commercial feed; and industrially manufactured commercial feed. Farms based on extensive feeding use supplementary diets comprised of a mixture of locally available ingredients such as rice bran, wheat bran and mustard oilcake. Supplementary feeds are used in the extensive carp polyculture farms and occasionally in extensive tilapia farms. Most feed ingredients are farm by-products, and farmers mix the feed ingredients manually. In general, farmers use a mixture of 50 percent rice bran, 20 percent wheat bran and 30 percent oilcake. Most users of supplementary feeds are resource-poor farmers.

Farm-made feeds support the bulk of the freshwater feed requirement, although they are mainly used for striped catfish (70 percent), followed by

Nile tilapia (15 percent), native and Thai climbing perches, stinging catfish and walking catfish (10 percent), and Indian major, Chinese and common carps (5 percent). Farmers produce formulated pellets using their own machines or have the local feed mills manufacture the pellets for them. The field survey suggested that there are now about 400 farm-made feed manufacturers in Bangladesh, most (70 percent) operating in the Mymensingh area. Typically, these farm-made feed manufacturers use 22 hp hauler machines with a capacity to produce 2–3 tonnes a day. The price of these machines is approximately BDT75 000–80 000.[8] The survey revealed that 80 percent of the farm-made feed manufacturers produce 1–3 tonnes of feed per day, with the remaining 20 percent producing 4–5 tonnes per day. With respect to training, 80 percent of the farmers are self-taught, with the remaining 20 percent being taught how to manufacture feeds by other feed producers.

Increasingly, farmers bring their feed ingredients to the feed mills to be manufactured into pellets, and pay for the service. The feed manufacturers usually charge in about BDT1.5/kg to process the feed. The average price of farm-made aquafeeds was found to be BDT24.21/kg, which is about 20–25 percent lower than industrially manufactured pellet feeds. Ingredients are purchased from local markets (there are shops that stock or specialize in selling feed ingredients). A variety of ingredients are used in the production of farm-made/semi-commercial aquafeeds. In general, farmers use a mixture of rice bran, rice polish, mustard oilcake, sesame oilcake, soybean meal, fishmeal, maize, oyster shell, lime, salt and vitamin premixes. Many of the ingredients (i.e. rice bran, mustard oilcake, oyster shell) are agricultural by-products, but more than 80 percent of the ingredients for farm-made feed have to be purchased (Table 4). Farmers mostly depend on local markets for purchasing feed ingredients. Rickshaws, vans and motorized vehicles are mainly used to transport the feed ingredients from the local markets. Despite the importance of maintaining the quality of feed ingredients during transportation, storage and processing, it is evident that farmers have little knowledge on how best to store and handle their feed ingredients.

TABLE 4
Sources of feed ingredients for farm-made aquafeed production

Ingredient	Source (n = 20)[1]		
	Own farm	Market	Both
Rice bran	2 (10%)	3 (15%)	15 (75%)
Wheat bran	0 (0%)	18 (90%)	2 (10%)
Mustard oilcake	2 (10%)	12 (60%)	6 (30%)
Fishmeal	0 (0%)	20 (100%)	0 (0%)
Soybean meal	0 (0%)	20 (100%)	0 (0%)
Maize	0 (0%)	20 (100%)	0 (0%)

[1] n = sample size of farm-made aquafeed producers.

Source: Ahmed (2015).

[8] USD1= Bangladesh taka (BDT) 81.10 on 9 December 2012.

Industrial feed manufacture is growing rapidly. Currently, there are more than 100 industrial-scale feed manufacturers in Bangladesh. Most aquafeed manufacturers also produce poultry feeds. Most manufacturers produce four types of feeds: (i) nursery (mash/powder, crumble); (ii) starter; (iii) grower; and (iv) finisher. Nursery feeds are sold in bags of 1, 5 and 20 kg, and starter, grower and finisher feeds are sold in bags of 20 or 25 kg bags. Nutritional information including the crude protein, crude lipid, crude fibre and energy, as well as the moisture content and the date of manufacture is usually printed on the feed bag. Prices range from BDT26/kg to BDT48/kg depending on the culture species for which it is intended, feed type, quality, season, and levels of supply or demand (Table 5). Depending on the species / life stage, industrially manufactured feeds usually have protein levels of 25–40 percent and are used by wealthier farmers and, while more expensive on a per kilogram basis than farm-made feed, they can be expected to result in better performance (i.e. faster growth, higher yield and better feed conversion).

TABLE 5
Price comparison between the three finfish feed types

Feed type	Price (BDT/kg)
Supplementary feed	12–15
Farm-made aquafeed	18–24
Industrially manufactured pellet	26–48

Source: Field survey (2012).

Both floating and sinking feeds are produced. Sinking feeds account for 70 percent of production, with the remaining 30 percent manufactured as floating feeds. Floating feeds cost an average of 20 percent more than sinking feeds. Feeds are primarily produced for five fish species or species groups: (i) striped catfish (45 percent); (ii) Nile tilapia (25 percent); (iii) native and Thai climbing perches, stinging catfish and walking catfish (15 percent); (iv) carps (10 percent); and (v) shrimps and prawns (5 percent).

The large aquafeed manufacturers now include a number of national and international joint-venture companies. The feed industries are located throughout the country, but concentrated in the Chittagong, Gazipur and Mymensingh regions. Production capacities range from 20 000 to 95 000 tonnes per annum (mean: 49 500 tonnes per annum). The majority of the feed manufacturers (60 percent) are medium-scale producers (40 000–60 000 tonnes per annum), while 30 percent and 10 percent are small-scale (10 000–40 000 tonnes per annum) and large-scale (60 000–95 000 tonnes per annum) producers, respectively. The production capacity of these feed mills ranges from 10 to 20 tonnes/hour. In general, the production volume of aquafeed is one-third that of poultry feed. Farmers' preference for industrially manufactured pellet feeds depends on a number of factors. These include quality, price, availability and the technical support supplied by the feed company.

The quality of feed depends on the ingredients, proximate composition and feed manufacturer. The primary ingredients used include fishmeal, mustard

oilcake, sesame oilcake, defatted rice bran, rice polish, wheat flour, maize, meat and bone meal, soybean oil, calcium phosphate, salt and vitamin premixes. Although similar ingredients are used by the different manufacturers, the formulations differ. Most feed ingredients are sourced locally. However, some, including fishmeal, meat and bone meal, defatted soybean meal, maize and even some rice bran, are imported, primarily from Australia, Canada, China, Europe, India, Malaysia, Thailand and the United States of America.

4.2.2. Aquafeed issues

Policy and regulations

- Feed quality and cost are two of the most acute issues facing the feed industry. The combination of the rising cost of feed and, therefore, production costs, with a stable fish price has led to reduced profitability. This "cost-price squeeze" has resulted in farmers and feed millers devising linked coping strategies. Farmers opt for cheaper feed, and feed manufacturers oblige (in order to keep them as customers) by producing feed of lower quality. This is usually achieved by lowering the feed's protein content. The impact of using poorer-quality feeds is suboptimal production. This cost–price squeeze phenomenon represents a complex situation that is first and foremost a policy issue. It could involve re-examining the import duties on imported ingredients, improving the efficiency of the logistics for transporting and marketing the feed ingredients, and improving the efficiency of the market system for fish and shrimp, while avoiding market distortions from the introduction of price support or other farm subsidies, or providing assistance to producers so that inefficiencies in the supply chain are resolved. A net effect of a more efficient supply chain would be lower transaction costs, which would translate to lower or at least stable logistics, input, production and marketing costs (of feed and fish). Farmers would then not have to settle for lower-quality cheaper feed, and manufacturers would not need to make a trade-off between quality and price to maintain their customer base. However, quality would need to be monitored, especially for the smaller manufacturers. In this regard, an implementing guideline is needed to operationalize the Fish Feed and Animal Feed Act (2010). One important measure would be to ensure quality through a standard that is backed up by a product certification system for feed manufacturers and an effective monitoring system. A network of quality assessment laboratories would provide the infrastructure for a feed assessment service that supports the product quality monitoring system and provides a service to farmers and farm-made feed manufacturers that might need to assess the nutritive quality of their feed ingredients.
- The use of feed additives, growth promoters, hormones and antibiotics in feed needs to be addressed. To regulate this practice, an assessment is needed of the efficacy as well as adverse impacts of their use. Implementation guidelines to address this issue would be need to be developed under the Fish Feed and Animal Feed Act (2010).

Manufacturing

- The products of the small-scale farm-made feed producers are of a low nutritive value and are poorly manufactured, resulting in suboptimal performance. Feed represents the highest production cost in aquaculture. Improving the overall feed efficacy (i.e. improved nutritive quality and less wastage) would contribute significantly to better yields and returns. Commercially manufactured aquafeeds that have been finely milled, extruded and dried have far superior physical characteristics to their farm-made counterparts, which tend to be poorly bound and have a high percentage of fines, and often disintegrate before they are ingested by the fish. Thus, moving the farmers from farm-made feeds to more robust commercially manufactured pellets is suggested. This will result in cost savings by reducing feed wastage and improving feed conversion ratios (FCRs). The BFRI (2011) reported that, in 2010–11, only 45 percent of the capacity in the commercial feeds mills was utilized. The project thus suggests utilizing this excess capacity such that the commercial operators extrude more efficiently those feed ingredients that are normally extruded at the farm level.
- Technical assistance to the small-scale feed manufacturers to improve feed manufacturing practices would significantly improve feed quality and on-farm feed utilization.
- The volume of feed produced depends on the farmers' purchasing power and willingness to pay a reasonable price for quality feed. A number of larger manufacturers are helping their own cause by providing technical advice and training to their dealers so that they can provide advice to the farmers to improve feed management and utilization. The more progressive feed manufacturers have established a network of well-trained technical advisers for farmers and dealers, and they provide farm management advice and incentives to farmers who adopt BMPs. The service includes assistance to seed producers so that seed are healthy and the supply is reliable. A scheme in the shrimp growing districts includes advising and providing technical assistance to farmers to shift from the low-input, low-output improved extensive systems to the higher-input, higher-output biosecure semi-intensive production system. Advice is usually provided through dealers.

Trading/retail

- There are two outlets for feed: a depot, which is the halfway point between the manufacturing plant and the retailers; and the larger-scale dealers that obtain their supply either from the manufacturing plant or from the depot. A depot is established by the manufacturer where a large inventory is kept to supply a number of local dealers in its area of coverage. Feed transit times at the depots are usually 1–1.5 months. The personnel at the depot include technicians who can provide technical and business advice to dealers as well as to farmers.
- Typically, a feed manufacturer supplies feeds to about 100 feed dealers. During the peak growing season of March–October, sales of feed dealers

average 1 850 kg per day, with sales dropping to 115 kg per day in November–February.

- Many dealers are constrained from providing credit to farmers to purchase feeds because the manufacturers offer the dealers a limited, one-time consignment-type supply arrangement. Typically, the first batch of feed supplied to a newly accredited dealer is sold on consignment; in other words, the first supply is replenished after the dealer has paid for it. This arrangement puts a constraint on the dealer's ability to sell to customers on credit. Increasingly, and in order to improve feed sales, feed manufacturers are recognizing the need to provide credit to the feed dealers. Some manufacturers now extend credit lines to dealers, which are then able to provide credit to the farmers. While credit terms vary, the money is usually repaid upon the harvesting of the crop. Dealers providing credit services tend to have developed long-term, trusting relationships with the farmers, so that in the event of a crop failure and their inability to pay back credit from a single production cycle, they will be repaid upon the harvesting of subsequent crops. Inherently, it takes time to develop these relationships, making it problematic for new farmers (entrants) to obtain credit from the dealers.
- There is considerable variation in the types of services that are available to the farmers. Those farmers that purchase commercially manufactured aquafeeds tend to have access to dealership services that are not available to those farmers that purchase products from feed ingredient dealers and make their own farm-made feeds. While the services vary among dealers, it is evident that many of the commercially produced aquafeed dealers form long-term relationships with their feed suppliers and farmers, often providing both extension materials and finance to the famers. The extension materials are developed by the feed manufacturers and are designed to optimize the farmers' use of their purchased feeds by improving their feed management practices, providing feed tables and promoting record-keeping activities. The feed dealers are used as the conduits for the distribution of these materials. In contrast, those farmers purchasing feed ingredients to make farm-made feeds are not supplied with this type of information and appear not to have access to these types of extension materials. Nevertheless, some feed ingredient dealers provide some limited formulation advice.
- Finally, better roads and transportation infrastructure would considerably reduce the cost of feeds and facilitate their delivery.

Utilization

- The technical and economic constraints reported by farmers include: high price of feed; inadequate supply of finished feed and feed ingredients; poor feed quality; procurement problems; deterioration of feed; water pollution owing to excessive feed use; and a poor knowledge of feed management practices. A social constraint is their not being organized into farmers groups or associations.
- The three major capacity-related issues at farmer level are the farmers' capacity to purchase quality feed and in sufficient volumes, their capacity

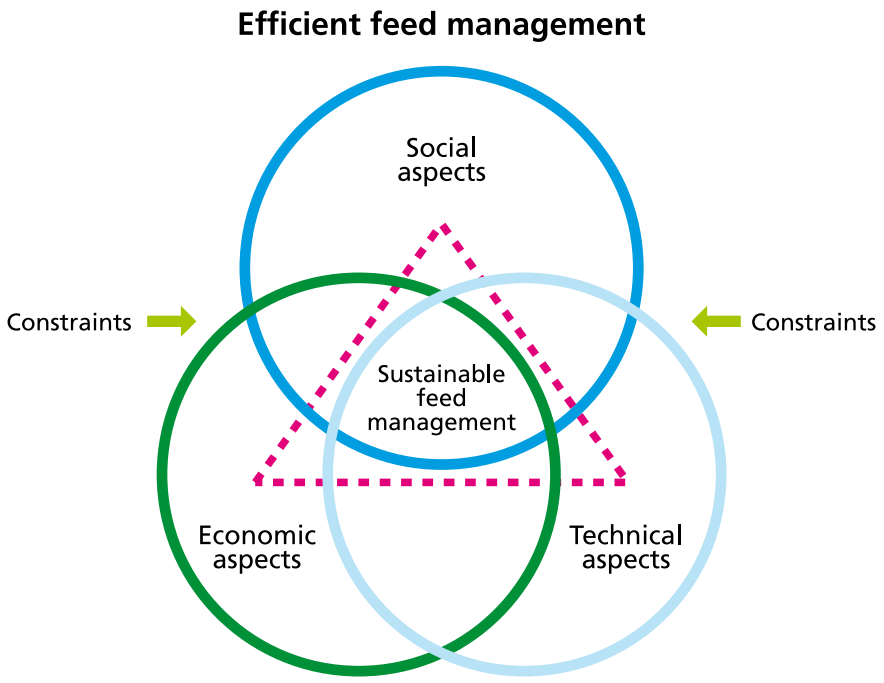
to use feeds optimally, and their ability to assess the quality of the feeds that they purchase and to demand quality standards. A fourth and minor issue is their ability to maintain the quality of feed. Farmers often have little knowledge on how best to store and handle their feed ingredients. Those using farm-made aquafeeds prefer to purchase small amounts of ingredients so that they do not have to store feeds. This behaviour is also the result of a lack of capital (or farmers not being organized) to purchase feeds in bulk, which can be significant because bulk purchases are normally accorded discounts.

- Farmers are generally aware of the advantages of using industrially manufactured pellet feeds over farm-made aquafeeds, but inadequate capital or lack of access to capital and a lack of technical knowledge prevent them from buying the better-quality feed and improving their feed management strategies.

Inefficiencies related to the constraints

Figure 5 illustrates the conceptual framework for examining the inefficiencies of the feed sector.

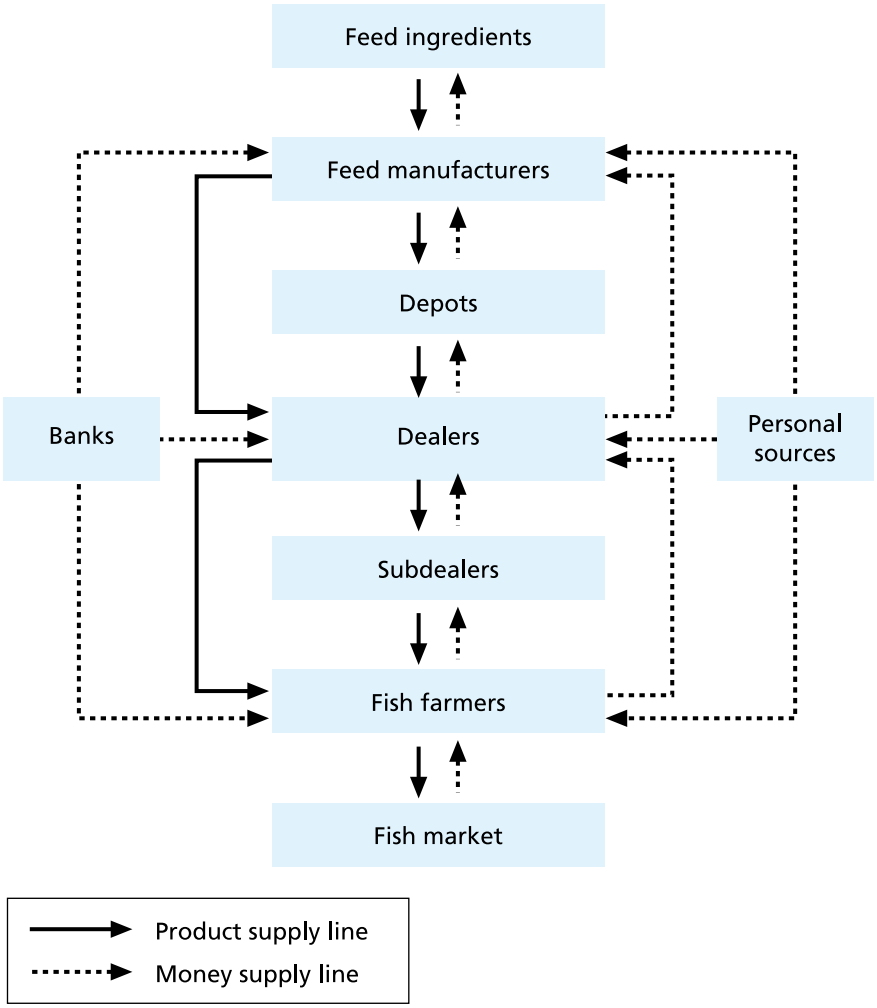
FIGURE 5
Conceptual framework for analysing the constraints to feed management



Source: Presentation by N. Ahmed (National Consultant on Aquaculture Feed) given at the Stakeholders Workshop (2012).

There are two supply chain models in the feed sector: the farm-made aquafeed chain; and the industrially manufactured feed chain. The difference between them is in the distribution of the feed. The industrial feeds are distributed through national dealer networks (Figure 6), while the farm-made aquafeeds are either sold directly to farmers or are produced as "made-to-order feeds" for farmers who bring their own ingredients for processing.

FIGURE 6
The market chain of industrial aquafeed with financing sources



Source: N. Ahmed, Bangladesh Agricultural University, Mymensingh, Bangladesh, personal communication (2013).

Based on the findings of the field survey reports, and the FAO country field and verification missions, Table 6 summarizes the inefficiency factors. Table 7 illustrates their impacts along the supply chain. Concomitant with seed production, the common impact is a lower quality of product, which in turn adversely affects the farmer's productivity, which translates into lower profitability and an inability to afford better-quality feeds. This is exacerbated by the lack of age/size-specific feed formulations, which is a serious issue at the farm-made feed manufacturing level. These issues are compounded by improper feed management and storage, and by poor culture management practices.

TABLE 6
Inefficiency factors in the farm-made aquafeed supply chain

Supply of raw materials	Manufacture of industrial pellet feeds	Production of farm-made feeds	Sale and distribution	Utilization
• Unavailability/ scarcity of raw materials	• High cost of manufacturing	• Variable standards of quality	• Poor transport systems in many areas	• Wastage from poor feed management
• High cost of raw materials	• Lower operational efficiencies by having to meet seasonal requirements for feed of different age groups	• Poor quality or adulteration of raw materials	• Substandard storage	• Poor feed conversion ratios from: low-quality feed and non-age specific feed formulations, exacerbated by poor quality seed and poor feed management practices
• High level of reliance on imported feed ingredients (particularly protein sources)		• Seasonal variation in the availability of raw materials	• Inability to provide feed on terms other than cash on delivery	• Inability to assess feed quality or demand a quality standard or purchase higher-priced better quality feed
		• Higher feed ingredient costs		• High unit costs due to individual rather than group purchases
		• Higher cost of production		• Substandard on-farm feed storage

TABLE 7
Impacts of inefficiency factors on the performance of the role players along the feed chain

Supply of raw materials	Manufacture of industrial pellet feeds	Production of farm-made feeds	Sale and distribution	Utilization
• None	• Increased price of feed or maintained price at lower quality (i.e. lower protein content), particularly problematic for small-scale manufacturers	• Low quality or undetermined and variable quality	• Higher costs • Late or no delivery • Reduced quality	• Lower yield than potential; low returns and reduced cash flow • Low bargaining power; cannot avail of discounts on bulk purchase • Locked into low-quality feed • No access to feed

4.2.3. Findings of the verification mission on aquafeed

The verification mission confirmed the following issues.

Feed quality

The increasing cost of feed ingredients drives feed manufacturers to replace the fishmeal component with a lower-quality, cheaper protein source, or in some cases to replace quality ingredients with lower-quality or adulterated ingredients that reduce the nutrient profile (notably the crude protein content). Alternatively, increasing feed costs affects feed affordability, causing farmers to opt for lower-priced but also lower-quality feeds. The low quality of some of the aquafeeds currently being produced is of concern to the farmers, who have little practical recourse to the feed producers, particularly when they find that they have inadvertently purchased low-quality feeds that are providing suboptimal growth.

Legislative framework

The Fish Feed and Animal Feed Act (2010) and the Fish Feed Rules (2011) provide the legal framework for aquafeed production and use in Bangladesh. A review of the legislation suggests that while it contains the essential components that are required to regulate the aquafeed production sector, the implementation of the regulations is proving a challenge for the DoF. Currently, the DoF does not have the technical or diagnostic capacity to regulate the feed manufacturing sector and, at present, it remains largely unregulated. To implement the act successfully, issues of compliance with prescribed standards for feeds, feed ingredients and the use of feed additives need careful technical, economic and social consideration.

Aquafeed production

There are about 100 commercial aquafeed manufacturers operating in the country. However, as the DoF is still in the process of registering the producers, the exact number and their current production capacity is unknown. The sector is characterized by a combination of large integrated manufacturers, often of foreign origin, producing 60 000–95 000 tonnes of feed per annum, and a larger number of smaller mills producing smaller quantities of feed (8 000–40 000 tonnes per annum) (BFRI, 2011). Typically, many of the manufacturers produce both poultry and fish feeds. However, some of the larger feed producers specialize in aquafeeds exclusively. Feeds are produced for all the major culture species. Both floating and sinking feeds are produced, with feeds being formulated according to the species / life stage of the fish. While feed prices vary according to the culture species, formulation and the quality of feed ingredients used, they generally range from a low of BDT25.45/kg for sinking finisher carp feeds to BDT48.0/kg for floating climbing perch nursery feeds. In general, the FCRs attained using the sinking feeds are in the region of 2.0–2.5, while those attained using the more expensive floating formulations are in the region of 1.5. The high FCRs associated with the sinking feeds suggest that there are issues in terms of the feed formulation; either failing to satisfy the nutritional requirements of the fish, or poor feed management, or perhaps, more likely, a combination of the two. There are up to 400 farm-made feed manufacturers in Bangladesh. Average production capacity is in the region of 3 tonnes per day. From a technical perspective, the formulations used appear to be generic and based on the experience of the feed manufacturer, or in some cases provided by the feed ingredient dealers. They are neither species-specific nor are they age/size-class-specific. As a result, they are unlikely to be optimal in terms of satisfying the nutritional requirements of the fish. Ingredient sources appear to be used in the formulations without any clear understanding of how the ratios should be used to maximize the efficiency of the formulation. This problem is compounded by the high cost and/or unavailability of some of the higher-quality ingredients, which are often replaced by lower-quality alternatives.

Feed dealers and traders

There is considerable variation in the types of services that are available to the farmers. Farmers that purchase commercially manufactured aquafeeds tend to have access to dealership services that are not available to those farmers that purchase products from feed ingredient dealers and make their own farm-made feeds.While the services vary among dealers, it is evident that many of the commercially produced aquafeed dealers form long-term relationships with their feed suppliers and farmers, often providing both extension materials and finance to the famers. Finance is available to some famers, but again this is primarily available to those farmers using commercially produced aquafeeds. Finance terms and availability vary among dealerships and depend on the relationship between the feed dealers and the farmers. While collateral is not required to secure these loans, the dealer visits the farmers to assess their infrastructure, farming skills, wealth and ability to repay the loan. Evidently, the loans are based on the

development of long-term (±5 year) relationships with the farmers, such that in the event of a crop failure, the dealer either extends the line of credit (payment terms) or in some cases, the loan is repaid from the profits from the next crop. The credit provided can be substantial. One feed dealer from Mymensingh reported that towards the end of the production cycle an average farmer that he supplied would require credit in the region of USD750 per month. Loans are generally short-term, with credit periods ranging between three months for tilapia and striped catfish to six or seven months for the carps (S. Aslam, Brac, personal communication, 2012). Some dealers report charging interest (up to 15 percent), while others provide the loans free of charge. The feed manufacturing companies are also aware that the costs of their feeds are becoming increasingly problematic for many farmers. In response, some of them have extended lines of credit, or they provide feed on credit to the dealers, enabling them to pass credit services on to the farmers. The credit terms vary between the companies and dealers. While Brac Feed Enterprises has set up a pilot credit facility – providing 15–20 tonnes of feed per month on credit to 12 selected dealers (S. Aslam, Brac, personal communication), other dealers reported more substantial loans. For example, one dealer indicated that while the CP Feed Company provided him with an annual credit line, the other companies that he dealt with limited their credit to 200 tonnes of feed a month.

Feed additives

At present, there is very little information on the use of feed additives and the extent to which that farmers are using them.

An exception is the use of the antibiotic nitrofuran, which in the past led to the rejection of a number of shipments of giant river prawn (*Macrobrachium rosenbergii*) to the European Union (Member Organization). This issue has since been resolved, and diagnostic and traceability protocols have been developed to monitor nitrofuran use in the shrimp sector. Minimal feed additives are being used in the freshwater sector, and banned substances such as antibiotics and hormones are not in use. Nevertheless, there is some concern that banned substances may be present in some of the feed ingredients imported into the country, specifically antibiotics in meat and bone meal. Chemicals available include vitamin and mineral mixes and probiotic formulations for use in farm-made feeds, and chemicals to alleviate pond-water quality issues (e.g. low dissolved oxygen levels, hydrogen sulphide). While the use of appropriate levels of vitamin and mineral mixtures is acceptable, the efficacy of the probiotics and chemical additives could not be confirmed, and thus it could not be established whether the farmers are using legitimate products or are wasting their resources. The widespread adoption of commercial feeds and the concomitant increase in the intensification of production systems in some sectors (e.g. striped catfish), suggests that water-quality issues and disease may become a problem for some farmers. If this is the case, it is reasonable to suggest that many farmers may resort to using banned chemicals to deal with poor water quality and diseases.

5. Conclusions

In line with the objectives of the project, the following conclusions have been drawn.

5.1 Implementation of the programme to improve fish seed quality

The Fish Seed Multiplication Programme (FSMP) has made some progress towards improving the quality of carp broodstocks, and would have done better if the farms had been better resourced with expertise and physical facilities and if their efforts and attention had been more focused on broodstock development and providing technical advice and training to hatcheries. Private hatcheries produce almost all of the seed required by fish farmers (as well as shrimp and prawn farmers), and there seems to be no shortfall that government seed multiplication farms and hatcheries need to fill. This argues for cutting the seed production and sale (usually below production cost) function of the FSMFs in order for them to concentrate on genetic improvement.

The role of the BFRI in training hatchery operators, obtaining and maintaining pure lines of foundation stock, breeding, and supplying hatcheries with improved broodstock of a number of species is an important part of the national seed quality improvement effort. However, the linkage between the BFRI and the FSMP farms was not clear.

5.2 Technical, economic and policy constraints related to the production of quality aquafeeds

The key constraints to producing quality feed include:

- The rising cost of production, which is primarily driven by higher costs of feed ingredients, many of which are imported. Reducing feed ingredient prices is primarily an economic issue, but also includes policy implications.
- Compliance with the Fish Feed and Animal Feed Act (2010) and Fish Feed Rules (2011), which provide specific guidance on the quality of feed ingredients that may be used, their inclusion rates and the proximate composition of the feeds.Mechanisms for enforcing compliance with the regulatory framework are absent. This is first a policy constraint, and second a capacity building issue.
- The farmers' lack of capacity to assess and demand quality feeds.
- The farmers' lack of capital to purchase higher-priced quality feeds, a factor that is compounded by poor-quality inputs (seed and feed) and abetted by suboptimal farm management practices.

The structure of the feed industry, which comprises small farm-made feed formulators, small- and medium-scale commercial feed manufacturers, and large livestock feed manufacturers producing well-known brands of poultry feed (the major proportion of their output) and fish and shrimp feed, presents a difficult policy issue and capacity-building task. The smaller feed producers need upgrading with respect to attaining feed quality standards, and updating of their manufacturing equipment and processes. Their role is significant as they supply 1.18 million tonnes of the 3.28 million tonnes of feed used every year. Capacity

building for this group will require significant resources but will probably result in significant gains for aquaculture production in general. Regulating the small-scale feed producers is another problematic issue; because they are small, they largely operate under the radar of the regulators.

This supply chain perspective reveals the inefficiencies caused by the numerous technical, economic and policy constraints occurring at each stage and cascading down the chain from the supply of raw materials to production, distribution and on to feed utilization by the farmers. Their interactions through the supply chain exacerbate and, if not resolved, perpetuate the inefficiencies. The persistent outcome is an inefficient feed industry sector, which acts as a brake on the growth of the aquaculture sector.

5.3 Major issues to address in order to build the capacity of aquafarmers to optimize the use of feed and feed additives

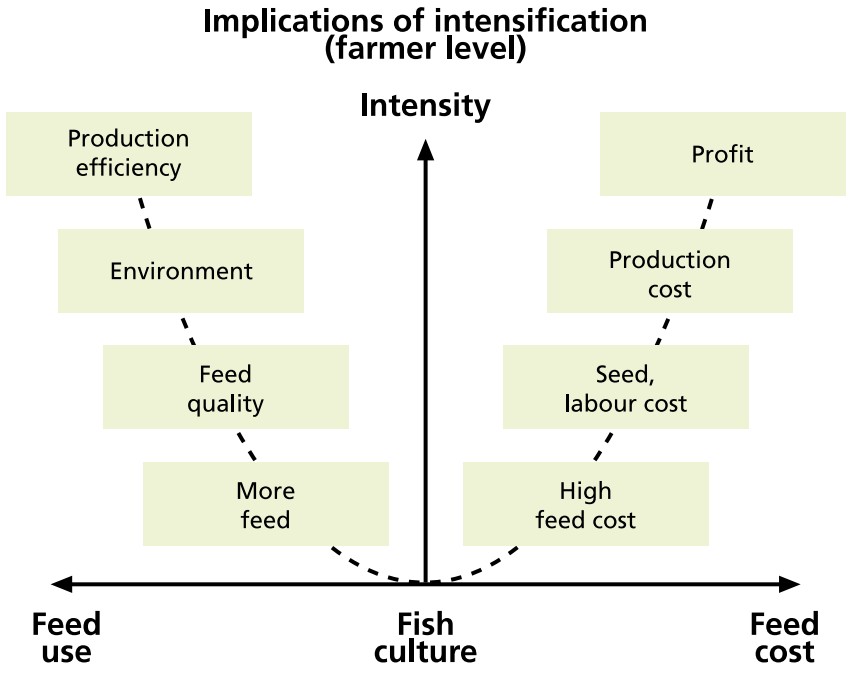
A number of strategies have been adopted by freshwater fish farmers to optimize the utilization of feed resources by the fish. Polyculture of carps is a common and proven practice to utilize feed resources efficiently. Other innovative practices include mixing high-value species (as well as carps) with the main culture species, which is usually striped catfish. The farmers interviewed admitted to barely making a profit from the low-value striped catfish; however, they compensated for this with the sale of high-value species such as climbing perch, stinging catfish and walking catfish. Similarly, tilapia farmers reported adding a few carp to their production ponds to improve production parameters and feed utilization. These are feed-optimizing strategies.

In the shrimp subsector, more shrimp farmers use traditional culture systems (60 percent) as opposed to the improved extensive systems (35 percent) and the semi-intensive systems (5 percent). This is gradually changing and more semi-intensive culture techniques are being adopted, stimulated in part by the demonstration of higher productivity (5 000 kg/ha in the semi-intensive systems compared with 500 kg/ha in the improved traditional and 250 kg/ha in the traditional systems) and profitability of semi-intensive biosecure systems using quality seed and feed (BDT30 000 from one crop in one acre,[9] as reported by one farmer in Khulna when he shifted from extensive to semi-intensive culture). Farmers are being assisted by the feed companies to improve their production and marketing, to access good-quality postlarvae by the companies providing technical advice to hatcheries, and to adopt better feed management, health management and culture practices. The lesson learned from the shrimp farming subsector highlights the importance of and need to develop and promote BMPs to the freshwater fish farmers. In addition, the freshwater fish farmers are poorly organized. Being associated into clusters or associations would improve their uptake of BMPs and strengthen their transactional power with input suppliers and buyers.

An illustration of the implications for service provision and capacity building for farmers, the level of inputs needed, and the expected outcomes in yield and profitability as they move from a low-intensity to a higher-intensity culture system is presented in Figure 7.

[9] 1 hectare (ha) = 2.47 acres.

FIGURE 7
Implications of intensification in terms of support to farmers, costs and profitability



Source: Presentation by N. Ahmed (National Consultant on Aquaculture Feed) given at the Stakeholders Workshop (2012).

The use of feed additives is common and is probably a response used to compensate for the low quality of seed and feed. An assessment of the efficacy of these would provide the farmers with a scientific basis for whether or not to use them. If these additives are found to have adverse effects on human health or the environment, a regulatory component might have to be imposed.

5.4 Support services to build the capacity of small-scale aquafeed producers to enable them to improve the technical efficiency of their production processes

There are four key areas that could increase the technical quality and the economic efficiency of farm-made feed and that supplied by small-scale commercial feed producers:

- assuring the quality of ingredients;
- upgrading equipment;
- providing technical advice and training on GMPs;
- stabilizing the cost of the feed ingredients.

A reliable power supply from the national power grid would raise technical efficiencies by reducing downtime and the cost of operating standby power generators. Reducing or at least stabilizing the cost of feed ingredients, many of which are imported, is a policy issue at the core of which lie the duties imposed on

the raw materials, as well as the cost of handling, transporting and marketing the materials. While the Fish Feed and Animal Feed Act (2010) and the Feed Rules (2011) provide standards for feed ingredient materials and finished products, an analytical service is needed to implement these provisions.

6. Recommendations

6.1 Aquaculture seed

The major area of the seed subsector requiring attention is improvement in seed quality. The findings and conclusions of the field survey on seed were confirmed by the verification mission, which developed a set of recommendations. These are incorporated with those of the FAO field mission and presented below as the recommendations of the project:

- As a long-term strategy, genetic selection and a selective breeding programme should be undertaken. The selective breeding programme needs a collaborative process and cooperative arrangement among government FSMFs and government and private hatcheries.
- These are illustrated in the field survey and the verification mission reports on aquaculture seed and broodstock management (Routray, 2015; Sarder, 2015).
- Broodstock banks with all necessary facilities should be established in limited places.
- Personnel should be trained to undertake brood banking operations.
- Base populations of Indian major and Chinese carps, Nile tilapia and striped catfish should be collected from different sources.
- Broodfish ponds (at least 20) for the rearing of base populations, producing 15 families at a time and 50–60 families in total, and at least 10–15 incubation chambers with 60 nurseries should be developed in a biosecure facility where no escape, intermixing or theft is possible and the area is not vulnerable to flooding or other disasters.
- As an immediate intervention strategy, the utilization of short-term preserved milt/cryomilt from selected elite (genetically improved) broodstock should be undertaken. If there is no elite broodstock available, then exchange between hatcheries should be encouraged to widen the effective population size and to reduce the problem of inbreeding.
- Hatcheries built earlier should be modified to reduce the loss of eggs/hatchlings.
- Hatchery owners should be made aware of and understand the implications of the shrinking gene pool; they should be instructed to keep hatchlings resulting from each breeding and rear them to broodstock.
- Broodstock raising programmes should be strictly followed and separated from table fish production.
- A fish semen cryobank should be established.
- The main areas for follow-up assistance should be broodstock banking, breed development, cryobanking, upgrading of hatcheries and enforcement

of hatchery regulations. There is an urgent need for practical hands-on training of hatchery personnel, including the owners and key technical staff involved in carp broodstock management, hatchery management and nursery management, cryopreservation, and HACCP analysis.

- To support the programme, the capacities of government FSMFs will need to be strengthened and their efforts concentrated on broodstock banking. Capacity building should entail upgrading of skills of technical personnel, especially in the genetic management of broodstock, and the equipping of government hatcheries with computing facilities (to maintain databases, pedigree records, etc.). It will also require a monitoring system for proper utilization of distributed broodstock.
- The Fish Hatchery Act (2010) provides for hatchery registration and certification; it should be accompanied by a certification standard for processes and the development of hatchery better management practices (HBMPs).

6.2 Aquafeed

In the aquafeed subsector, the main areas requiring attention relate to improving feed quality, the technical efficiency of farm-made aquafeed producers, and the capacity of farmers to utilize feed efficiently. There is a strong link between the efficient use of feed and the quality and health of the seed made available to farmers. The verification mission developed a set of recommended actions for improving the aquafeed subsector. These have been integrated with the recommendations from the FAO field mission and are presented below as project recommendations addressing the three main areas requiring attention.

Regulatory Improvements

1. Assist the DoF in implementing its mandate to regulate the aquafeed production sector by:

- providing the guidelines and technical support to implement the Fish Feed and Animal Feed Act (2010) and the Fish Feed Rules (2011). The guidelines could be developed through a national consultation process led by the DoF. The plan for developing and putting in operation the institutional and personnel capacity to implement the guidelines will be part of the consultation process;
- setting up a feed unit at the DoF and training staff in the implementation of the Fish Feed and Animal Feed Act (2010) and Fish Feed Rules (2011);
- setting up a feed diagnostic laboratory at the DoF (analytical capacity and trained personnel);
- upgrading the feed laboratory at the BRFI as a secondary/reference diagnostic laboratory;
- developing sampling schedules and protocols for monitoring feed ingredients, aquafeeds and feed additives (where appropriate);
- training feed inspectors (e.g. in methods of secure sampling, chain of custody).

Commercial aquafeeds

1. Develop an aquafeed producers association by:
   - conducting registration of commercial, semi-commercial and farm-made aquafeed producers;
   - holding consultations to develop a charter/agreement of association;
   - developing an organizational structure;
   - developing long-term funding mechanisms.

2. Develop an aquafeed certification programme by:
   - initiating stakeholder discussions between commercial aquafeed producers and the DoF;
   - identifying a lead agency;
   - developing a certification programme (standards, monitoring, funding and financial arrangements).

3. Promote a migration from farm-made feeds to commercially produced aquafeeds by:
   - designing a production model (e.g. economic model, volumes required, farmer numbers, etc.);
   - mapping commercial producers and farmers/farmer groups using farm-made/semi-commercial feeds that are willing to participate in a programme;
   - developing a funding model to improve farmer access to feed ingredients for extrusion in commercial feed mills;
   - trialling a production programme that migrates farmers from their traditional practice of producing farm-made feed to extruding their feed ingredients at commercial production facilities;
   - facilitating capacity building for small-scale feed manufacturers by encouraging them to form a national association and providing them (through the association) with technical assistance to adopt BMPs.

Farm-made feeds

1. Increase the technical capacity to improve the quality of farm-made feeds by:
   - developing better aquafeed production / feed management practices (BMPs);
   - promoting the BMPs through their dissemination and the training of feed ingredient suppliers and farm-made feed manufacturers / farmer groups;
   - developing a credit facility for small aquafeed producers to enable them to upgrade their facilities, equipment and processes;
   - encouraging government interventions to improve operational efficiencies by improving utilities, particularly a reliable power supply and an improved transportation system.

2. Improve the capacities of farmers to utilize feeds efficiently by:
   - encouraging and assisting farmers to organize into associations for improved uptake of BMPs by:
   - identifying farm-made/semi-commercial feed producers,

- holding consultations to develop a charter/agreement of association,
- developing an organizational structure,
- developing long-term funding mechanisms;
- developing and promoting the adoption of BMPs that include guidance for proper storage and handling to preserve feed quality, improved feeding protocols and health management.

Feed dealers

1. Improve access to finance / development of appropriate financial models by:
undertaking a value-chain analysis of commercial, semi-commercial and farm-made aquafeeds;

- developing small-scale financial models to improve farmers' access to commercial, semi-commercial and farm-made feed/feed ingredients;
- promoting and trialling financial models through appropriate financing institutions and feed/feed ingredient dealers, etc.;
- approaching feed ingredient dealers that supply products to those farmers using semi-commercial and farm-made feed ingredients and promoting the distribution and adoption of better feed management practices.

Feed additives

1. Improve understanding of the use of feed additives by:
undertaking a survey to establish the current use of feed additives across all subsectors;

- providing assistance to the DoF to develop a monitoring and response programme to monitor the use of feed additives across all the subsectors, possibly in collaboration with the existing FAO Food Safety Programme (FAO Project GCP/BGD/047/NET);
- undertaking trials to establish the efficacy of the feed additives currently in use, determine their efficacy, and advise farmers of the appropriateness of their use.

References

Ahmed, N. 2015. Field survey report on technical, economic and social constraints to aquafeed production and management in Bangladesh. *In* M.R. Hasan. & R. Arthur, eds. *Aquaculture seed and feed production and management in Bangladesh - Status, issues and constraints*, pp. 57-77 on CD–ROM. FAO Non-Serial Publication. Rome, FAO. 48 pp. + CD–ROM.

Bangladesh Fisheries Research Institute (BFRI). 2011. *Evaluation of nutrient quality and shelf life of commercial feed ingredients and feeds on aquaculture production in Bangladesh.* Annual Progress Report 2009–2010. Mymensingh, Bangladesh.

FAO. 2014. FishStat Plus - Universal software for fishery statistical time series. Vers. 2.32. In: *FAO Fisheries and Aquaculture Department* [online]. Rome. Updated 28 November 2013. [Cited 9 February 2015]. www.fao.org/fishery/statistics/software/fishstat/en

Routray, P. 2015. Report of the verification mission on aquaculture seed production and broodstock management. *In* M.R. Hasan. & R. Arthur, eds. *Aquaculture seed and feed production and management in Bangladesh - Status, issues and constraints,* pp. 79-88 on CD–ROM. FAO Non-Serial Publication. Rome, FAO. 48 pp. + CD–ROM.

Annex 1

Outcomes of consultations with institutions and the stakeholders' workshop

This section briefly describes the issues discussed between FAO Bangladesh, the Department of Fisheries (DoF), WorldFish and the Bangladesh Shrimp and Fish Foundation (BSFF).

1. Consultations

FAO Bangladesh: The results of the study will be the foundation of a follow-up project such as a Technical Cooperation Programme (TCP) that would focus on key seed and feed quality issues. The TCP could also help address feed and seed management issues related to climate change; a fishery component of the Bangladesh Climate Change Resilience Fund is planned to be included. In addition, should the Technical Cooperation Programme Facility (TCPF) project find the need to set up a feed analysis service in strategic areas in the country, it might be possible to attach this capability to the planned chain of food safety laboratories to be established under a current Netherlands-assisted project.

Department of Fisheries: The Director General designated the Deputy Director of Finance and Planning as the contact person in the department for the TCPF project. He wanted the project – or a follow-up activity – to provide advice on developing implementation guidelines for the newly enacted Fish Hatchery Act (2010) and the Fish Feed and Animal Feed Act (2010). He gave a short assessment of the situation on seed and feed, the salient points being as follows:

- Fifty-five percent of total fish output is now contributed by aquaculture, and the culture area for the various species is increasing, but expansion is hampered by, among other factors, inbreeding and genetic erosion of cultured species, especially carps.
- Unregulated and unscientific seed production is occurring. It would be important to register hatcheries and to set up a standard for their licensing, and to institute a process for a certification scheme for seed production. Compliance with product quality as well as environmental standards could be facilitated by a standard operations manual.
- Operational issues include monitoring, surveillance and enforcement. For example, who would pay for the analysis of feed samples for quality checks? Perhaps the government should pay for the first test and, if the feed mill does not agree with the results, the costs of the second test should be paid by the owner.
- There are more than 300 feed factories of all types and scale, but product quality, particularly that of the smaller mills, is generally low and there is a need for a certification standard. The Director General proposes a process of certification for feed. The same operational issues for feed also apply to seed.

- There is scope for the Bangladesh Aquaculture Alliance (BAA), which comprises private-sector players, to assist in the development and promotion of certification schemes, standards and better practices.

WorldFish Bangladesh and South Asia and Bangladesh Shrimp and Fish Foundation (BSFF): Two subjects were discussed: collaboration in the follow-up activity to the seed and feed project; and assistance in the development of a National Aquaculture Development Strategy and Action Plan of Bangladesh, as requested of FAO by the Ministry of Fisheries and Livestock (MoFL), Government of Bangladesh. The importance of implementing the Fish Hatchery Act (2010) and the Fish Feed and Animal Feed Act (2010) was stressed during the meeting. WorldFish is willing to take part and provide some support for a stakeholders' workshop that would recommend measures to implement the Fish Hatchery Act. It can also provide support to the formulation of a National Aquaculture Development Strategy and Action Plan of Bangladesh. The BSFF would be collaborating in both activities.

2. Stakeholders' workshop

The workshop to improve the relevance of the TCPF project was held on the afternoon of 26 April 2012 at the FAO Representation, Dhaka, and was attended by 24 participants representing the DoF, the private sector, and FAO. This section briefly describes the proceedings of the workshop and gives a summary of the outcomes.The FAO Representative gave the broad rationale for the workshop, which was to provide the opportunity for the stakeholders to examine the findings of the mission critically and to provide guidance on the project's future activities. This project is expected to lead to a broader set of activities on seed and feed in relation to the expansion of a sustainable aquaculture sector and the socio-economic development of the country. The Director General of the DoF recalled the earlier discussions with FAO on the constraints to aquaculture development related to the quality of seed and feed, which led to the government requesting this assistance. He emphasized the need for implementation guidelines to support the recently approved Fish Hatchery Act (2010) and Fish Feed and Animal Feed Act (2010). He particularly mentioned the need for certification standards for hatcheries and feed manufacturers and the strengthening of institutional and personnel capacity to support the implementation of the certification scheme.

The government officers, who included brood bank managers, hatchery operators, extension officers and other officials, noted that:

- Too many activity areas exist, and thus there is a lack of focus on the major objective of the government seed multiplication farms. They suggested removing the peripheral activities.
- Target production and revenue given to the seed multiplication farms need to be reviewed; they need to be matched to the capacities and resources of the farms.
- Feed-quality testing facilities should be set up under the DoF.
- Efficacy and impacts of feed additives and growth promoters should be assessed.

- Water quality (especially ammonia content) in broodstock farms and hatcheries should be assessed, monitored and, as needed, controlled.
- The government is conducting a programme to register fish hatcheries, and it should proceed as fast as possible. The target is for 10 000 farms to be registered per year.
- The Carp Brood Bank Project was to be phased out by the end of 2012, but it may continue as a regular programme of the government if adequate support is provided.
- Brood banks can be established in the larger government hatcheries where an adequate number of ponds and other hatchery facilities are available, such as in Kotchandpur, Raipur, Nimgachi and Parbatipur hatcheries.
- It was suggested that a public-private partnership (PPP) be explored in the development and implementation of research and technology development projects for seed and feed. One mode of PPP could be government and private-sector collaboration on a project basis, with the major funding coming from government (or a development assistance agency), and the private sector providing complementing technical as well as business expertise and operational personnel.

*Collection of Nile tilapia (*Oreochromis niloticus*) eggs from females in hapas, Trishal, Bangladesh. The collected eggs will be hatched in incubation systems, reared in hapas and will be fed with a 17 α-methyl testosterone treated feed until they are sex reversed. This is the most common method to produce all male tilapia in Bangladesh.*

COURTESY OF FAO/THOMAS A. SHIPTON

Annex 2

An indicative national programme to improve efficiencies along the aquafeed supply chain

1. **Rationale:** Focusing on efficiency of the market chain gives a systematic rather than a disjointed view of the aquafeed sector. This enables addressing of key and critical factors of inefficiencies that affect the viability and sustainability of the feed industry and the profitability and sustainability of the fish-farm enterprises.
2. **Purpose:** Improve productivity, competitiveness and sustainability of fish farms and viability of the aquafeed industry.
3. **Scope:** Supply chain of the industrial, semi-commercial and farm-made feeds for fish and crustaceans.
4. **Models of the Bangladesh aquafeed supply chain:**

a. Industrial feed chain actors and functions:

Manufacturers	Depots and dealers	Farmers
• Produce feed	• Transport, store and distribute feed	• Utilize feed
• Source and assemble raw materials	• Develop local clientele	• Provide feedback of efficacy of feed to dealers
• Develop distribution system	• Inform manufacturer of market situation	
• Provide business advice and technical training to dealers	• Provide technical advice to farmers	
• Provide technical advice and extension service to farmers		

b. Farm-made feed supply chain actors and functions:

Ingredient suppliers	Feed makers	Retailers	Farmers
• Source and assemble ingredients and raw materials	• Produce feed for sale to retailers • Provide made-to-order feed-manufacturing service to farmers	• Develop local clientele	• Provide own ingredients and raw materials to feed producers for manufacture of moist and dry pellet feed • Utilize feed

5. **Inefficiency factors in the supply chain and impacts (based on issues and constraints identified by the national consultants and the FAO field mission):**

Inefficiency factors				
Supply of raw materials	**Manufacture of industrial pellet feed**	**Production of farm-made feed**	**Sale and distribution**	**Utilization**
• Unavailability/ scarcity of raw materials • High cost of raw materials • All major ingredients are imported	• High cost of manufacturing • Lower efficiency by having to meet seasonal requirements for feed for different age groups of cultured species	• Variable standards of quality • Poor quality of raw materials • Seasonal variation in the availability of raw materials • Higher cost of production	• Poor transport systems in many areas • Substandard storage facilities • Inability to provide feed on terms other than cash on delivery	• Wastage from poor feed management • Poor feed conversion ratios (FCRs) from: - poor feed management - low-quality feed - non-age specific feed - poor-quality seed • Inability to assess feed quality, demand a quality standard or purchase higher-priced, better quality feed • Individual rather than group purchase • Substandard on-farm storage

Impact of inefficiencies				
Supply of raw materials	**Manufacture of industrial pellet feed**	**Production of farm-made feed**	**Sale and distribution**	**Utilization**
	• Increased price of feed or price is maintained but quality is low (e.g. lower protein content), particularly by smaller manufacturers	• Low quality • Undetermined and variable quality standard	• Higher costs • Late or no delivery • Reduced quality	• Lower yield than potential; low returns; small cash flow; locked into low-quality feed • No access to feed • Low bargaining power; cannot avail of discounts on bulk purchase

6. Support services to the aquafeed supply chain:

Industrial feed manufacturers	Farm-made aquafeed producers	Dealers	Farmers
• Research and technology development	• Research and technology development	• Market information	• Research and technology development
• Government policy and regulations	• Government policy and regulations	• Training	• Government policy and regulations
• Financial services	• Financial services	• Transportation	• Financial services
• Market intelligence	• Training and extension		• Training and extension
• Training and extension	• Information and communication		• Information and communication
• Transportation	• Transportation		• Seed supply
• Raw material supply	• Raw material supply		• Veterinary advice

7. Measures to address inefficiencies:

Research and technology development (R&TD)

- Development of feed formulations for specific ages/sizes of fish
- Technical and economic study on the efficacy of feed additives
- Survey of farm-made feed production practices and facilities
- Feed analytical service for semi-commercial and farm-made aquafeed producers

Policy and regulations

- Feed Act awareness, technical guidelines for implementation of Feed Act and Regulation, capacity building for monitoring and enforcement, registration and licensing of small-scale feed producers
- Quality assurance standards for ingredients and finished product
- Import duties for ingredients – assessment of impacts on industry

Training and extension

- Better manufacturing practices (BMPs) for development and promotion to semi-commercial and farm-made feed producers
- Better on-farm feeding and feed management practices and on-farm demonstration
- Organization of farmers associations – demonstration of BMPs, bulk purchase arrangements, organized marketing
- Quality maintenance of feed ingredients and feed

Financial services

- Credit programme and crop insurance for organized farmers adopting BMPs
- Credit programme for semi-commercial and farm-made feed producers

A farmer is ready to feed his fish in his carp farm, Mymensingh, Bangladesh.

COURTESY OF FAO/NESAR AHMED

Annex 3

An example of a structured research and development (R&D) programme for aquaculture seed

R&D areas	Priority activities (examples)	Partnerships (lead agency and partner institutions)[1]
1. Production technology: a. Broodstock development and management b. Seed production • breeding • hatchery • nursery	• Collection and maintenance of pure lines • Selective breeding programme • Genetic quality assessment • Hatchery best management practice guide • Training of hatchery technicians	DoF, BFRI, BAU, WorldFish, FAO
2. Distribution/marketing of seed	• Training for nursery operators • Improvement of seed transport system • Best practices in seed nursery and transport	DoF, BFRI, BAU, selected private hatchery and nursery operators
4. Grow out	• Better management practices (BMPs) • Training of farmers	DoF, BFRI, BAU, selected progressive farmers, BSFF
5. Socio-economics and livelihoods	• Farmers organizations, farmer clusters • Credit support to hatcheries, nurseries and farmers	DoF, BAU, WorldFish, selected NGOs, BSFF, FAO, NACA
6. Biodiversity and environment	• Risk assessments for introductions of new species • Habitat management • Assessment of impact of hormones and other additives	DoF, BAU, WorldFish, DoE, FAO, NACA
7. Governance of the seed subsector	• Implementing guidelines for Fish Hatchery Act (2010) • Registration of hatcheries • Certification standards for hatcheries • Code of practice for nurseries and traders	DoF, WorldFish, BSFF, FAO

[1] BAU = Bangladesh Agricultural University, BFRI = Bangladesh Fisheries Research Institute, BSFF = Bangladesh Shrimp and Fish Foundation, DoE = Department of the Environment, DoF = Department of Fisheries, FAO = Food and Agriculture Organization of the United Nations, NACA = Network of Aquaculture Centres in Asia-Pacific.

*A farmer with his harvest of shrimp (*Penaeus monodon*), Khulna, Bangladesh.*

COURTESY OF FAO/BEGUM NURUN NAHER

Annex 4

An example of a structured research and development (R&D) programme for aquaculture feed

R&D areas	Priority activities (examples)	Partnerships (lead agency and partner institutions)[1]
1. Raw materials: access and availability a. Assessment of local ingredients b. Source of local ingredients c. Testing of ingredients for quality and safety	• Survey, identification and assessment of sustainable local sources of ingredients • Promoting the production of plant-based feed ingredients • Efficacy and safety of additives • Feed testing facilities: upgrading of capacities and harmonization of standards	DoF Fish Inspection and Quality Control Laboratory (Khulna), BFRI, Department of Livestock Services, Department of Agriculture Extension, BCSIR, WorldFish, FAO
2. Manufacture of aquafeed (small & medium scale) a. Machinery and other equipment: technical, economic and energy efficiency b. Process: technical and economic efficiency, environmental friendliness	• Assurance of reliable energy source • Design and development of technically efficient machinery and milling process • Ready repair and maintenance of equipment • Feed formulation for different species and life stages of fish • Training of feed manufacturers and technicians in feed formulation and processing	BCSIR, DoF, Department of Livestock Services, BFRI, BAU Faculty of Engineering, FAO, WorldFish
3. Distribution/marketing of aquafeed	• Proper handling, packing and storage • Bulk buying from organized farmer groups • Credit facility for distributors and dealers	DoF, feed manufacturers association, farmers associations
4. Utilization of aquafeed	• Development and promotion of better on-farm feeding and feed management manual • Training of farmers in better feed management.	DoF, BFRI, farmers associations
5. Socio-economics and livelihoods	• Farmers socio-economics and livelihoods clusters • Credit support for small- and medium-scale feed producers, dealers and farmers	DoF, BSFF, BFRI
6. Environment	• Energy efficient feed manufacturing • Better feed management	DoF, DoE, BFRI, BSSF, FAO

R&D areas	Priority activities (examples)	Partnerships (lead agency and partner institutions)[1]
7. Governance of the aquafeed feed subsector	• Implementing guidelines for Feed Act • Good feed manufacturing practices • Association of small and medium-scale feed manufacturers	DoF, BFRI, WorldFish, BSFF, FAO

[1] BAU = Bangladesh Agricultural University, BCSIR = Bangladesh Council of Scientific and Industrial Research, BFRI = Bangladesh Fisheries Research Institute, BSFF = Bangladesh Shrimp and Fish Foundation, DoE = Department of the Environment, DoF = Department of Fisheries, FAO = Food and Agriculture Organization of the United Nations.

Annex 5

Suggested socio-economic elements to best practices for feed production and marketing and seed production and distribution

A. Social and economic elements to consider for the best practices guidelines on feed production, feed marketing, seed production and seed distribution.

1. Guiding principles:

1.1 Better management practices (BMPs) are guided by scientific information or, in the absence of such, by the best available empirical and proven experience.
1.2 A best practice guideline is a part of the voluntary or self-management governance mechanisms.
1.3 It complements and should enhance the other governance mechanisms (both market-based and the mandatory). Some practices are market oriented in that they would improve market access and profitability; some are intended to improve capacity to comply with regulations, such as being organized into an association or being more aware of regulations. Compliance with regulation however is NOT a best practice; the ability to do so is an outcome of a best practice guideline.
1.4 The social and economic elements of a best practice guideline enable the pursuit of profitability without compromising social responsibility and environmental sustainability.
1.5 On the other hand, the pursuit of social and environmental objectives shall, as much as possible, provide opportunities for improving the profitability of producers and operators.
1-6 Regulations, legally prescribed standards and voluntary standards shall help the seed and feed subsectors to become socially and environmentally responsible without affecting their growth.
1.7 The BMPs should be informed by and aligned with relevant international conventions, agreements, protocols and principles.

2. Social elements: the social elements of a BMP help the seed and feed subsectors avoid social risks and improve social and environmental responsibility.

2.1. Feed manufacture (farm-made feed)
- 2.1.1. Use of certified ingredients
- 2.1.2. Use of local ingredients as much as possible
- 2.1.3. Payment of proper wages for hired workers
- 2.1.4. Transparency in declared feed quality (e.g. protein and other nutrient contents)
- 2.1.5. Non-use of harmful additives

2.2. Feed manufacture (industrial feed)
- 2.2.1. Observance of labour standards
- 2.2.2. Transparency in declared feed quality
- 2.2.3. Non-use of harmful additives
- 2.2.4. Environmentally friendly manufacturing process
- 2.2.5. Preference to hiring of local workers (in the community where factory is located)

2.3. Feed marketing
- 2.3.1. Fair pricing
- 2.3.2. Fair competition
- 2.3.3. Provision of incentives to dealers
- 2.3.4. Discounts on bulk purchase
- 2.3.5. Provision of technical advice to dealers and farmers
- 2.3.6. Proper labelling
- 2.3.7. Proper storage of feed
- 2.3.8. Farmer-friendly packaging size and price of a package or bag
- 2.2.9. Farmer-friendly terms of purchase
- 2.3.10. Strategic dealership locations convenient to farmers
- 2.3.11. Assistance in transport of feed to farms
- 2.3.12. Sufficient stock of each type of feed
- 2.3.13. No manipulation of price by such practices as hoarding.

2.4. Seed production (hatchery)
- 2.4.1. Guaranteed and certified quality of seed (genetic properties and health)
- 2.4.2. A reputation for quality and reliability of seed supply
- 2.4.3. Avoiding negative impacts on the community's domestic and irrigation water supply
- 2.4.4. Hiring labour from the community as much as possible
- 2.4.5. Purchasing supplies from the community as much as possible
- 2.4.6. Compliance with labour standards and adherence to fair labour practices
- 2.4.7. Insuring the hatchery facilities and equipment

2.5. Seed distribution
- 2.5.1. Fair competition among seed producers and dealers
- 2.5.2. Proper pricing of seed; no collusion with others in manipulating the price of seed
- 2.5.3. Provision of certified healthy seed
- 2.5.4. Technical advice to farmers

3. Economic elements: the economic elements enable the pursuit of economic viability/financial objectives without compromising social and environmental responsibility.

3.1. Feed manufacture
- 3.1.1. Energy-efficient operations
- 3.1.2. Least-cost principle in feed manufacture

3.2. Feed marketing
    3.2.1. Energy-efficient marketing operation
    3.2.2. Good management of inventory
    3.2.3. Anticipation of farmers' feed requirements

3.3. Seed production
    3.3.1. Use of high-quality broodstock
    3.3.2. Energy- and water-efficient operation
    3.3.3. Proper timing of harvest and sale of spawns

3.4. Seed distribution
    3.4.1. Maintain health of fingerlings in nursery and in transport
    3.4.2. Assure reliable water supply for nursery ponds
    3.4.3. Assure an optimum volume of seed in nurseries at any given time to meet farmers stocking needs

B. Recommendations for a capacity-building programme

1. Policy – The Feed and Hatchery Acts should be elaborated and provided with implementing technical guidelines. A process certification guideline is developed. The technical guidelines are promoted for wide awareness by seed producers and feed manufacturers.
2. Infrastructure - The feed analytical laboratories are installed and made operational; training of technicians for the analytical laboratories is conducted.
3. Institutional - A national genetic broodstock management programme that includes the participation of the government hatcheries and fish seed multiplication farms (FSMFs) and private-sector and non-governmental organizations (NGOs) is developed; the FSMFs of government may need to separate their income-generating functions from sale of seed and concentrate on broodstock development and breeding. Associations of seed producers and feed manufacturers are encouraged and assisted to be organized.
4. Technical - Better practice guidelines (hatchery BMP and good farm-made feed manufacture guidelines) are developed, and seed producers and distributors and small-scale feed producers and distributors are trained.
5. Personnel - Training needs assessment is conducted and a training programme for technical personnel in the feed and seed subsectors such as small-scale feed producers and hatchery operators/technicians is developed.
6. Operational - The government provides the enabling environment/mechanism and support for the adoption of the best practice guidelines. One way to support the effort would be to organize stakeholder consultations for the planning of the BMP guidelines so that they have a sense of ownership in their development.

The next section is part of the capacity-building programme for the two sub-sectors.

C. Feasibility of organizing a national association of small- and medium-scale feed manufacturers and a national network of seed producers

1. National association of small- and medium-scale feed manufacturers
   1.1. Prepare a plan for a workshop in order to form/strengthen the national association of small- and medium-scale feed manufacturers; draft a short justification for forming an association.
   1.2. Obtain a formal agreement from the workshop.
   1.3. Disseminate the workshop results on this to the members of this subsector of the feed industry.
   1.4. Constitute a task force that includes some representatives of the industry to draft a plan for organizing the association; draft charter and by-laws.
   1.5. Meanwhile, conduct a survey and make a register of the small- and medium-scale feed manufacturers; solicit their opinions and suggestions and incorporate these in the draft charter.
   1.6. Organize a national meeting of small- and medium-scale feed manufacturers with the objective of officially forming the association, adopting the charter, electing a set of officers and adopting a work plan.
   1.7. Register the association – this has the additional benefit of being able to regulate better the sector by bringing the operations into the formal sector. The basic profiles of each manufacturer are obtained and included in the electronic registry.
   1.8. Start work on an industry code of practice to enhance the performance and image of the small-scale feed manufacturing industry.

2. National network of seed producers
   2.1. Same steps as above from 1.1 to 1.3.
   2.2. Create a registry of all seed producers and nurseries and register all the operators; the registration should include their basic profiles; an electronic database should be created.
   2.3. Constitute a specialist group including representatives of the seed and nursery sectors to develop a national R&D and innovation programme that includes the participation of government agencies such as the Department of Fisheries (DoF) and the Bangladesh Fisheries Research Institute (BFRI), non-governmental agencies (NGOs), foundations (e.g. the Bangladesh Shrimp and Fish Foundation [BSFF] and WorldFish) and the private sector, such as the private hatcheries and nurseries.
   2.4. Establish a national steering committee.
   2.5. Develop specific priority projects whose components can be implemented in various regions or districts in a networking arrangement.
   2.6. Find funding assistance for the project.

Field survey report on technical, economic and social constraints to aquaculture seed production and management in Bangladesh

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1. Introduction

1.1 Background

Aquaculture has been playing a significant role in fish production in the last few decades. An adequate supply of quality seed is a prerequisite for increasing and sustaining aquaculture production. A large number of hatcheries have been established in the country to provide the required quantity of seed, but maintenance of seed quality is always ignored. Some initiatives have been taken by the government to improve the quality of seed, but the outputs of these efforts is not much visible or well documented. Therefore, the present study is designed (a) to identify the issues associated with quality, processes and systems in broodstock and seed production; and (b) to suggest measures to improve quality, the efficiency of the process, and the capacities of brood banks, hatcheries and nurseries.

1.2 Period

The field survey was conducted during the period between 8 February 2012 to 29 March 2012.

1.3 Institutions/organizations/laboratories visited

FAO Bangladesh, different facilities under the DoF and BFRI (under the Ministry of Fisheries and Livestock), Bangladesh Agricultural University and private carp, tilapia and catfish hatcheries in Bangladesh were visited.

2. Scientific/technical component

2.1 Objectives of the study

The main objective of the field survey study was to identify and highlight the key technical, economic and social constraints to seed production and management in Bangladesh, with special emphasis on quality seed production by broodstock improvement.

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2.1.1 Specific objectives

Collection of benchmark information on the existing government quality seed production programme including brood bank.

- Investigation into the efficacy of the operation and implementation of the government and NGO's fish seed improvement programmes, including brood bank.
- Identification of constraints to produce quality seed and to implement the seed improvement programme.
- Assessment on the need for an economic assessment of the current seed production systems.
- Suggestions for improving seed quality, brood banks and establishment of the need for the development of better management practices (BMPs) in the seed production sector.

2.2 Methods/activities

- Benchmark information on quality seed production programme including brood bank was collected from DoF, BFRI and Brac[11] through visits to the institutes and the collection of relevant literature.
- Information on broodstock and seed production was collected from government and private hatcheries for carps, striped catfish (Thai pangas), Nile tilapia, climbing perch (koi) and also carp nurseries by visiting the hatcheries and farms.
- Data were collected by questionnaire survey and personal interview of hatchery owners, managers, operators, nursery operators and other relevant persons.
- For the survey, six sets of questionnaires for carp brood bank, private and government carp hatchery, private pangas, tilapia koi hatcheries and private carp nurseries were prepared.
- The survey lasted over 18 days and was conducted in Jessore, Rajshahi, Bogra, Mymensingh, Jamalpur, Sreemongal, Comilla and Gazipur.
- A total of eight brood banks, 17 private and government carps hatcheries, eight pangas hatcheries, nine tilapia hatcheries, four koi hatcheries and four carp nurseries were visited.
- Discussions were held with the owners and operators of different hatcheries and nurseries. Discussions were also made with the Project Director of the Brood Bank and the scientists responsible for broodstock production of carp and tilapia in BFRI and Brac.
- Collected data were assembled and compiled in separate Excel sheets and analyzed.

2.3 Carp and other fish seed production in Bangladesh

Aquaculture production in Bangladesh accelerated in last three decades with the contribution of hatchery-produced seeds. Earlier, farmers were dependent on natural seed, but since the late 1980s most of the seed has been produced in hatcheries through artificial hypophysation. Seeds are being produced from

[11] A national NGO.

nearly 1 000 hatcheries spread across the country using various hormones and spawning systems. All the carps and other fish species mentioned in Table 1 are widely popular among the people, and seeds are being artificially produced by both private and public hatcheries. The aquaculture production of the country has increased many fold over the decades, but there is still much more potential in this culture-fisheries sector. This can be achieved by the timely supply of quality seed to the growers. In fact, seed produced in hatcheries (especially in the private hatcheries) are not performing well, which causes frustration among many of the fish farmers. If the quality issue is not addressed properly, the pace of aquaculture expansion will be slowed and ultimately, sustainable aquaculture production will not be achieved. The government has taken initiatives to address the quality issue by establishing brood banks for Indian major carps to produce quality broodstock and supply them to the private and government hatcheries for seed production, but it did not achieve its goals, due to reasons such as lack of staff, insufficient farm area, non-availability of pedigreed/improved broodstock and lack of a scientific approach to broodstock management and stock improvement. Besides brood banks for Indian manor carps, steps should be taken to improve the quality of seed of other exotic carps, catfishes, koi and tilapia, as they make a significant contribution to the total aquaculture production of the country.

2.4 Information received

The data collected through the field survey and individual and group discussions were compiled in the Excel sheet and analyzed. The important information is summarized below:

1. Hatchery-produced seed are the main inputs for aquaculture, and about 99 percent of total seed are produced in private and government hatcheries. The hatcheries are mainly designed for production of carp (both indigenous and exotic carps) seed.
2. Government hatcheries are primarily involved in fry and fingerling production of indigenous and exotic carps. Some hatcheries are involved in the culture and breeding of indigenous endangered fish and small indigenous species (SIS). They also provide training on broodstock production, breeding, nursery and culture to private hatchery operators, nursery operators and farmers.
3. Government hatcheries try to maintain the quality of broodstock as they collect seed from natural sources for brood production, although the quality of natural seed is unknown. They also collect fry of known sources from BFRI and other government hatcheries for broodstock production.
4. Government hatcheries are old and comparatively small in terms of production capacity. However, hatcheries have sufficient breeding facilities but need some renovation.
5. Most of the hatcheries use circular tanks for stimulating and spawning of fish with the participation of pairs of matured broodstock. This “pool breeding facility” provides scope for increasing genetic diversity of the fry, which is hardly found or totally absent in private hatcheries.
6. Government hatcheries rear the broodstock with regular supplementary feeding by maintaining nutritional requirements and water quality, but there is no genetic management of the broodstocks due to lack of knowledge.

TABLE 1
List of indigenous and exotic carps and other finfish species commonly used for artificial seed production in Bangladesh

A. Indigenous fish species

Common name	Scientific name
Indian major carps	
Catla	*Catla catla*
Mrigal	*Cirrhinus cirrhosus*
Rohu	*Labeo rohita*
Other carps and barbs	
Bata	*Labeo bata*
Kurio labeo	*Labeo gonius*
Olive barb	*Systomus sarana*
Orangefin labeo/kalbasu	*Labeo calbasu*
Putitor mahseer	*Tor putitora*
Catfishes	
Gangetic mystus	*Mystus cavasius*
Pabdah catfish	*Ompok pabda*
Stinging catfish (local name: shing)	*Heteropneustes fossilis*
Walking catfish (local name: magur)	*Clarias batrachus*
Perch	
Climbing perch (local name: koi)	*Anabas testudineus*

B. Exotic fish species

Common name	Scientific name
Chinese carps	
Bighead carp	*Hypophthalmichthys nobilis*
Black carp	*Mylopharyngodon piceus*
Grass carp	*Ctenopharyngodon idella*
Silver carp	*H. molitrix*
Other exotic carps and barbs	
Common carp (including mirror carp)	*Cyprinus carpio*
Silver barb	*Barbonymus gonionotus*
Catfish	
Striped catfish (local name: Thai pangas)	*Pangasianodon hypophthalmus*
Tilapia	
Nile tilapia	*Oreochromis niloticus*
Perch	
Thai climbing perch (local name: Thai koi)	*Anabas testudineus*

7. Hatchery managers sometimes could not maintain the quality of broodstock and seed due to over-stretched activities, lack of manpower (including hatchery technicians), high seed production costs and low sale value. The private hatcheries often sell seed at lower prices as compared to the government hatcheries, as they have lower production costs. Many of them maintain a few broodstock throughout the year and in many cases, broodstock are collected from a farmer's pond for breeding.
8. Private hatcheries have variable production capacity and management practices. They recruit the broodstock from succeeding generations without following the basic genetic principles. They stock and rear the broodstock at high density, beyond the recommended stocking density.
9. Many private hatcheries produce seed of all the cultured species without having enough broodstock, and some of them produce huge amounts of seed, which is beyond their capacity and deteriorates the quality of seed.
10. The private hatcheries have a lower number of broodstock and often practice multispawning, even two to four times a year, within very short intervals of two to three weeks. This breeding practice not only results very high mortality of both broodstock and fry during the succeeding spawning, but also affects the quality of fish seed.
11. Many private hatcheries produce interspecific hybrids of their own interest and sometimes at the demand of nursery operators, as few hybrids show higher growth and survival during their early life history.
12. The government has set up 20 brood banks in the fish seed multiplication farms at different places of the country, which is definitely a positive approach for quality improvement; however, in true sense these are not real brood banks. Brood banks should contain separate stocks (e.g. Padma stock, Jamuna stock, Halda stock, etc.) in separate ponds, but due to space constraints, stocks are not maintained properly.
13. Continuous collection of seed from rivers for producing broodstock in brood banks and providing to private hatcheries is not an effective way to improve the quality, as the genetic status of the collected seed is unknown.
14. Government brood banks provide broodstock to private hatcheries at a price lower than tablefish in the market. This is not a good practice, as it is a waste of resources and undermines the quality of these valuable fish.
15. There is a high demand for broodstock reared in brood banks, and only a few hatcheries can receive the broodstock from a single bank. The brood banks have limited targets for broodstock production due to space problems and over-extended activities (e.g. breeding and seed production, fingerling production, broodstock production and keeping them for own breeding purpose, etc.), and this hampers the core activities needed for quality broodstock production.
16. Broodstock from brood banks are sold to hatcheries following the set guidelines, but there is no monitoring system to oversee the fate of the distributed fish.
17. Brac initiated a genetic stock improvement programme for rohu and catla via the Fish Hatchery and Brood Fish Improvement Project in Sreemongal, Moulvibazer in 2003. The brood bank started with the collection of fry of the

species from Padma, Jamuna and Halda and an F1 generation was produced through diallele crossing. After that, no further generations were produced, but the original and F1 broodstock are being used for seed production.

18. Seeds of Thai pangas, Nile tilapia, Thai and local koi are being produced, either along with carps or separately, in many parts of the country. In the case of Thai pangas and koi, broodstocks are produced from succeeding generations without maintaining genetic principles and records of pedigree. Sometimes males or females are collected from other hatcheries or areas to prevent inbreeding.
19. Inbreeding is taking place in both pangas and koi species, as their growth has been retarded after two to three generations. No new pure stocks are introduced into the breeding pool.
20. There are around 300 small and large tilapia hatcheries in the country, and these produce 3 000 million of fry each year. Most of the hatcheries produce broodstock from fry or fingerlings of their own source without following the genetic principles. Some hatcheries collect fry from BFRI for broodstock production and use them for two years for breeding.
21. BFRI has its own tilapia broodstock and maintains its quality through a selective breeding programme. Founder stock were obtained from the WorldFish Center in 2005 and F4 and F5 generations have been produced through the stock improvement programme.
22. BFRI produces 0.7–0.8 million of fry every year and sells them to private hatcheries. They distribute fry to hatcheries in 50 districts, with a range of 10 000 to 100 000 fry for broodstock production.
23. Brac has four tilapia hatcheries, and broodstock are produced in one of the hatcheries in Magura following cohort mating and then distributed to three other hatcheries. No broodstock are sold from these hatcheries to other private hatcheries. They maintain the quality of broodstock by replenishing the new stock from the WorldFish.
24. Hapa breeding is the most common practice for tilapia, and four to six fish are stocked per m^2 with a 1:3 male-female ratio. Eggs of different stages are collected from the female's mouth and incubated in either jars or trays for hatching.
25. At high temperatures, tilapia often stops breeding in the hapas, especially in the month of August and onwards. Pond breeding during the hot period can be suggested.
26. All the hatcheries produce monosex tilapia by sex reversal using 17-methyl-testosterone at a variable dose ranging from 60–100 mg/kg of feed. They fed the fry for about 21–28 days but do not check their sex.
27. There is a big concern that hormone is being indiscriminately used at higher doses. Water from the hormone treatment pond is discharged directly to beels (floodplains), rivers and other natural waterbodies without treatment, and this could be harmful to other fish and aquatic animals.

3. Problems identified

The following major problems are identified:

- Government fish seed multiplication farms having brood banks have inadequate capacity (both infrastructure/facility and human capacity) for quality broodstock production for providing broodstock to private hatcheries.
- Hatcheries are poorly staffed without hatchery technicians, and staff are not trained.
- Staff are overburdened by too many activities, such as production of broodstock, breeding of indigenous and exotic carps, fingerling production, production of small indigenous fish species and in some cases, production of endangered fish species, and yearly targets weaken the quality assurance activities.
- There is a lack of genetically improved broodstocks in government and private hatcheries.
- There is no comprehensive and coordinated effort of DoF, BFRI and universities for improvement or upgrading of broodstocks.
- Natural fry are unavailable, and there is a lack of information of their quality status.
- Pedigree records and/or data on the broodstocks used in private and government hatcheries are lacking.
- Laboratory facilities for the genetic analysis of fish are lacking.
- There is a lack of good hatchery management practices.
- Stocks of exotic carps, pangas, koi and tilapia are impure, and there is no effort made to bring new fish from original stocks.
- There is an indiscriminate use of hormone in the sex reversal of tilapia.
- Potential hazards for the aquatic environment exist due to the release of untreated hormone mixed with water.
- Implementation of the Fish Hatchery Regulations is lacking.

4. Conclusions

Production of carp seed in the hatcheries facilitates aquaculture development in Bangladesh. The country currently has a surplus of hatchery-produced seed, but their performance in nursery and grow-out systems is not satisfactory in many instances. This might be due to low quality of seed that results from inbreeding, hybridization and negative selection of broodstock. For sustainable aquaculture, the issues related to quality of broodstock and seeds need to be identified. The present study identified a number of issues that need to be properly addressed; these include origin of seed for broodstock production, broodstock management, seed production system (including infrastructure and manpower), efficiencies of brood banking, etc. To address these problems, a new research project needs to be undertaken.

5. Recommendations

- Brood banks with all facilities should be set up in few big farms where fish from different stocks (Padma, Jamuna, Halda stocks, etc.) can be maintained with individual stock identity.
- As wild seed of indigenous carp is not available and its purity is not known, improved strains should be developed through genetic selection and a selective breeding programme. Improved broodstock from a selective breeding programme can be provided to brood banks.
- New pure stocks of exotic carps, pangas, koi and tilapia from original sources should be collected and their purity should be maintained through genetic selection and selective breeding programmes.
- Training on the genetic management of broodstocks and good hatchery management practices needs to be provided to hatchery managers and other hatchery staff.
- A facility for genetic analysis of broodstock as well as seed should be developed and pedigree records should be maintained.
- A computer facility should be provided to establish a database of the broodstocks.
- Adequate manpower should be recruited, including hatchery technicians.
- The Fish Hatchery Regulation and a hatchery registration and certification system should be properly implemented.
- A monitoring system should be developed to oversee the distribution of broodstock from brood banks.
- Hormone-mixed water should be treated before releasing into open waters.

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Field survey report on technical, economic and social constraints to aquafeed production and management in Bangladesh

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1. Background

Because of its favourable resources and agro-climatic conditions, Bangladesh is considered one of the most suitable countries in the world for freshwater aquaculture. Aquaculture is thus one of the fastest-growing animal food-producing sectors in Bangladesh. During the last four decades, its development has attracted considerable attention because of food supply, income, export earnings and livelihood opportunities (Dey, Alam and Bose, 2010; Jahan, Ahmed and Beltonne, 2010; Belton *et al.*, 2011). Bangladesh was the fifth-largest global aquaculture producer in 2010 after China, India, Viet Nam and Indonesia (FAO, 2012). About 371 309 ha of freshwater ponds with over three million farmers are involved in aquaculture. The total annual fish production in Bangladesh was estimated to be 3.06 million tonnes in 2010–11, of which 1.46 million tonnes (48 percent) were obtained from inland aquaculture, 1.05 million tonnes (34 percent) from inland capture fisheries and 0.55 million tonnes (18 percent) from marine fisheries (DoF, 2012). Within a decade, fish production increased from 1.78 million tonnes in 2000–01 to 3.06 million tonnes in 2010–11, an average annual growth rate of over 7.0 percent. Overall, aquaculture and fisheries play an important role in the economy of Bangladesh, as fish contributes 60 percent to national animal protein consumption, 4.4 percent of gross domestic product and 2.7 percent of export earnings (DoF, 2012).

Indian major carps, such as catla (*Catla catla*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus cirrhosus*) have long been cultured in Bangladesh. Indian major carps are the most dominant group of culture species, accounting for 55 percent of the total aquaculture production (DoF, 2012). Table 1 shows that rohu is the most dominant species, contributing 22.0 percent to aquaculture production in Bangladesh, followed by catla (17.2 percent). Exotic carps, which include Chinese carps (silver carp (*Hypophthalmichthys molitrix*) and grass carp (*Ctenopharyngodon idella*)) and the common carp (*Cyprinus carpio*) contribute 17.0 percent to aquaculture production in Bangladesh. Among these species, silver carp accounts for 10.5 percent of aquaculture production and is ranked fifth among culture species. According to DoF (2012), both carps (native and exotic) contribute about three fourths (72.0 percent) to aquaculture production in Bangladesh.

[12] Department Fisheries Management, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh.

Catfish such as striped catfish (*Pangasianodon hypophthalmus*), stinging catfish (*Heteropneustes fossilis*) and walking catfish (*Clarias batrachus*) are also cultured in Bangladesh, contributing 13.4 percent to aquaculture production. Among these species, striped catfish (locally known as Thai pangas or pangas) accounts for 12.8 percent of aquaculture production and is ranked third among culture species. Nile tilapia (*Oreochromis niloticus*) is another popular aquaculture species and accounts for 8.1 percent of aquaculture production and holds sixth position among culture species. Barbs such as silver barb (*Barbonymus gonionotus*), pool barb (*Puntius sophore*) and olive barb (*Systomus sarana*) contribute 4.3 percent to aquaculture production. Climbing perch (*Anabas testudineus*) and snakeheads (spotted snakehead, dwarf snakehead, striped snakehead and giant snakehead) have also recently been cultured in Bangladesh and account for 1.1 percent and 0.2 percent of aquaculture production, respectively (DoF, 2012).

TABLE 1
Major aquaculture species and their contribution to fish production in 2010–11

Species	Aquaculture production (tonnes)	Percent (%) of total aquaculture production	Rank as culture species
Indian major carps			
Rohu	268 563	22.0	1
Catla	209 146	17.2	2
Mrigal	151 821	12.5	4
Kalbasu and bata[1]	36 393	3.0	9
Exotic carps			
Silver carp	127 826	10.5	5
Common carp	57 509	4.7	7
Grass carp	21 020	1.7	10
Catfish			
Striped catfish (Thai pangas)	156 375	12.8	3
Stinging and walking catfish	6 780	0.6	12
Nile tilapia	98 758	8.1	6
Barbs			
Silver barb (Thai sarpunti)	40 421	3.3	8
Pool barb (punti)	6 575	0.5	13
Olive barb (sarpunti)	5 539	0.5	14
Climbing perch	13 406	1.1	11
Snakeheads	2 298	0.2	15

[1]Statistics often do not distinguish among different species.
Source: DoF (2012).

Finfish aquaculture in Bangladesh is primarily dependent upon a supply of fish seed and aquafeed of adequate quality and quantity. Feed is one of the most important inputs to increase fish production, and feed intake is a major factor controlling growth for fish. There is great potential to increase the productivity of aquaculture through increased feed supply. Feed costs generally constitute the highest single operating cost in aquaculture of Bangladesh (Ahmed, 2007). Thus, there is a high degree of variability among farmers in terms of their use of supplemental feeds to minimize the production costs. A variety of feeds is used for aquaculture, including supplementary diets, farm-made aquafeeds[13] (i.e. feeds for aquaculture) and industrially produced pelleted feeds. With the intensification of aquaculture, the use of industrially produced aquafeeds has recently been increased to enhance productivity.

The production and supply of quality aquafeeds is an essential prerequisite to increasing production efficiencies. However, the aquaculture industry in Bangladesh is constrained by poor quality feed. Maintaining feed quality remains challenging, and in many cases, poor feed quality results in low production. It has also been reported that farmers are often induced to use various feed additives, growth hormones, enzymes, antibiotics and probiotics. Nevertheless, potential public health and environmental impacts are the major concern for using these additives. Although the Government of Bangladesh has formulated the Fish Feed and Animal Feed Act (2010) to ensure the quality of feed, it is not apparent how this act is being implemented. It is therefore necessary to understand the current practices of aquafeed use in terms of sustainable aquaculture in Bangladesh.

1.1 Objectives

The objective of the study was to identify the technical, economic and social constraints to aquafeed production and management in terms of sustainable aquaculture practices in Bangladesh.

The specific objectives were:

(a) to investigate the technical, economic and policy constraints related to the production of quality aquafeeds;

(b) to assess the major issues that need to be addressed to build the capacity of farmers to optimize the use of feed and feed additives; and

(c) to identify the support services that are needed to build the capacity of small-scale aquafeed producers to enable them to improve the technical efficiency of their production processes.

[13] The terms "fish feed" and "aquafeed" are interchangeably used in this report. Aquafeed is comprised of a number of ingredients that are mixed in various proportions to culture fish, prawns and shrimp.

2. Methodology

2.1 Study Area

The study was conducted in several districts of Bangladesh, including Bagerhat, Bogra, Comilla, Gazipur, Jessore, Khulna, Kishorganj and Mymensingh (Figure 1). These districts were selected in order to get a holistic picture of Bangladesh's aquaculture, particularly feeding practices, but including feed production and marketing. They were chosen based on three criteria, importance to: (1) inland aquaculture, (2) coastal aquaculture and (3) feed production and marketing (Table 2). Mymensingh is the hub of freshwater aquaculture in Bangladesh (Ahmed, Alam and Hasan, 2010). Bogra and Comilla are also important for freshwater aquaculture. Although Kishoreganj and Gazipur have lower fish production, both districts are promising for feed marketing. Geographically, Khulna and Bagerhat have also been identified as the most important and promising areas for coastal aquaculture, including prawn and shrimp farming. Hydrological conditions are also favorable for aquaculture in these districts, as Bangladesh is located within the monsoon tropics. Moreover, conditions are highly encouraging for aquaculture because the quantity of fish fry produced in their hatcheries has risen rapidly in recent years. A significant number of fish-feed depots and dealers are also located in these districts.

FIGURE 1
Map of Bangladesh showing the study areas

TABLE 2
Selection criteria of the study area with fish production from aquaculture in 2010–11

Study area		Aquaculture production (tonnes)	
		Fish	Prawn/shrimp
Inland aquaculture	Mymensingh	218 952	34
	Bogra	46 007	–
	Comilla	63 483	–
	Jessore	52 037	12 752
Coastal aquaculture	Bagerhat	18 529	50 218
	Khulna	9 053	35 776
Feed production and marketing	Gazipur	17 057	2
	Kishorganj	15 432	–

Source: DoF (2012).

2.2 Data collection methods

The three stages of the field visits were conducted over a period of 45 days on an intermittent basis from March to August 2012. A combination of participatory, qualitative and quantitative methods was used for data collection (Table 3).

TABLE 3
Data collection methods and sample size for target groups

Method	Target group	Sample size	Information gathered
1) Questionnaire interviews	Managers/technical staff of feed industries	10	Types of feed production, feed ingredients, production capacity, processing, quality control, price, supply and demand, constraints
2) Rapid appraisal	Semi-commercial/ farm-made aquafeed producers	20	Feed ingredients, processing, production costs, returns, price of feed, feed-related constraints
3) Rapid market appraisal	Feed dealers, agents, transporters, day labourers	50	Feed distribution, transportation, marketing, value chain and marketing constraints
4) Focus-group discussion	Fish farmers	100	Feed application, feed utilization, quality of feed, feed price, fish productivity, feed-related constraints
5) Key informant interviews	Knowledgeable observers, researchers, policy-makers and practitioners	50	Cross-check and validity of collected information

Questionnaire interviews with managers (or technical staff) of industrially produced pelleted feed were preceded by the preparation and testing of the questionnaire. Pilot testing of the questionnaire was carried out with feed managers, the aim of the pilot survey being to ensure that the questions included in the schedule were clear of ambiguities and that the respondents could answer the questions easily. The questionnaire was modified and improved based on experience gained from the pilot survey. Feed managers were selected through simple random sampling[14]. There are currently 100 feed manufacturers in Bangladesh. Among them, the managers of a total of ten feed manufacturers were interviewed at their offices and/or work sites. Several visits were made to the selected feed manufacturers to observe feed manufacturing practices. The interviews lasted about an hour, and were focused on feed manufacturing systems, types of feed production, use of feed ingredients, production capacity, processing, quality control, price, supply and demand, and feed-related constraints.

Rapid appraisal was conducted to gather information from farm-made aquafeed producers. Rapid appraisal is a method of rapid assessment[15] to collect information quickly and systematically (Chambers, 1994; Townsley, 1996). Rapid appraisal can be applied to get a quick insight into the issues affecting a local community and the priorities for change. Rapid appraisal can gather information for decision-makers within weeks that is not possible with a sample survey. For this study, a total of 20 farm-made aquafeed producers were surveyed using this method. During rapid appraisal, a list of questions was used that focused on farm-made aquafeed production, use of feed ingredients, production costs, production capacity, price of feed and feed-related constraints.

Rapid market appraisal (RMA) is an efficient way to obtain policy-relevant and intervention-focused information about any commodity subsector (Holtzman, 2003). RMA techniques mostly rely on discussion with key market actors and knowledgeable observers of a subsector. This study was designed to apply RMA to include: i) identifying aquafeed marketing channels; ii) visiting physical facilities such as feed-landing sites, depots and markets; and iii) directly observing aquafeed trading operations. For this method, several visits were made to feed markets in the study area. A total of around 50 market actors were contacted for discussion.

Participatory rural appraisal (PRA) is a group of methods to collect information from rural communities on a participatory basis. The advantage of PRA over other methods is that it allows wider participation of the community, and therefore, the information collected is likely to be more accurate.

[14] A sample is drawn from a population in such a way that every possible sample has an equal chance of being selected.

[15] Rapid assessment is a way to investigate complicated situations in which issues are not yet well defined and where there is insufficient time or a lack of other resources necessary for long-term, traditional qualitative research. Rapid assessment is used to develop a quick, preliminary understanding of a situation from the insider's perspective.

For this study, the PRA tool "focus group discussion" (FGD) was conducted with fish farmers. FGD is a group meeting where people from the target communities discuss selected topics. A total of ten FGD sessions were conducted for this study, with each group consisting of 6–12 persons, thereby allowing the participation of a total of around 100 farmers. FGD was used to provide an overview of fish-farming practices, feeding systems, feed management and procurement, feed quality and feeding constraints.

A "key informant" is someone with special knowledge on a particular topic. Key informants are expected to be able to answer questions about the knowledge and behaviour of others, and the operations of the broader systems. Interviews were conducted with government fisheries officers, researchers, policy-makers and relevant project staff. A total of over 50 key informants were interviewed in their offices and/or working fields. Key-informant interviews were conducted to validate collected information and to identify feed management strategies based on the participants' knowledge, skill and experience.

Data from the questionnaire interviews were coded and entered into a spreadsheet using Microsoft Excel software. Descriptive statistics were derived using SPSS (Statistical Package for Social Science). Results from data analysis, in combination with qualitative information collected through various methods, were used to describe feeding practices with technical, economic and social constraints.

3. Key findings

Aquafeed is an emerging issue in Bangladesh for sustainable aquaculture. A variety of feeds are used for aquaculture, including supplementary feeds, farm-made/semi-commercial feeds and industrially manufactured pelleted feeds. Commercially formulated pelleted feed containing animal protein was not used previously in aquaculture. In recent years, an increasing number of farmers have been using industrially manufactured pelleted feed for catfish, tilapia and climbing perch farming. In terms of farming intensity, there is considerable overlap in feed use by farmers (Table 4). In general, extensive farmers mainly use supplementary feed. In contrast, farm-made/semi-commercial aquafeeds and industrially manufactured pelleted feeds are used by improved-extensive and semi-intensive farmers, respectively. The following sections describe three types of feed production, distribution and application.

TABLE 4
Feeding practices by category of farmers and farming intensity

Feed	Farming system	Farmer characteristics
Industrially manufactured pelleted feed	Semi-intensive and intensive[1]	Comparatively better-off and large farmers, using higher inputs for aquaculture
Farm-made aquafeed	Improved-extensive and semi-intensive	Medium farmers, intermediate level of inputs for aquaculture, unable to pay for high inputs
Supplementary feed	Traditional and extensive	Small and marginal farmers, resource poor, using lower inputs for aquaculture

[1]Intensive farming is limited in Bangladesh due to inadequate biophysical conditions.

3.1 Industrially manufactured pelleted feeds

In recent years, commercially manufactured aquafeed has become a multimillion dollar industry in Bangladesh. Although the first industrial aquafeed manufacturer, namely Saudi Bangla Fish Feeds Ltd., started in the early 1990s in Bangladesh, establishing of feed industries has been widespread since the 2000s. There are around 100 aquafeed industries in Bangladesh. Although 68 feed industries were recorded during the field survey, there are many unreported feed industries in Bangladesh[16]. The feed industries are located throughout the country. Most feed industries have substantial experience (5–10 years) of aquafeed production and marketing. Almost all technical staff of feed industries have received organized training on feed production and processing.

Most aquafeed industries also produce poultry feed. According to the survey of feed managers, it was found that feed industries produced 55 percent poultry feed and 45 percent aquafeeds. The poultry sector remains the leading consumer of industrially manufactured feed in Bangladesh, and thus feed managers suggested that poultry feed production is more profitable. Nevertheless, aquafeed is becoming an emerging sector in Bangladesh. According to key informants, poultry feed is still more profitable than aquafeed, because of year round business all over Bangladesh. Conversely, aquafeed is less profitable due to the six to nine month fish-culture period[17]. The peak season of aquafeed business is from March to October, while the lean season is from November to February. In general, the production volume of aquafeed is one-sixth that of poultry feed. According to key informants, the production of poultry feed is estimated to be 3.5 million tonnes per annum in Bangladesh,

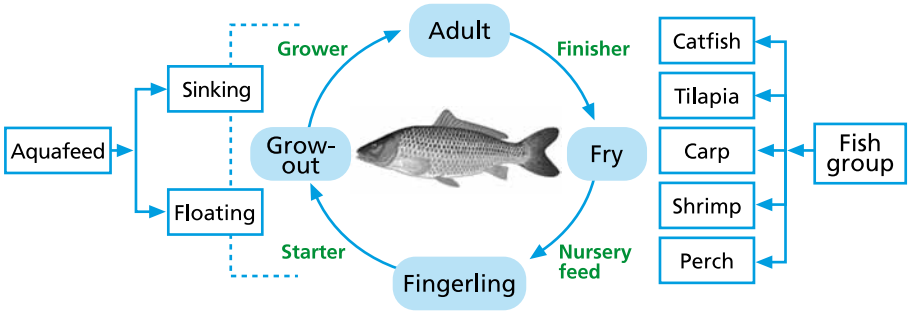
[16] The Department of Fisheries is in the process of registering the feed industries.
[17] Fish culture is limited during the dry season from November to February due to scarcity of water and unfavourable environmental condition (weather temperatures below 15 ^{0}C).

compared to 0.6 million tonnes of aquafeeds. A typical feed manufacturer produces an average of 49 500 tonnes per annum of aquafeeds, with production ranging from 20 000 to 95 000 tonnes per annum, depending on capacity, financial ability, skilled manpower, seasonality, and demand for feed. According to the survey, most feed industries (60 percent) are medium-scale producers (40 000–60 000 tonnes/year), while 30 percent and 10 percent are small-scale (10 000–40 000 tonnes/year) and large-scale (60 000–95 000 tonnes/year) producers, respectively. It has been reported that the production capacity for aquafeeds ranges from 10–20 tonnes/hour. Almost all surveyed feed industries reported that their production capacity has increased due to increased demand. It has been reported that the production of aquafeeds has increased 25 percent over the last five years. Nevertheless, 45 percent of the capacity in feed industries is currently underutilized (BFRI, 2011).

A significant number of aquafeed industries are joint venture projects between Bangladesh and other countries (e.g. China, India, Malaysia, Thailand, Germany, and the United States of America). The feed manufacturers use machinery and equipment that are imported from China, India, Thailand, Europe and the United States of America. Two types of aquafeed are produced by the feed industries, i.e. floating and sinking feeds. The majority of feed manufacturers produce sinking feed, as the production of floating feed requires specialized technology. It is roughly estimated that around 70 percent of the aquafeeds produced are sinking and the rest (30 percent) are floating. Each type of feed can be classified as: (1) nursery (mash/powder, crumbled), (2) starter (starter 1, starter 2, starter 3), (3) grower (grower 1, grower 2) and (4) finisher (Figure 2). All of these aquafeeds are mainly produced for the culture of five groups of aquatic animals: (1) catfish, (2) tilapia, (3) carps, (4) prawns and shrimp[18], and (5) climbing perch (no finisher feed for climbing perch). According to the survey, about 15 percent of aquafeed is produced for nursery feed, 25 percent for starter, 50 percent for grower and 10 percent for finisher feed. Survey results also revealed that about 60 percent of aquafeeds are produced for pangas, 25 percent for tilapia, 8 percent for prawns and shrimp, 5 percent for carps and 2 percent for climbing perch. In general, a typical feed company produces around 20–35 types of feed (i.e. 5–7 categories of feed (nursery mash, nursery crumbled, starter 1, starter 2, grower 1, grower 2, finisher) x 4–5 groups of fish = 20–35)). Although almost all aquafeed industries produce pangas feed and others, because of the limited farming in coastal areas, only a few industries produce prawn and shrimp feeds.

[18] The term "prawn" is used for freshwater crustaceans only and the brackish water/marine crustaceans are called "shrimp".

FIGURE 2
Types of aquafeeds for different groups of fish and their different culture stages



In general, the feed manufacturers use similar ingredients to produce aquafeeds. The ingredients that are used include fishmeal, mustard oilcake, sesame oilcake, defatted rice bran, rice polish, wheat flour, maize, meat and bone meal, soybean oil, defatted soybean meal, calcium phosphate, salt and vitamin premixes. Although similar ingredients are used by the different feed manufacturers, the formulations that are used differ. The majority of feed ingredients are imported from Australia, Canada, China, Europe, India, Malaysia, Thailand and the United States of America. Because of increased productivity, the supply of feed ingredients has increased 25 percent over the last five years. However, some ingredients, including rice bran, oilcake and fishmeal are locally sourced.

According to feed managers, a number of processing stages are followed in the production of aquafeed by feed industries, such as: mixing, grinding, shifting, extrusion, shaping, drying, coating, cooling and packaging. After mixing of feed ingredients, a grinding system reduces the raw component blend to small particle size. The blend particle is then transferred to the control shifter for processing and is finely ground and to eliminate insoluble substances. After that, the extrusion process is followed, which is essentially a cooking process with appropriate heat. The sinking or floating characteristics are controlled through the extrusion process. Then the hot product melt is shaped and cut, and dried out. After that the dried, extruded feeds are coated and subsequently cooled. Finally, packaging and labeling are done at the plants.

Almost all industrially manufactured aquafeeds are marketed internally for domestic use. A considerable number of people find employment in the feed marketing chain as traders, intermediaries, transporters and day labourers. The feed-marketing system is competitive and plays a vital role in connecting the manufacturers to the farmers. Market competitiveness has also increased due to the involvement of many feed industries. With a few exceptions, manufacturers do not directly communicate with farmers. A market network has recently been developed with transport facilities. The communication network between the market actors is generally good and is assisted by mobile phones. The majority of

feed manufacturers do not have their own vehicles and depend on hired vehicles to transport their feed. Only a few large feed companies have a limited number of vehicles to transport feed. In general, trucks and pickups are used to transport feed from the manufacturers to the depots. A typical feed manufacturer has 20–30 feed depots. Each feed depot has a storage facility (storage time 1.0–1.5 months) which is controlled by the feed company. A feed manufacturer is usually tied with around 100 dealers, depending on the production capacity, distribution system, marketing strategy and mode of transportation. A dealer sells an average 1 850 kg/day of feed during the peak season (March–October), while 115 kg/day is sold during the lean season (November–February). Feed dealers directly supply the feed to the subdealers or farmers. They operate storage facilities and have supply contracts with the subdealers and/or farmers. In general, subdealers are tied to a limited numbers of dealers. Pickups and vans are commonly used to transport feed from the dealers to the subdealers. Finally, the farmers carry the feed from the subdealers using vans, rickshaws or by foot. Usually the cost of transporting the feed from the manufacturers/depots to the dealers is borne by the dealers. Similarly, the cost of feed transportation from the dealers to the subdealers is borne by the subdealers, and ultimately the farmer bears the cost of transporting the feed to the farm.

Aquafeeds are sold for cash or on credit. The field survey indicates that around 70 percent of feeds are sold on credit. Usually feed manufacturers sell their product to dealers on credit and the dealers pay back after selling of feed. If dealers pay back within a month, no interest is charged for credit; however, if pay back is made after a month, interest is charged based on the prevailing bank rate. The feed industries' capital installations and much of their working capital are provided by the banks. Feed industries typically enjoy a very close working relationship with their banks, for which this sector is a major business. Local branches of national banks provide credit at a 15 percent yearly interest rate, with collateral of land. In most cases, dealers also take a commission from feed industries for selling feed. Feed dealers' own finance comes mainly from a mix of personal and informal sources. Feed dealers also receive feeds as loans from feed manufacturers. Usually, dealers sell feed to farmers with credit, as farmers buy feed in advance towards the beginning of the farming season and pay back after harvesting. In addition to cash dealing, farmers also often take temporary credit from dealers or subdealers, buying feeds one day and paying one or two days later.

Most feed manufacturers use different trade names to sell their products, and they usually use two or more brand names (e.g. diamond, gold, super gold, gold plus, premium) as a part of their marketing strategy. According to the survey, feed industries usually sell 1 kg, 5 kg and 20 kg bags of nursery feeds, and 20 or 25 kg bags of starter, grower and finisher feeds. The price of feed varies between BDT25.45 and BDT50.25 per kg or USD0.31 and 0.62 (Table 5), depending on feed type, culture species, quality, season, and supply and demand. In general, floating feeds are more expensive than sinking feeds, costing on average 20 percent higher.

TABLE 5
The prices of feed by category of feed type and species[1]

Fish	Feed type	Price (BDT/kg)[2]	
		Floating feed	Sinking feed
Pangas	Nursery	40.00	35.58
	Starter	39.25	31.72
	Grower	36.25	29.48
	Finisher	35.25	27.76
Tilapia	Nursery	42.50	36.07
	Starter	39.75	32.52
	Grower	36.75	29.86
	Finisher	35.75	28.33
Carps	Nursery	39.25	35.37
	Starter	35.50	31.49
	Grower	30.75	27.16
	Finisher	28.75	25.45
Prawn/shrimp	Nursery	50.25	37.50
	Starter	47.25	33.75
	Grower	45.50	32.25
	Finisher	45.50	32.00
Climbing perch	Nursery	48.00	42.39
	Starter	44.50	38.33
	Grower	40.50	35.81
	Finisher	No finisher feed	

[1]*Source:* Feed manufacturers.
[2]1 USD = BDT 81.00 in July 2012.

Farmers select their feeds according to a number of factors, including quality, price, availability and the technical support supplied by the feed companies. In order to improve feed sales, some feed companies employ technical personnel to assist and advise both the dealers and the farmers. The quality of feed depends on its proximate composition and the feed manufacturer. The proximate composition of the different aquafeeds that are available in the market varies considerably (Table 6). Nutritional information such as moisture, protein, lipid, fibre and energy is provided on the feed bags. In general, aquafeeds for the culture of high-value aquatic animals (e.g. prawns, shrimp, climbing perch, carps) contain more protein and lipid levels than those for low-value fish (e.g. pangas, tilapia) culture. According to Ali and Hoq (2010), aquafeeds for carp culture require a protein level 25–35 percent, compared to 30–40 percent for prawn and shrimp feed, 35–45 percent for climbing perch, 25–30 percent for tilapia, 25–30 percent for pangas and 30–40 percent for other catfish (stinging and walking catfish).

TABLE 6
Proximate composition of industrially manufactured pelleted feed for aquaculture (% dry matter basis)

Feed ingredients			Feed type			
			Nursery	Starter	Grower	Finisher
Moisture		(maximum)	11–12	11–12	11–12	11–12
Crude	protein	(minimum)	30–38	28–32	26–30	22–28
Crude	lipid/fat	(minimum)	5–7	4–6	4–5	4–5
Crude	fibre	(maximum)	4–6	4–6	4–6	4–6
Ash		(maximum)	12–18	12–18	12–18	12–18
Calcium		(minimum)	1–1.2	1–1.2	1–1.2	1
Phosphorus		(minimum)	0.6–1.3	0.6–1.2	0.6–1.2	0.8–1.0

Source: Nutritional information as provided on the feed bags.

Almost all farmers apply the broadcast feeding method. The application of the different aquafeeds that are available in the market varies considerably depending on the culture species and culture stage (Table 7). According to the feed managers, the quality of industrially manufactured aquafeeds has recently been increased due to technical intervention. It has been reported that the feed conversion ratio (FCR) varies from 1.2 to 1.5 for floating feed and from 1.5 to 1.8 for sinking feed.

3.2 Farm-made aquafeed

Farm-made aquafeed producers mainly use hauler machines. In 1994, the Bangladesh Fisheries Research Institute (BFRI) was first to introduce a farm-made aquafeed machine to Bangladesh (Ali and Hoq, 2010). This machine was further improved in 1998. A typical hauler machine with 10 horse power (HP) capacity produces 100–150 kg of feed per hour. The price of this feed machine is around BDT25 000–30 000. The feed produced from this machine contains water and thus has to be dried. In 2005, the feed machine was improved by BFRI for producing semidried pelleted feed. The production capacity of this machine with 20 HP is 150–200 kg of feed per hour. The price of this machine is around BDT75 000–80 000.

Although a farm-made aquafeed machine was introduced in 1994, the practice was begun only a decade later, in 2004. According to the survey, farm-made aquafeed producers have low experience, an average 4.55 years. Nevertheless, it has become more popular during the last two to three years. Although 250 farm-made aquafeed producers were recorded by BFRI (BFRI, 2011), the number has increased in recent years. According to key informants, it is estimated that there are around 400 farm-made aquafeed producers in Bangladesh. Most of them (70 percent) are concentrated in the Mymensingh area. According to the survey of farm-made aquafeed producers, 40 percent are involved in this practice for their own fish culture, while 25 percent are involved for profit making, 25 percent for helping aquaculture and 10 percent to access technology. The peak season of farm-made aquafeed production is from April to September, during the fish-farming season. All produced farm-made aquafeeds are used for

local fish culture, not for commercial marketing. According to the field survey, 80 percent of farm-made aquafeed producers are small scale (1–3 tonnes/day) and the rest (20 percent) are medium-scale producers (4–5 tonnes/day). Most farm-made aquafeed producers (80 percent) got their experience directly from their work, while only 20 percent got informal training from a neighbour (i.e. farm-to-farmer training).

A variety of ingredients are used in the production of farm-made aquafeeds. In general, farmers use a mixture of rice bran, rice polish, mustard oilcake, sesame oilcake, soybean meal, fishmeal, maize, oyster shell, lime, salt and vitamins. Nutritional values of these feed ingredients vary considerably (Table 8). This feed is usually prepared by mixing 40 percent rice bran, 25 percent mustard oilcake, 20 percent fishmeal, 10 percent maize and 5 percent other ingredients (oyster shell, lime, salt and vitamins).

TABLE 7
Feeding rate by feed type and culture species

Species	Feed type	Average body weight of fish (g)	Feeding rate (% of body weight)	Number of feeding per day
Thai pangas	Nursery	0.2–25	30–15	4
	Starter	26–100	15–6	3
	Grower	101–250	6–3	2
	Finisher	Above 251	3–2	2
Nile tilapia	Nursery	0.2–10	25–18	4
	Starter	11–30	18–7	3
	Grower	31–250	7–4	2
	Finisher	Above 100	4–2	2
Carps	Nursery	0.5–50	50–10	3–4
	Starter	51–200	10–6	3
	Grower	201–700	6–3	2
	Finisher	Above 700	3–2	2
Prawn and shrimp	Nursery	0.02–0.5	18–10	4
	Starter	0.6–20	10–7	3
	Grower	21–40	7–5	2
	Finisher	Above 40	5–3	2
Climbing perch	Nursery	0.2–12	50–25	4
	Starter	13–30	25–7	3
	Grower	Above 30	7–3	2
	Finisher	No finisher feed for climbing perch		

Source: Leaflets of feed companies.

TABLE 8
Nutritional values of raw materials for farm-made aquafeeds

Ingredient	Crude protein (%)	Crude lipid (%)	Carbohydrate (%)	Energy (cal/kg)
Fishmeal	55–65	10–12	1–2	4 754
Maize	8–10	3–4	65–70	3 854
Meat and bone meal	45–55	10–15	1–2	4 112
Mixed dried fish	30–40	5–8	2–4	3 132
Mustard oilcake	28–35	8–14	30–40	4 178
Rice polish	10–14	10–15	55–60	4 066
Rice bran (auto)	10–14	20–25	45–50	3 650
Rice bran (traditional)	7–10	10–15	50–55	3 388
Sesame oilcake	30–35	10–15	30–35	4 753
Soybean meal	40–45	10–15	30–35	5 499
Wheat bran	12–16	3–6	70–80	3 794
Wheat flour	12–18	2–3	75–80	4 488

Source: Ali and Hoq (2010).

Although many ingredients (e.g. rice bran, mustard oilcake) represent on-farm agricultural by-products, it was estimated that around 80 percent of feed ingredients used in the production of farm-made aquafeeds are purchased. Farmers mostly depend on local markets for purchasing feed ingredients. Table 9 shows the sources of feed ingredients for farm-made aquafeed production. Farmers mainly use rickshaws, vans and motorized vehicles to transport the feed ingredients from the local markets. Despite the importance of maintaining the quality of feed ingredients during transportation, storage and processing, it is evident that farmers have little knowledge on how best to store and handle their feed ingredients. Most farmers using farm-made aquafeeds reported that they prefer to purchase small amounts of ingredients and not store their feeds – this purchasing behaviour was attributed to a lack of financial means to purchase in bulk, and to inadequate storage facilities.

TABLE 9
Sources of feed ingredients for farm-made aquafeed production

Ingredient	Source (n = 20) [1]		
	Own farm	Market	Both
Rice bran	2 (10%)	3 (15%)	15 (75%)
Wheat bran	0 (0%)	18 (90%)	2 (10%)
Mustard oilcake	2 (10%)	12 (60%)	6 (30%)
Fishmeal	0 (0%)	20 (100%)	0 (0%)
Soybean meal	0 (0%)	20 (100%)	0 (0%)
Maize	0 (0%)	20 (100%)	0 (0%)

[1]n = sample size of farm-made aquafeed producers.

A large number of farmers who do not have feed machines bring their feed ingredients to farm-made aquafeed producers to prepare feed, and pay for the manufacturing process, an average of USD18.75 per tonne (i.e. BDT1.5 or USD0.019/kg), ranging from USD15 to 25 per tonne. The cost of feed processing depends on the season, volume, demand and electricity supply. A feed machine usually manufactures an average of 3 tonnes/day of feed, ranging from 1 to 5 tonnes. In general, 20–25 farmers are tied with a feed machine for producing farm-made aquafeed. In general, 75 percent of farm-made aquafeeds are produced for pangas culture, 14 percent for tilapia, 6 percent for climbing perch and 4 percent for carps. Survey results also reveal that 28 percent of farm-made aquafeeds are starter feed, 54 percent are for grow-out operation and 18 percent are for finisher. None of the farmers use farm-made aquafeeds for nursery operation. The average price of farm-made aquafeed was calculated as USD0.30 (BDT24.21) per kg, which is 20–25 percent lower than that of industrially manufactured pelleted feeds. There is little difference among the prices of different feed types for different fish species because of using feed ingredients in different proportions. The price, as well as the total production costs of farm-made aquafeeds has increased 25–30 percent over the last five years. The FCR of farm-made aquafeed has been reported as being between 2.0 and 2.5.

During the last five years, a significant change has been occurring for farm-made aquafeed production (Table 10). According to the field survey, the demand for feed has increased 50 percent over the last five years, but production capacity has increased by only 30–40 percent. Thus farmers often use industrially manufactured pelleted feed. As commercial feed is expensive, thus feed mill intervention has occurred in recent years. In general, the feed mills have large production capacity due to the use of large machines. Because the capacity of their farm-made aquafeed production is low, a significant number of farmers often go to feed mills for the production of formulated pellets. The farmers transport their feed ingredients to the feed mills to manufacture the pellets and then pay for the manufacturing process. A number of positive attributes were reported for feed mills, including lower processing costs (USD15–20/tonne), quicker processing time, proper mixing of feed ingredients, better shape of pellet, and technical advice by the owners of feed mills.

TABLE 10
Changes for farm-made aquafeed production during the last five years

Events	Change (n = 20)[1]		
	Increased	Decreased	Unchanged
Production capacity	20 (100%)	0 (0%)	0 (0%)
Availability of feed ingredients	15 (75%)	4 (20%)	1 (5%)
Price of feed ingredients	20 (100%)	0 (0%)	0 (0%)
Feed quality	11 (55%)	6 (30%)	3 (15%)
Feed production costs	20 (100%)	0 (0%)	0 (0%)
Feed price	20 (100%)	0 (0%)	0 (0%)
Labour involvement	20 (100%)	0 (0%)	0 (0%)
Marketing facilities	12 (60%)	6 (30%)	2 (10%)
Transport facilities	11 (55%)	6 (30%)	3 (15%)
Market competitiveness	20 (100%)	0 (0%)	0 (0%)
Storage facilities	16 (80%)	0 (0%)	4 (20%)
Demand for feed	20 (100%)	0 (0%)	0 (0%)
Profit	15 (75%)	2 (10%)	2 (10%)
Government monitoring	3 (15%)	0 (0%)	17 (85%)
Environmental awareness	13 (65%)	3 (15%)	4 (20%)
Social responsibility	12 (60%)	6 (30%)	2 (10%)

[1]n: sample size of farm-made aquafeed producers.

3.3. Supplementary feed

Fish farms based on extensive feeding practices use supplementary diets consisting of a mixture of locally available feed ingredients such as rice bran/wheat bran, mustard oilcake and fishmeal. Supplementary feeds are used by all of the extensive farmers, mainly for carp polyculture but also for carp-pangas and carp-tilapia polyculture. In general, farmers use a mixture of 50 percent rice bran, 30 percent oil cake and 20 percent fishmeal. Although farmers are aware of the positive effects of industrially manufactured pelleted feeds and farm-made aquafeeds, inadequate financial support and a lack of technical knowledge prevent them from upgrading their feed management strategies. In addition to use of supplementary diet, extensive farmers mainly depend on the natural productivity of ponds (i.e. phytoplankton, zooplankton and benthos).

In Bangladesh, the most commonly used aquaculture feed is rice bran, a by-product of rice, the main crop of the country. There are three types of rice crop in Bangladesh: aman, aus and boro. Aman rice accounts for 50 percent of the total rice crop area in Bangladesh, while aus and boro account for 27 and 23 percent, respectively. In 2010, over 30 million tonnes of rice was produced from about 10.8 million ha of rice fields (BRKB, 2011). The three types of rice provide a year-round supply of rice bran which accounts for 5 percent (1.45 million tonnes) of the total rice yield (Barman and Karim, 2007). The average

price of rice bran was estimated to be USD0.18/kg. Considering the importance of rice bran as fish feed, it is necessary to maintain its quality during production, storage and transportation. The quality of rice bran depends on its nutrients, freshness, fineness, storage conditions and the duration of storage. In general, rice bran produced in automated rice mills has a higher nutrient value than that produced in the rural husking mills (Table 8).

Mustard oilcake is widely used as a fish feed ingredient in Bangladesh and is one of the most important ingredients in fish feeds. It is a by-product of mustard seed oil. Annual oilseed production in Bangladesh is 267 000 tonnes, of which 72 percent (192 240 tonnes) accrues to mustard oilseed (Basak, Pandit and Khurram, 2007). Mustard oilcake comprises around 25 percent (48 060 tonnes) of the total mustard oilseed production. The overall demand for mustard oilcake has increased as the aquaculture sector has grown in Bangladesh. The average price of mustard oilcake was estimated to be USD0.21/kg. The quality of mustard oilcake depends on the oil production system, freshness, fineness, storage conditions and the duration of storage. Mustard oilcake is rich in protein (Table 8).

Fishmeal is widely used as a protein source in aquafeeds. Fishmeal is recognized by farmers as a high-quality, highly digestible feed ingredient. Fishmeal in Bangladesh is generally produced from "low-value fish/trash fish"[19]. Fishmeal can be manufactured from small pelagic marine fish that are not used for human consumption. It can also be made from fisheries bycatch and the waste products created during the processing of various seafood products. The fishmeal can vary considerably depending upon the quality and composition of the substrate that is used to prepare it. The Bangladesh Fisheries Development Cooperation has four fishmeal production plants with a total capacity to produce 8 tonnes per day. Around 4–5 tonnes of fish are required to produce 1 tonne of dry fishmeal (Miles and Chapman, 2006). Fishmeal is rich in protein and has a favourable amino acid composition that promotes good growth. It contains between 55 and 65 percent protein (Table 8). Almost all respondents reported buying fishmeal from the local market. The average price of fishmeal was reported to be USD0.35/kg.

3.4 Constraints in feed management

With respect to feed production, distribution and marketing, and feed management practices, a number of social, economic and technical constraints were found. These include the high price of feed, an inadequate supply of feed/feed ingredients, poor feed quality, procurement problems, the decomposition of feed, water pollution due to excessive feed use, and a poor knowledge of feed management practices in terms of environmental sustainability. Feed ingredient supply, quality and cost are evidently becoming a serious problem for both the commercial and farm-made feed producers. High-quality protein

[19] "Low-value fish/trash fish" are fish that are considered to have little value as food fish, and therefore are generally discarded when caught. Currently, trash fish are not discarded, but are generally used for the manufacture of fish and poultry feeds.

sources are generally imported from abroad, and recently there has been a significant increase in prices. The increasing cost of feed ingredients is impacting the quality of feeds produced in a number of ways. According to BFRI (2011), the quality of commercial aquafeeds is a concern, as an analysis of 300 feed samples from 16 different feed manufacturers found that 29–51 percent of all feeds across all feed types (nursery, starter, grower and finisher) failed to comply with the Feed Regulations. This suggests that the quality of commercially produced aquafeeds is problematic. In a survey of 45 feed ingredients that are available on the market, 64 percent were of a poor quality and had been adulterated in some manner (BFRI, 2011). It has been reported that feed ingredient prices have increased by two fold over the past year. It is thus reasonable to suggest that simply moving the farmers from farm-made aquafeeds to commercially manufactured pelleted feeds will result in increased cost with additional quality concerns. A number of environmental issues surrounding the use of feed additives, chemicals, hormones, probiotics and other aqua-products (e.g. aquaclean, zeofresh, oxylife, aquamix, gastrap, cevit-aqua, panvit-aqua, antivirus) are also important. It is therefore important to focus on the environmental biosafety issues associated with the use of feed additives.

TABLE 11
Positive and negative attributes of different aquafeeds

Feed	Positive attribute	Negative attribute
Industrially produced pelleted feed	• High quality (protein level) • Higher production of fish • Suitable for semi-intensive/ intensive farming	• Expensive feed • High production costs • Environmental impacts • Often quality concern
Farm-made aquafeed	• Reasonable cost of feed • Considerable production of fish • Suitable for poor farmers	• Not quality feed • Lower feed production capacity • Unavailability of feed ingredients
Supplementary feed	• Low-cost feed • Locally sourced and uses farm by-products • Environmentally friendly	• Low productivity of fish • Inefficient utilization of pond • Low supply of ingredients

4. Recommendations

The following suggestions for the improvement of feed management practices are put forward for sustainable aquaculture development:

1) *Implementation of the Feed Regulation:* The implementation of the Feed Act and Regulation, and the development of awareness among key stakeholders will improve the quality of feed and restrict the use of banned chemicals. In order to resolve this issue, the DoF needs to develop a monitoring programme and capacity building to ensure that the aquafeed manufacturers comply with the regulations in terms of feed quality, composition and labeling.
2) *Feed producers' associations:* The development of feed producers' associations would provide both the government and the feed manufacturers with a representative forum for discussion on how to implement the regulations and inform the manufacturers of the governments' implementation programme.
3) *Certification of quality feed:* The low quality of some of the aquafeeds that are currently being produced is of concern to the farmers. The introduction of a certification programme would enhance the quality of feed.
4) *Technical support:* Technical support should be provided to the farm-made aquafeed producers in terms of quality feed production in a scientific manner. Training would help to develop the skills and knowledge of the farm-made aquafeed producers.
5) *Biosafety:* The issue of the environmental sustainability of aquafeed, particularly that of the use of feed additives, is poorly understood. Therefore attention should be given to the environmental impacts of feed additives.

5. References

Ali, M.Z. & Hoq, M.E. 2010. *Improved fish feed management in aquaculture.* Extension Manual No. 38, 16 pp. Mymensingh, Bangladesh Fisheries Research Institute.

Ahmed, N. 2007. Economics of aquaculture feeding practices: Bangladesh. *In* M.R. Hasan, ed. *Economics of aquaculture feeding practices in selected Asian countries*, pp. 33–66. FAO Fisheries Technical Paper No. 505, Rome, FAO.

Ahmed, N., Alam, M.F. & Hasan, M.R. 2010. The economics of sutchi catfish (*Pangasianodon hypophthalmus*) aquaculture under three different farming systems in rural Bangladesh. *Aquaculture Research,* 41: 1668–1682.

Barman, B.K. & Karim, M. 2007. Analysis of feeds and fertilizers for sustainable aquaculture development in Bangladesh. *In* M.R. Hasan, T. Hecht, S.S. De Silva & A.G.J. Tacon, eds. *Study and analysis of feeds and fertilizers for sustainable aquaculture development,* pp. 113–140. FAO Fisheries Technical Paper No. 497, Rome, FAO.

Basak, N.C., Pandit, J.C. & Khurram, M.M.H. 2007. On-farm evaluation of three mustard varieties under different fertilizer package. *Bangladesh Journal of Scientific and Industrial Research*, 42: 335–340.

Belton, B., Karim, M., Thilsted, T., Murshed-E., Jahan, K., Collis, W. & Phillips, M. 2011. *Review of aquaculture and fish consumption in Bangladesh.* Studies and Reviews 2011–53. Dhaka, WorldFish Center.

BFRI. 2011. *Evaluation of nutrient quality and shelf life of commercial feed ingredients and feeds on aquaculture production in Bangladesh.* Annual Progress Report 2009–2010. Mymensingh, Bangladesh Fisheries Research Institute.

BRKB. 2011. *Rice statistics in Bangladesh.* Gazipur, Bangladesh Rice Knowledge Bank (BRKB), Bangladesh Rice Research Institute. (available at: http://www.knowledgebank-brri.org/)

Chambers, R. 1994. The origins and practice of participatory rural appraisal. *World Development*, 22: 953–969.

Dey, M.M., Alam, M.F. & Bose, M.L. 2010. Demand for aquaculture development: perspectives from Bangladesh for improved planning. *Reviews in Aquaculture*, 2: 16–32.

DoF. 2012. *Fisheries statistical yearbook of Bangladesh 2010–2011.* Volume 28, 46 pp. Fisheries Resources Survey System (FRSS). Dhaka, Department of Fisheries, Ministry of Fisheries and Livestock.

FAO. 2012. *The state of world fisheries and aquaculture 2012.* Rome, FAO Fisheries and Aquaculture Department.

Holtzman, J.S. 2003. *Rapid appraisals of commodity sub-sectors.* Bethesda, USA, Abt Associates Inc.

Jahan, K.M., Ahmed M. & Beltonne, B. 2010. The impacts of aquaculture development on food security: lessons from Bangladesh. *Aquaculture Research*, 41: 481–495.

Miles, R.D. & Chapman, F.A. 2006. *The benefits of fishmeal in aquaculture diets.* Florida, USA, Institute of Food and Agriculture Science, University of Florida.

Townsley, P. 1996. *Rapid rural appraisal, participatory rural appraisal and aquaculture.* FAO Fisheries Technical Paper No. 358, 109 pp. Rome, FAO.

A typical fish market, Jessore, Bangladesh.

COURTESY OF FAO/THOMAS A. SHIPTON

Report of the verification mission on aquaculture seed production and broodstock management

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1. Introduction

1.1 Background

Aquaculture production is highly dependent on good quality seed, and in turn, quality seed can only be produced from healthy and improved broodstock. For development of this sector, along with quality seed, the farmers need to be supplied with recent, useful and practical information related to aquaculture. Although aquaculture production has recorded impressive growth during the last four decades in Bangladesh, the average pond productivity from semi-intensive culture systems remains at a very modest level (2.62 tonnes/ha/year). The fish growers try to get best quality seed from the hatcheries, and most hatchery staff are of the opinion that the seed they produce are from good broodfish. However, even the hatchery owners are ignorant about the status of their broodfish. The result is that the farmers (fish growers) often end up with average-growing seed material. The non-availability of quality seed is one of the biggest stumbling blocks to better fish production in Bangladesh. Insufficient and uncertain supply of this critical input and non-maintenance of seed quality can upset the whole fish culture process in the coming days. The private sector may not be able to meet this quality demand unless the government and advanced entrepreneurs venture into broodstock improvement that will lead to quality fish seed production.

Bangladesh is currently producing more than 629 175 kg of seed from nearly 1 000 hatcheries and nurseries located in different regions of the country (DoF, 2010). However, the response of fish growers is not very positive when it comes to the growth of hatchery-produced seed, indicating their poor quality. Seed quality has deteriorated due to inbreeding in many hatcheries that do not follow any broodstock management, hatchery management or genetic principles during spawning operations.

1.2 Purpose

The main objective of this consultancy mission is to verify the results of the previous field survey (Sarder, 2015); identify and bring out the key technical, economic and social constraints to seed production and management in Bangladesh, with special emphasis on quality seed production by stock improvement; and provide necessary recommendations.

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1.3 Period

The verification mission was conducted during the period between 07 August 2012 to 26 August 2012.

1.4 Institutions/organizations/laboratories visited

FAO Bangladesh, different facilities under the Department of Fisheries (DoF) and the Bangladesh Fisheries Research Institute (BFRI) (under the Ministry of Fisheries and Livestock), Bangladesh Agricultural University (BAU), and private carp, tilapia and catfish hatcheries were visited.

2. Scientific/technical section

2.1 Activities undertaken

The main activities undertaken during the mission are as follows:

- An analysis of the operational efficiency and implementation of the government fish seed improvement programme, the identification of technical areas that required improvement, and the proposal of interventions that will improve the efficiency of the programme was done. Hatchery management practices, with special focus on induced breeding of Indian major carps, were assessed.
- A description of the prevailing hatchery management practices used by hatcheries was prepared and an assessment of the remedial actions that hatchery operators can adopt to improve seed production was made.
- Broodstock management of Indian major carps (IMCs) was explained and the genetic status of existing IMC broodstocks was investigated.
- Appropriate approaches for genetic improvement of existing broodstocks of IMCs were identified and long-term and immediate intervention strategies were developed.
- An assessment of the need for the development of best practices and a code of conduct for hatchery/nursery operators and fry distributers was made. A. technical standard and management scheme for fish seed production in Bangladesh was designed and demonstrated and a detailed good management practice (GMP)/hazard analysis and critical control point (HACCP)/ standard operating procedures (SOP) manual may be developed in the future mission or under some other project.

The mission's main focus was on the improvement of the carp, tilapia and catfish seed development sector in a holistic manner. The objective of achieving better productivity can be achieved by developing the hatchery infrastructure without technical flaws, proper broodstock management, water management and the use of basic genetic principles like maintaining an effective breeding population, feed and disease management, and exchange of broodfish or exchange of male gametes. The consultant has given due importance to all these matters along with the immediate and long-term strategies needed for this sector.

2.2 Carp seed production in Bangladesh

Seed production enterprise in Bangladesh is robust and well established. Seed of most species that are cultured is being produced from nearly 1 000 hatcheries spread across the country using various hormones and a plethora of hatchery designs. All the carps and other fish species mentioned in Tables 1 and 2 are widely popular among the people, and some of the species also find their way to neighbouring countries. Although fish production in Bangladesh has shown an increasing trend since the 1980s, there is much more potential in the culture-fisheries sector. This potential can be achieved by the timely supply of quality seed to the growers. Breeding has been practiced in the country for several years and the seed quality issue has been addressed to some extent by establishment of brood banks. However, in a true sense these brood banks do not fulfill their intended purpose, due to several reasons such as poor staffing, insufficient farm area, non-availability of pedigreed/improved broodstock and lack of a scientific approach to broodstock management and stock improvement. Recently, poor growth of hatchery-bred seed has been reported by fish farmers from the Indian subcontinent, including Bangladesh. Although, in the beginning, the government initiatives were solely responsible for carp seed production, now the private sector, including small hatchery owners, supplies the major portion of the seed requirement of the country.

2.3 Improving the national fish seed production system

2.3.1 Brood banking

The broodstock in most of the farms is not reared following any broodstock management methods. They are presently being reared as per tablefish production, where somatic growth is given more importance. Apart from the maintenance of elite genetic stocks having proven qualities, broodstock management and their nutrition and health should be given priority to get quality fish seed. Maintenance of records/data by the hatcheries is very poor or almost non-existent. As some of the staff are not properly educated, training on this aspect is also needed. Replenishment of broodstock has not been done from the beginning. However, during the last four years some hatcheries have been replenishing their broodstock from designated brood banks. There are many fish spawning/multiplication centers named as brood banks. However, when traced back, it was found that the farmers take the seeds from the hatcheries which in turn, collect spawn from riverine sources and rear them in hatcheries before handing them over to other hatcheries. So in a true sense, most of the carp hatcheries are working in isolation. Considering the high fecundity of all these carps, all these hatcheries are using only a few individuals every year to meet the demand/target. All the hatcheries in both sectors should be given guidelines and training on broodstock rearing and management.

Presently there are 21 seed hatcheries declared as brood banks in Bangladesh under the control of the DoF (20) and Brac (1). In a true sense, these centers are not working like brood banks, as separate stocks having different histories (e.g. Padma stock, local stock, Jamuna stock, Halda stock, etc.) are not properly

maintained due to space constraints. The consultant is of the view that four brood banks with all facilities and procedures may be established where breeding plans and genetically improved stock would be maintained. One of these could be the Nimgachi Hatchery and Farm, which is ideally located in the Sirajganj area. This place has physical facilities that can be renovated, and other facilities such as a laboratory for soil and water analysis and a semen bank can be created. This center may be adequately staffed to function as a center of excellence and could be an international center for germplam conservation. Three other places (Kotiady Fish Seed Farm, Kishorganj; Shantiganj Fish Seed Farm, Sunamganj; and Boluhur Fish Seed Farm, Kotchandpur) are geographically isolated and may be developed later for establishing brood banks to cater to the needs of specific regions.

The hatchery owners should consider the following questions for better quality broodstock production:

- Where is the broodstock reared?
- Do they have a plan for broodstock raising and rearing?
- Do they have a replenishment/exchange programme?
- Are they keeping the records of broodfish stocking, source and other habitat details?
- Do they live with a dogma that they have a very good riverine stock that was collected several years back?

Hatchery owners need both improved on-field performance and greater confidence. So, stock improvement without affecting their regular programmes may be a better way to produce quality broodstock.

A new vista has opened for the aquaculture sector of Bangladesh with the passing of the Fish Hatchery Act (2010) by the government. This will definitely help in maintaining and propagating good varieties of finfish. As it is in the initial years, many hindrances affecting enforcement will need to be dealt with in a pragmatic manner.

2.3.2 Implementing selective breeding programmes

A national-level selective breeding programme for selected fish species may be undertaken to overcome inbreeding problems in fish hatcheries. The improved stocks that will be developed at these centers may be supplied to the brood banks for dissemination purposes. The brood banks would be required to implement breeding plans to maintain the status of the supplied stocks. These brood banks may be specially designed to undertake selective breeding programmes. Without a sustained selective breeding programme, the role of the brood banks will be redundant. The first step to start a breeding programme is to collect the genetic material that forms the base population. It is important to start with a broad genetic base. There are examples indicating mass selection in carp and tilapia may have failed due to narrow genetic variation in the base population. Genetic variability can be ensured in the base population by forming a synthetic population.

As a long-term strategy, the development of better varieties from fish base populations of carps, tilapia and pangas may be initiated. But as a priority, species such as rohu, catla, tilapia, pangas and other prioritized species may be undertaken at selected government farms. As carps mature in two years, the production of genetically selected carp may take some years; thus proper infrastructure, a base population of fish and trained manpower must be developed during this time. A typical protocol for selective breeding of fish for better genetic gain has been shown in Figure 2 of the main report, page 11.

For developing this strategy and to prepare the farms, the following steps may be considered in designing breeding programmes:

- *Base population and production system:* For producing 15 families at a time and a total of 50–80 families in a year, at least 10–15 incubation chambers or tanks for incubation with glass jar hatchery may be needed.
- *Breeding system and breeds:* prioritized species and breeding systems such as diallel or mass breeding etc. are needed.
- *Breeding objectives and calculation of economic values (weight):* Priority of the objective to be set by giving scores (weight) to individual criteria.
- *Development of selection criteria and estimation of selection parameters.*
- *Monitoring and comparing alternative programmes.*
- *Breeding programme and the area should be safe from calamities such as flooding.*
- *Improvement of staff and facilities:* training of personnel and acquisition of equipment such as computers and software for analysis and tags and tag readers.

2.3.3 Hatchery management and nursery infrastructure

Presently, both the private and government sectors produce carp seed by adapting technology developed during the 1960s. Several developments have taken place to modernize the production of carp spawn without any loss due to mechanical or physical damage or to any hindrances to the broodfish during spawning operations. Similarly, the nursery management practices currently used need to be improved in terms of natural productivity and hatchling survival. Based on observation of both private and government hatcheries, corrective measures, requirements and other management measures are suggested as shown in Table 3. Many of the pangas and catfish hatcheries produce seed without adhering to GMPs and proper broodstock management protocol. There are nearly 300 tilapia hatcheries, with approximately 100 hatcheries receiving broodstock from BFRI, while the rest manage by using broodstock from other sources and without knowing their proper genetic status. Many of the hatcheries use excessive amounts of water due to ignorance about recent advancements in seed production. Some of the hatchery owners were suggested remedial measures; however, it is imperative that the government update their knowledge and enhance their efficiency in a programmed manner. This may include an awareness campaign, farmers meetings, hand-on-training, exposure visits, etc.

TABLE 3
Current hatchery management practices during the induced spawning of Indian major carps and suggested remedial measures

Existing facility/practices/management	Requirements/rectification/ management suggested
Brood handling & selection (three times: one catching for selection, one for injection and release into spawning pool and a third catching from pool and release into ponds	One-time selection and injection to reduce broodstock stress and allow better spawning
Broodstock transport from pond to pool by hammock	Hammock may be made from durable nylon or synthetic waterproof cloth with bamboo handles to reduce weight
Many farmers apply intramuscular (IM) hormone administration below the scales near the dorsal fin	IM injection should be replaced with intraperitoneal (IP) injection, as IM may slip and cause hormone wastage. IP also has better and faster assimilation and action.
Spawning programmes conducted at night cause drudgery to workers who are less efficient because all the workers do not sleep at night	Conducting spawning programmes during the day will reduce drudgery and bring more efficiency, and thus hatchery work and monitoring will be better
Spawning pool is of rectangular size and thus not suitable for effective movement of fish and creation of riverine simulation	Circular spawning pool is useful in reducing injuries to fish and also makes spawning more effective
Protruding inlet pipe in the spawning pool damages eggs, obstructs catching of fish and occasionally causes injury to fish and handlers	This should be rectified by cutting the protruding portion in a parallel fashion with the wall of the pool (45° to wall)
Protrusion of the inlet and spawn collection pipes in incubation chamber can cause bursting of very delicate water-absorbed embryos (≈ 30% embryo loss due to bursting)	This can be rectified by cutting the protruding portion of the pipes; the spawn collection pipe should be smooth and a slope of at least 1" should be maintained.
Raising of broodstock should be different than tablefish production. Regular checking of the health of broodfish should be undertaken.	Broodstock should be maintained at 1 000–2 000 kg/ha. Principal broodstock management system should be followed with 60:20:20 (IMCs; 3 species)
Broodstock maintenance and spawning and seed-rearing record keeping	Record keeping of broodstock raising and spawning should be maintained to reduce inbreeding. This has been included in the Fish Hatchery Rules (2011)
Exchange and replenishment programmes from riverine sources are practiced in many of the hatcheries	Exchange between hatcheries and from riverine stock is a good step, but the genetic status is not known, so it may not give desired results. Pure stocks from hatcheries should be exchanged.
Short-term milt dilution with extender and preservation and utilization for exchange and stock improvement is not practiced	Utilization of milt should be encouraged to maintain a wide gene pool and increase the effective population size in hatchery
Water-testing facility for seed rearing units and hatchery is not available	A water-testing facility for seed rearing and hatcheries should be established by the government that can serve as a center for soil and water analysis and as an advisory center
Filtration system is not in place for the hatchery intake water	A filtration system with cemented rings loaded with sand gravel and other filtering materials and covered around with a muslin cloth (hapa cloth) may be handy

Existing facility/practices/management	Requirements/rectification/ management suggested
Spawning pool has no spawn collection outlet pipes, collection by siphoning	This should be rectified by installing an underground pipe with an outlet at the side of the tank and providing a slope of at least 1" towards it for easy draining
Duck mouths in the incubation chambers are faced towards walls and some are facing directly back to the other. Water-absorbed embryos are very delicate and any contact against them will result in bursting (≈ 10% embryo loss due to bursting, generally unseen)	This can be rectified by arranging the angles of duck mouths. Angling one towards the inside and the other towards the outside in a bifurcating manner will reduce the dead pockets and egg accumulation on one side. By reducing direct collision with the back of the duck mouths, embryo bursting and loss can be avoided.
The bottom of the duck mouths in the incubation chambers have grooves that may become dead pockets that are difficult to clean and create infection after 1–2 operations	To reduce dead pockets and avoid debris accumulation, the duck mouths should be above the bottom and not grooved

2.3.4 Stock improvement using milt of improved male fish

To overcome the present level of inbreeding (nearly 30 percent) in many hatcheries and improve the quality of seed, it is imperative to undertake stock improvement by using cryomilt or, as an immediate measure, temporarily preserved milt. This practice would be less cumbersome and easy for DoF to implement under the present circumstances of reduced manpower.

Besides stock improvement by using cryopreserved or short-term preserved milt, other interventions may be considered to produce quality seed. These include exchange of broodstock, rearing hatchlings produced from each batch of fish spawning, and the use of broodstock management methods.

2.3.5 National document on good management practice/hazard analysis and critical control point (GMP/HACCP) in hatcheries

2.3.5 National document on good management practice/hazard analysis and critical control point (GMP/HACCP) in hatcheries

During visits to a number of hatcheries, it was observed that there is no uniform hatchery infrastructure and many of them use more water than required. Many of the technical problems such as faulty water pipe connections and improper slope in the spawning tanks lead to egg breakage during breeding programmes. It was felt by the mission that a national document about GMP/HACCP in hatcheries would be a handy reference for many hatchery users, both beginners and the more experienced ones. This will also provide the bankers with a good understanding to lend money to seed producers.

2.3.6 Enforcement of Fish Hatchery Rules (2011) and training of personnel

The enactment of Fish Hatchery Act (2010) is a significant step towards ensuring quality assurance in fish seed. This act is believed to be unique, and the first in South Asia. The regulation is exhaustive, and there are several clauses that ensure

quality. The process of hatchery registration has already started. However, there are several technical aspects with which hatchery owners must comply that may be very difficult to enforce; for instance, they are asked to provide breeding plans for each year, establish a broodfish development process, etc. However, once the registration process is completed, it will be easy for the DoF to monitor and enforce the act effectively. It was felt that a rider to the regulation such as "a hatchery owner must exchange his/her stock (5–10 percent) each year with stock from a government-recognized brood bank" may make a great difference. Knowledge on genetic selection and the maintenance of broodstock is grossly lacking in many officials, hatchery managers and owners. Thus training should be imparted to both government personnel and private hatchery managers in these aspects, viz. selective breeding, use of short-term preservation and utilization methods for carp milt, and broodstock management, including advances in hatchery management methods.

2.3.6 Strengths and weaknesses of the seed-production sector

Strengths

- Water resources for fish breeding and seed production are adequate.
- Breeding of all important aquaculture species is successful in many hatcheries and popular among private hatchery owners. This sector is growing at a very impressive rate.
- Induced breeding techniques are very successful and popular among farmers, and the demand for carp, tilapia and pangas seed and fish is very high.
- Polyculture of carps is very popular among farmers and there are no marketing problems.

Weaknesses

- Poor-quality seed and retardation in growth in the culture phase and no broodstock management or genetic norms followed in any of the hatcheries.
- Hatcheries exchange their stock with riverine stocks from brood banks without assessing their genetic status.
- No use of preserved milt for stock improvement.
- Very few fish (low population size) used for breeding purposes every year.
- Knowledge level about the quality seed is very low.
- Genetic introgression of silver carp with bighead carp.
- No proper enforcement of seed certification and the Fish Hatchery Act (2010).

2.3.7 Collaboration

The following national and international organizations have worked for fish culture/aquaculture development in Bangladesh. They have contributed significantly to the development of aquaculture in the country:

International

- Food and Agriculture Organization of the United Nations
- Japan International Cooperation Agency
- Asian Development Bank Network of Aquaculture Centres in Asia-Pacific
- WorldFish
- United States Aid for International Development

National

- Department of Fisheries (DoF)
- Bangladesh Agriculture Research Council
- Private hatcheries and seed production farms
- Cooperative societies

However, no systematic genetic improvement programme has been taken up in Bangladesh to improve the genetic status of carp seed.

3. Problems that must be addressed

- Assessment of the genetic status of carp stocks by following direct methods using statistical and molecular tools
- Improvement of broodstock and establishment of live gene banks/brood banks in selected farms
- Systematic breeding programmes to improve the quality of carp seed
- Cryopreservation of carp milt and establishment of fish semen cryobanks
- Quality control measures and regulation to control the quality
- Disease diagnostic and soil and water testing laboratory

4. Recommendations

Basing on the findings of the consultancy, the following recommendations for immediate interventions and long-term strategies are suggested:

- As a long-term strategy, a genetic selection and selective breeding programme may be undertaken.
- Brood banks should be established in limited places with all facilities.
- Trained personnel are essential to undertake this.
- Base populations of carps, tilapia and pangas should be developed by collecting from different sources.
- Broodfish ponds (at least 20) for the rearing of base population, producing 15 families at a time and a total of 50–60 families with at least 10–15 incubation chambers with 60 nurseries should be developed in a biosecure facility where no escape, intermixing or theft is possible and the area is safe from flooding and other calamities.
- As an immediate intervention strategy, the use of short-term preserved milt/cryomilt from selected elite milters must be undertaken. If there is no elite (genetically improved) material available, then exchange between hatcheries must be encouraged to widen the effective population size and bring a check to the inbreeding problem.
- Hatcheries constructed earlier may be modified to reduce the loss of eggs/hatchlings.
- Hatchery owners should be instructed and made aware of the shrinking gene pool and should be told to keep hatchlings from each batch of breeding and rear them to broodstock.

- A broodstock-raising programme should be strictly followed and should be separated from tablefish production.
- A fish semen cryobank may be established.

4.1 Follow-up actions

The problem areas that need intervention for better aquaculture development must be addressed in the future. A systematic study under an adequately funded project may be devised for implementation in Bangladesh in the future. The main thrust areas of the project would be brood banking, breed development, cryobanking, hatchery improvement and enforcement of the Hatchery Regulations. Besides this, hands-on training for personnel and hatchery owners on carp broodstock management, hatchery management, cryopreservation, advances in nursery management and HACCP may be undertaken.

5. Acknowledgements

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6. References

Sarder, M.R.I. 2015. Field survey report on technical, economic and social constraints to aquaculture seed production and management in Bangladesh. In M.R. Hasan. & J.R. Arthur, eds. *Aquaculture seed and feed production and management in Bangladesh - Status, issues and constraints*, pp. 49-56 on CD–ROM. FAO Non-Serial Publication. Rome, FAO. 48 pp. + CD–ROM.

DoF. 2010. *Fisheries statistical yearbook of Bangladesh.* Volume 26. Fisheries Resources Survey System (FRSS). Dhaka, Department of Fisheries, Ministry of Fisheries and Livestock.

Report of the verification mission on aquaculture feed production and management

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1. Introduction

The fish production sector is growing rapidly in Bangladesh. Between 2001–2002 and 2010–2011, total fish production increased from 1.89 million tonnes to an estimated 3.06 million tonnes. The rapid increase in fish supply is primarily a result of the rapid growth of the aquaculture sector that, by 2010–2011 contributed 1.46 million tonnes of product, equating to 47.7 percent of the country's fish production (DoF, 2012). Central to the growth of the sector has been the gradual intensification of production systems that has seen a move from the traditional low-input extensive production systems based on natural pond productivity and supplemental feeding, to semi-intensive/intensive production systems that require the use of formulated feeds. In semi-intensive/intensive production systems, feed traditionally represents one of the highest production costs and as such, the use of poor-quality feeds or the application of suboptimal feed management practices will significantly impact the economic performance of the farming operations. Taking into consideration the move to intensification and the concomitant increase in aquafeed use, it is reasonable to suggest that in the future, aquafeed supply and quality issues will become increasingly important to the sustained development of the sector.

The aquafeed subsector in Bangladesh comprises three major components, viz., supplemental feeds, farm-made feeds and commercially produced pellets. In 2007, Barman and Karim (2007) estimated that 100 000 tonnes of supplementary feeds were used in traditional extensive carp polyculture systems. Unfortunately, there is little information pertaining to the volumes of farm-made feeds that are produced. However, the initial project survey estimated that there were 400 farm-made aquafeed producers in operation, primarily in the Mymensingh area. In 2008, the 40 leading commercial aquafeed mills had an estimated capacity of 360 000 tonnes per annum, by 2010, the production capacity of these same producers had increased to an estimated 668 380 tonnes, valued at USD220 million (Belton *et al.*, 2011). As these figures do not take into consideration the 40–60 smaller commercial mills that are also in operation, the total production capacity is likely to be significantly higher. Nevertheless, using the production figures of the 40 largest commercial feed suppliers and assuming an average feed conversion ratio (FCR) of 1.5, it would suggest that at present commercial feeds account for 445 000 tonnes of fish production, equating to 32 percent of total aquaculture

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production. This rapid increase in aquafeed production capacity is testament to the rapid growth in the aquaculture sector, the increasing trend towards the intensification of production systems, and the increasing requirement for high-quality, commercially produced aquafeeds.

To date, it would appear that the aquafeed production and supply sector remains largely unregulated, and while the government has promulgated The Fish and Animal Feed Act (Act 2 of 2010) and associated regulations, quality and cost concerns persist throughout the supply chain. The overall objective of this component of the Technical Cooperation Programme Facility (TCPF) project is therefore to identify and develop an improved understanding of the key technical, economic and social constraints to feed production and management in the country. The key objectives call for:

a) an analysis of the legislative, policy and regulatory frameworks that relate to aquafeed production and use in Bangladesh;
b) the characterization and assessment of the current status of aquafeed production in the country;
c) an analysis of those factors that result in low-quality feed production, and the need to undertake a value-chain analysis to identify economic inefficiencies in the aquafeed supply sector;
d) the identification of appropriate support services needed to build capacity in the small- and medium-scale aquafeed manufacturing sector;
e) a needs assessment for capacity-building activities to assist small-scale fish farmers to improve on-farm feed and feed management practices and optimize the use of feed additives;
f) an assessment of the extent and the efficacy of the use of feed supplements and feed additives; and
g) an assessment of the social and economic issues that need to be addressed to improve the quality of aquafeeds and the efficacy of their use.

2. The mission

2.1 Team members

The mission comprised the following personnel:

- Dr Nesar Ahmed – National Consultant (Aquaculture Feed)
- Dr Thomas Ashley Shipton – FAO Consultant (Aquaculture Feed)
- Dr Mohammad Rafiqul Islam Sarder – National Consultant (Aquaculture Seed and Broodstock Management)
- Dr Padmanav Routray – FAO Consultant (Aquaculture Seed and Broodstock Management)

Dr Mohammad R. Hasan, Aquaculture Officer, FAO FIRA was the Lead Technical Officer (LTO). He provided backstopping for the team and joined the team during the project planning and feedback discussions.

2.2 Project briefing

Prior to the field visits, the purpose, scope and expected outputs from the mission were discussed with:

- Food and Agriculture Organization of the United Nations (FAO) Bangladesh
- Department of Fisheries (DoF)

Prior to the assessment, an initial review of the data that was collated by Dr. Nesar Ahmed during the initial rapid appraisal (March to August 2012) was undertaken.

2.3 Field visits

The field visit was undertaken between 10 and 15 August 2012. The site visit focused on the districts of Comilla, Bogra and Mymensingh. A series of discussions were held with:

- freshwater fish farmers;
- freshwater hatchery operators/grow-out farmers;
- farm-made feed manufacturers;
- commercial feed manufacturers;
- aquafeed retailers, distributors and technical advisors (commercial pellet feeds/feed ingredients and additives);
- government research personnel (Bangladesh Fisheries Research Institute, BFRI)
- government personnel responsible for the implementation of the Fish Feed and Animal Feed Act (2010) and associated regulations (DoF)

3 Findings

3.1 Quality issues – aquafeeds and feed ingredients

Feed ingredient supply, quality and cost is evidently becoming a serious problem for both the commercial and farm-made feed producers. High-quality protein sources are generally imported from abroad, and prices are subject to the global commodity markets. Recent months has seen significant price increases in many of these imported products. For example, in the six months from February to August 2012, imported fishmeal prices have increased from BDT38/kg[22] to BDT70/kg and bone meal prices from BDT28/kg to BDT40/kg, representing an increase in ingredient prices of 84 percent and 42 percent, respectively (S. Islam, Shab Sultan Fish Seed Farm, personal communication, 2012). The increasing cost of feed ingredients is impacting the quality of feeds produced in a number of ways. Firstly, farm-made feed producers report that when fishmeal prices rose or supplies in the market became scarce, they simply replaced the fishmeal component of the formulation with a lower-quality protein source such as meat and bone meal, inevitably impacting the quality of the feed and the growth response. Secondly, the price increases erode the profit margins of the feed manufacturers.

[22] 1USD = BDT81.53 on 9 August 2012.

Brac - Aquafeed Production Division, reports that over the past year, ingredient inflation has resulted in an average increase in their formulation costs of BDT10/kg. To maintain the feeds being affordable to the famers, they have only increased their retail prices by BDT4.5/kg. The higher feed ingredient costs have also eroded their sales, as some farmers have reverted to cheaper farm-made feeds or to cheaper feed brands that use lower-quality ingredient sources. Some of the larger feed manufacturing companies will likely have the economies of scale to accommodate the tighter profit margins, however, many of the smaller companies will unlikely be able to do so. This has already resulted in some rationalization within the industry, with some of the smaller production companies leaving the sector (J. Islam, General Manager Brac Feed Enterprises, personal communication, 2012). The increased ingredient prices and tighter profit margins will likely encourage some feed manufacturers to replace high-quality feed ingredients with low-quality or adulterated replacements, thus compromising the quality of the feed. Indeed, a BFRI (2011) report on the quality of commercial aquafeeds, found that of 300 feed samples that were taken from 16 different feed manufacturers, between 29 and 51 percent of all feeds across all feed types (nursery, starter, grower and finisher) failed to comply with the feed regulations. This suggests that feed quality in the commercially produced aquafeeds is problematic.

The poor quality of some of the aquafeeds that are available in the market is of concern to the farmers, as poor feed quality will equate to reduced growth rates, and this will negatively impact the economic efficiency of their farming operations. Farmers are in an unenviable position, in that once they have purchased substandard feeds, they have very little recourse to the feed manufacturers. While they can theoretically have the feeds tested for proximate composition (crude protein, crude lipid, moisture and ash), such tests are relatively expensive (c. BDT800 per sample) and are realistically beyond the technical reach of the smaller-scale farmers. Furthermore, such tests would not show the ingredients composition and whether good or poor-quality feed ingredients had been used in the manufacturing process. It is interesting to note that many farmers appear to be aware that the quality of the feeds that they are buying is substandard, and in particular, that the protein content is lower than that specified. One hatchery manager went as far as supplementing his commercial nursery feeds with fishmeal and meat/bone meal. While this practice probably raised the quality of the feed, it also increased his production costs (M. Rahman, Jamuna Tilapia Hatchery, personal communication, 2012).

In order to resolve this issue, the DoF needs to develop an aquafeed monitoring programme to ensure that the aquafeed manufacturers comply with the regulations in terms of feed quality, composition and labeling. This could be achieved through the development of a product-monitoring system and certification programme to assure farmers of the quality of the feeds that they are purchasing.

The quality of the feed ingredients that are available to the feed manufacturers is also of concern. BFRI (2011) reports that in a survey of 45 feed ingredients that were available in the market, 64 percent were of a poor quality and had been adulterated in some manner. Furthermore, bacterial analysis indicated that the

shelf life of many of the ingredients was less than two months. These ingredients included locally produced fishmeal (dried), mustard and sesame oil cakes and silkworm pupae meal. Other ingredients, including the imported fishmeal, soya and meat and bone meal had shelf lives of around six months. A further issue that was identified was the high moisture and unsaturated fatty acid levels in some of the feed ingredients, making them prone to spoilage.

The low quality of the feed ingredients available is of concern to the feed producers. If the feed manufacturers are unable to procure high-quality ingredients and at a reasonable cost, it is unreasonable to expect them to produce cost-effective, high-quality aquafeeds. To date, there have been no comprehensive studies that have focused on feed ingredient quality, availability and price. Discussions with aquafeed producers and feed dealers suggest that the feed ingredient supply value chain is complex, with different ingredients entering the value chain from multiple points, e.g. local and regional markets and imports from various countries (e.g. United States of America, Canada, India, China). In addition, some products are seasonal (e.g. locally available fishmeal) and thus only available to the feed manufacturers at certain times of year. The movement of the materials through the value chain is also unclear. While the large feed manufacturers will be supplied directly by the importers, those making farm-made feeds are supplied by a network of feed ingredient dealers. Smaller farmers that are unable to afford to buy in bulk from the feed dealers are forced to purchase small quantities of ingredients from the local markets at higher unit costs. Clearly, there are numerous opportunities along the value chain for the adulteration of the ingredients.

Improving the quality of the feed ingredients available to the feed producers represents a complex problem that is unlikely to resolve itself without interventions from government agencies. Monitoring feed ingredient quality and adulteration along the value chain is required, and where appropriate, adulterated ingredients seized and traders prosecuted. For example, one feed ingredient dealer indicted that the turnover rate of feed ingredients in his shop was 10–12 days, suggesting that ingredients move through the value chain at a relatively fast rate. Monitoring systems need to take cognizance of these timeframes such that there is sufficient time to test and seize ingredients prior to their incorporation into feeds. Interventions in this area will require the DoF to develop a better understanding of the movement of the feed ingredients through the value chain.

3.2 Legislative framework

The Fish Feed and Animal Feed Act (Act 2 of 2010) provides the legal framework for aquafeed production and use in Bangladesh. A review of the legislation suggests that it contains the essential components that are required to regulate the aquafeed production sector. Importantly, the act designates the Director General of the DoF, Ministry of Fisheries and Livestock, as the responsible agent for the implementation of the legislation and its regulations. It further stipulates that all feed producers, processors and traders require licensing, and provides appropriate licencing and fee mechanisms. It outlines feed labeling procedures and allows for restrictions on the use of harmful chemicals (e.g. antibiotics, hormones), and

standard inclusion rates in feed formulations – these chemicals/inclusion rates are outlined in detail in the associated feed regulations (Fish Feed Rules, 2011). The act provides the DoF with the right to enter premises for inspection and testing purposes. With respect to penalties, production licences can be revoked and illegal feed ingredients/products can be seized and destroyed. Owners and production mangers can be prosecuted for infringements and imprisoned for up to a year, fined BDT500 000, or both. In terms of prosecution, it is unfortunate that the penalties have been proscribed in the act, as a review of these penalties will require a parliamentary revision to the act. In the future, it would be more appropriate to stipulate the penalties in the regulations, where they can be more easily revised at the ministerial level. Nevertheless, as the existing framework allows for the closure of production facilities and the seizure and destruction of products, it is evident that there is sufficient deterrent within the system to encourage compliance.

The Fish Feed Rules (2011) provide an extremely comprehensive set of regulations to control the aquafeed production, trading and distribution sectors. The regulations outline the application and licence fee procedures for commercial feed mills, aquafeed and feed ingredient import/exporters, and wholesale and retail traders. Although not explicitly indicated in the regulations, it is important to note that the farm-made feed producers appear to be exempt from the licensing procedures – they would be unable to comply as a Category 1 (Fish feed production, processing and storage facility) establishment, which represents the only production category in the regulations. The regulations are proscriptive in terms of the facilities that must be available at the processing and feed handling sites. For example, among others, commercial feed producers require designated areas for receiving feed ingredients, feed processing equipment, weighing, packing, and laboratory, feed quality and environmental control facilities.

With respect to feed ingredients and feed formulations, the regulations provide specific guidance on the quality of feed ingredients that may be used, their inclusion rates and the proximate composition of the feeds produced. Specifically, Schedule 3 outlines the required proximate composition of the most common animal and plant protein sources used in formulations and their maximum dietary inclusion rates. Schedules 4 and 5 outline those feed additives that may be used in the manufacturing process (primarily vitamins, minerals, preservatives and sugars) and as binders (e.g. gluten meals, gelatin).

Importantly, Schedule 6 outlines the proximate composition of the feeds that are produced for all the major culture groups (i.e. carps, pangas, stinging catfish, walking catfish, climbing perch, Nile tilapia, freshwater prawns and marine shrimps). The dietary protein, lipid, carbohydrate, fibre, ash, calcium, phosphorous and moisture inclusion levels are specified for the various size classes of fish – nursery, starter 1 and 2, grower and finisher formulations. Regulating the proximate composition of the feed for specific growth stages (size classes) of the fish provides the feed compliance authorities with useful information in terms of feed quality, and provides the feed manufacturers and farmers with appropriate formulation guidelines. However, caution should be applied to the rigorous application of these limits. Evidently Bangladesh does not

produce high-quality animal feed ingredients (particularly protein concentrates such as fishmeals and soya concentrates), and has to rely on feed ingredient imports to provide much of the high-value protein that is used in the animal feed industry. This situation effectively renders the country prone to fluctuations in world commodity prices/availability. Over the past year, it has been reported that some feed ingredient prices have increased significantly, and that there are issues of ingredient availability (especially high-quality fishmeal and protein concentrates). Under these conditions, the feed producers may find it difficult to comply with some of the feed composition regulations, and to keep their feeds competitive and affordable to the farmers. Under such circumstances, they will likely substitute the expensive higher-quality proteins with cheaper lower-quality alternatives. For example, the starter feeds for the prawn industry stipulate a protein content of 40 percent. In the event that high-quality protein sources (amino acid profiles and a high protein concentration) are unavailable in the market or their cost is prohibitive, consideration could be given to relaxing the regulation to allow slightly lower-protein feeds (suboptimal formulations) to be marketed, which while at a lower cost to the farmer and producing suboptimal growth, may still be affordable to the farmers and prevent them from reverting to even less efficient farm-made feeds. Clearly any interventions in this area should not be taken lightly, and from a nutritional and economic perspective, considered extremely carefully.

The use of chemicals in aquaculture is addressed, and a list of harmful chemicals is provided (Schedule 7). These chemicals include hormones, various classes of antibiotics (sulphonamides, prymidine derivates, quinolones and tetracyclines), organophosphates, environmental contaminants (e.g. dichloro-diphenyl-trichloroethane (DDT), Dieldrin), heavy metals (e.g Pb, Hg, Cd, Cr), micotoxins, anthelmintics and dyes (e.g. malachite green). With respect to feed formulation, many of these chemicals (e.g. the steroids and many of the antibiotics) are simply banned, and are not permitted in the feed. Some chemicals, such as the tetracycline class of antibiotics, are allowed, and acceptable inclusion rates in the feeds are provided. Equally, acceptable levels of environmental contaminants such as organochlorides, heavy metals and micotoxins that may be present in the feed ingredients are addressed. To conclude, the regulations provide a comprehensive listing of the potentially harmful chemicals that could be used in the aquafeeds, and where appropriate provide maximum levels of inclusion.

3.3 Proposed interventions

Provide assistance to the DoF to implement its mandate to regulate the aquafeed production sector

While an appropriate feed regulatory framework is in place, the implementation of the regulations is proving problematic for the DoF. Currently the DoF in Dhaka has assigned three personnel to work on aquafeed issues, however, the staff are tasked with other duties, and are thus addressing the implementation of the regulations on a part-time basis. The DoF is currently in the process of registering the commercial feed producers, importers and traders. However, at present the majority of these companies remain unregistered. While the DoF has access to some

limited diagnostic services through private-sector laboratories and the nutrition laboratory at the BFRI, they do not have the diagnostic capacity (laboratory or human resources) to carry out their mandate to regulate the feed sector.

It would be appropriate to set up a feed unit at the DoF. This would require the installation of a diagnostic laboratory to monitor feed and feed ingredient quality. At a minimum, the laboratory should be equipped to undertake proximate composition analyses (crude protein, lipid, ash, crude fibre, ash and phosphorus). Technical personnel would have to be hired and analytical training provided. To save investment and operational costs, the more expensive and complex analyses that relate to feed additives/safety (e.g. antibiotic residues, hormones, heavy metals) could be undertaken at the food safety laboratory that is currently being set up as a component of the FAO Food Safety Project GCP/BGD/047/NET. A review of the laboratory instrumentation being installed by this programme indicates that all the necessary diagnostic facilities to monitor feed additives/safety will be available. Further, it should be noted that fish safety (for human consumption) is one of the core focus areas of this programme and thus, there is considerable scope for developing synergies.

In those cases in which there is a dispute concerning the sample analyses, the regulations stipulate that the samples should be retested at an independent laboratory. The nutrition laboratory at the BFRI has the appropriate diagnostic equipment and trained personnel to undertake these secondary analyses. However, as a research laboratory it is set up to run small sample numbers. For example, the Kjeldahl protein digester can run two (triplicate) samples concurrently. Designating the laboratory as a secondary testing laboratory would likely require the facilities to be upgraded such that it could run larger sample numbers.

Sampling schedules and protocols will need to be developed to monitor the quality of the feed ingredients and aquafeeds. Secure protocols for collecting samples will also need to be established – as the analyses may ultimately be used in prosecutions, samples will need to be collected in an appropriate manner (sealed and secured, witnessed, and chain of custody procedures implemented). While the extension officers at the 470 upazillas throughout the country could potentially be trained to collect samples, it would probably be more appropriate to employ a dedicated team of inspectors to undertake this task.

3.4 Aquafeed production

3.4.1 Commercially manufactured aquafeeds

The rapid growth of the aquaculture sector in recent years has resulted in significant investment in the commercial aquafeed production sector. Currently, there are in the region of 100 commercial aquafeed manufacturers operating in the country. However, as the DoF is still in the process of registering the producers, the exact number and their current production capacity is unknown. Nevertheless, the initial stakeholder survey revealed that the sector is characterized by a combination of large integrated manufacturers, often of foreign origin, producing between 60 000–95 000 tonnes of feed per annum, and a larger number of smaller mills producing smaller quantities of feed (8 000–40 000 tonnes per annum) (BFRI, 2011).

Typically, many of the manufacturers produce both poultry and fish feeds, however some of the larger feed producers specialize in aquafeeds exclusively. Feeds are produced for all the major culture species. Approximately, 55 percent of the production capacity is used to produce feeds for pangas, 22.5 percent for tilapia, 16 percent for climbing perch, walking catfish and stinging catfish, and the remaining 8.5 percent for the carps. Both floating and sinking feeds are produced, with feeds being formulated according to the species/life stage of the fish. While feed prices vary according to the culture species, formulation and the quality of feed ingredients used, they generally range from a low of BDT25/kg for sinking carp feeds to BDT46.8/kg for floating stinging catfish feeds. In general, the FCRs attained using the sinking feeds are in the region of 2–2.5, while those attained using the more expensive floating formulations are in the region of 1.5. The high FCRs associated with the sinking feeds suggest that there are either issues in terms of the feed formulation failing to satisfy the nutritional requirements of the fish or poor feed management or perhaps more likely, a combination of the two.

Proposed interventions

1. Development of a commercial aquafeed producers association

In recent years, significant private-sector resources have been invested in developing production capacity in the feed manufacturing sector, and there are now in the region of 100 feed manufacturers. Currently, there is no organization that formally represents the interests of the sector in its dealings with government agencies or the wider aquaculture community. The introduction of the new regulatory dispensation will require the industry to move from its current position where it is essentially unregulated to one in which it is regulated. This process will require the industry to adopt new procedures, such as independent product testing. The development of a producers association would provide both the government and industry with a representative forum with which to discuss how best to implement the regulations and inform the industry of the governments' implementation programme. Attaining buy-in from the industry and encouraging voluntary compliance with the regulations will greatly assist in improving the quality of aquafeeds available in the market. It is important to recognize that at present many of the products that are available in the market would fail to conform to the new regulatory dispensation. A producers association would provide a suitable forum for government to work with the industry to improve the quality of these products. Voluntary compliance should be encouraged, and efforts should be made to avoid a repressive management approach that relies purely on enforcement. Closing facilities due to non-compliance should be viewed as a last resort, as it will effectively remove much needed production capacity. The development of a producers association would require the identification and registration of the companies involved in commercial aquafeed production (currently the DoF has an incomplete registry of these companies). A series of consultations to develop a charter/agreement of association and an organizational structure would need to be developed and appropriate funding mechanisms identified.

2. Aquafeed standards and certification

The low quality of some of the aquafeeds that are currently being produced is of concern to the farmers, who have little practical recourse to the feed producers, particularly when they find that they have purchased low-quality feeds. The introduction of a certification programme that is sanctioned by a reputable organization such as a feed producers association or the DoF would provide the farmers with a mechanism with which to differentiate the quality of the feeds that are in the market. Discussions with the commercial feed suppliers suggest that the majority of farmers primarily base their purchasing decisions on the cost of the feed, with quality considerations being of secondary importance. With some farmers selecting feeds according to price as opposed to quality, it follows that the higher-quality, more expensive feeds will at times be at a potential disadvantage in the market place. Thus, those feeds that incorporate lower-quality ingredients and are cheaper to produce may have the competitive advantage – this is probably not the case for the high-value culture species such as the stinging catfish, where feed costs represent a relatively low percentage of the total production costs. Optimizing production, particularly at higher stocking densities, requires high-quality feeds to be used, and thus attempts need to be made to encourage farmers to adopt the best quality feeds available to them. Certification and farmer education extolling the advantages of using high-quality feeds is one way to promote the use of high-quality feeds and at the same time ensure that feed manufacturers remain committed to producing high-quality products – if they fail to do so, they lose their certification and the farmers can easily recognize that the company no longer manufactures high-quality feeds.

The organizational structure of a certification programme would need to be discussed with the aquafeed producers and the DoF. The programme would likely be best addressed as a private-sector initiative, possibly driven by an aquafeed producer association. The DoF could likely play a support role in terms of promoting the idea to the industry and farmers, assisting in the setting of the feed standards (based on the regulations), and setting up rules, protocols and compliance monitoring.

3. Promote a migration from farm-made feeds to commercially produced feeds

Traditionally, feed represents the highest production cost in aquaculture. This is particularly the case for some of the lower-value species such as the pangas that are fed relatively expensive formulated feeds. Commercially manufactured aquafeeds that have been finely milled, extruded and dried have far superior physical characteristics to their farm-made counterparts that tend to be poorly bound, have a high percentage of fines, and often disintegrate before they are ingested by the fish. Notwithstanding the formulations applied, it is reasonable to suggest that simply moving the farmers from farm-made feeds to more robust commercially manufactured pellets will result in cost savings in terms reducing feed wastage and improving FCRs. It was noted that one of the experienced hatchery operators who also operated pangas grow-out ponds (Mr S. Sultan, Sultan Fish Seed Farm) was originally using farm-made feeds. Last year he

stopped extruding his feeds through his small-scale feed mill, and instead was processing his feed mixture at a commercial processor that had spare production capacity. The commercial operator was charging him BDT1.5/kg to extrude his feed mixture and required a minimum of 2 tonnes of mixture to make the operation financially worthwhile. The farmer indicated that the change from a farm to a commercial extrusion process had two main advantages. The first was the improved pellet integrity that resulted in better feed efficiency, and the second was that there were no problems with drying the pellets, as this could be done mechanically and there was therefore no longer a need to rely on sun drying.

In terms of the economics of a typical pangas farming operation, and applying a farm-made feed formulation cost of BDT25/kg and an FCR of 2.5, the feed production cost per kilogram fish using the farm-made feed is in the region of BDT62.5/kg. At a farm-gate price of BDT80/kg for pangas, the feed cost of production represents 78 percent of the total farm gate (sales) price. This should be considered as extremely high, and it is the primary reason why pangas farmers are currently reporting their farming activities as marginal. It is reasonable to suggest that extruding the feed through a commercial extruder and improving the pellet integrity will improve the FCR by 0.5 (FCR improves from 2.5 to 2). Applying the same formulation (feed ingredient cost), adding an extrusion fee of BDT1.5/kg, and reducing the FCR to 2 will result in a reduction in feed production cost of BDT9.5/kg, equating to a reduction of the feed cost (as a percentage of farm gate price) from 78 percent to 66 percent (Box 1). The savings in feed production costs suggests that by simply encouraging farmers to move from a farm-based to a commercial extrusion process will significantly improve the quality of their feeds and the economics of their farming operations.

Box 1. Feed production costs associated with using a farm-made or commercially extruded pellet

Farm-extruded feed:
- Raw material cost: BDT25/kg
- FCR = 2.5
- Pangas farm gate price: BDT80/kg
- Feed production cost per kg pangas = 25 x 2.5 = BDT62.5

Feed production cost as a percentage of farm gate price = 78%

Commercially extruded feed:
- Raw material cost: BDT25/kg
- Processing cost: BDT1.5/kg
- FCR = 2
- Pangas farm gate price: BDT80/kg
- Feed production cost per kg pangas = (25+1.5) x 2 = BDT53

Feed production cost as a percentage of farm gate price = 66%

BFRI (2011) reported that in 2010–11 only 45 percent of the capacity in the commercial feeds mills was being utilized. While the excess production capacity is likely to be among the smaller, more marginal feed mills, there is clearly scope to utilize it such that the feed ingredients that are normally extruded at the farm level are extruded more efficiently by the commercial operators. Clearly, only those commercial feed manufacturers that have excess capacity would consider providing this service. In order to develop an intervention, a production model linking commercial feed mills with small-scale farmers needs to be developed, and suitable feed manufacturers/farmers identified and mapped. The production model must take into consideration the minimum volume (±2 tonnes) of feed required to process at the commercial mills and the small quantities of feeds that are being currently processed at the farm scale. The initial study survey indicated that 80 percent of the farmers manufacturing farm-made feeds were producing in the region of 100 kg of feed a week. This being the case, there will be a need to organize farmers into groups/associations such that sufficient volumes can be generated to make it worthwhile for the commercial feed manufacturers to engage in the process. Access to finance for the small-scale farmers has also been identified as a major production constraint in the small-scale sector, and it would thus be appropriate to address access to funding feed ingredients as a component of this intervention.

3.4.2 Farm-made aquafeeds

There are between 250–400 farm-made feed producers in Bangladesh (BFRI, 2011; Nesar Ahmed, Bangladesh Agricultural University, personal communication, 2012). The initial programme survey of the farm-made feed producers indicated that while they have an average production capacity of 3 tonnes per day, they are operating under considerable constraints. The major constraints that were reported by the farmers are presented in Table 1. These constraints comprise high input costs (equipment, ingredients, and production costs), unreliable or poor infrastructure (unreliable power supplies, poor market facilities and difficulties in moving ingredients/products between the markets/processors/farmers), a lack of technical knowledge in terms of feed production and formulation, and a lack of access to finance/credit to fund their operations.

TABLE 1
Major constraints reported by farm-made aquafeed producers

Constraint	Respondents (%)
Equipment costs	100
Unreliable power supply	100
Poor market facilities (movement of materials)	90
High production costs	80
Lack of technical knowledge	80
High ingredient costs	70
Lack of credit facilities	75
Poor product (pellet quality)	75

Proposed Interventions

1. Improve the technical capacity to improve the quality of farm-made feeds

From a technical perspective, the formulations that are used appear to be generic and are based on the experience of the feed manufacturer or in some cases are provided by the feed ingredient dealers. They are neither species specific nor are they size-class specific. As a result, they are unlikely to be optimal in terms of satisfying the nutritional requirements of the fish. Ingredient sources appear to be used in the formulations without any clear understanding of how the ratios should be used to maximize the efficiency of the formulation. This problem is compounded by the high cost/unavailability of some of the higher-quality ingredients that are often replaced by lower-quality alternatives. In addition, it was observed that there are also problems associated with the integrity of the pellets that are produced. Inadequate milling of the raw materials results in large particle sizes that not only compromises pellet binding, resulting in the pellets breaking up in the water prior to ingestion, but in addition, can reduce the digestibility of the feed ingredients. The development of better aquafeed production/management practices that are designed for distribution to the feed ingredient suppliers and farm-made feed manufacturers could be considered. The better management practices (BMPs) should focus on improving feed formulations, and in this regard, these could be based on the formulations that have been developed by the BFRI and are based on available ingredients. There would also be a need to provide information on ingredient preparation, mixing, binding, drying and storage, and the appropriate use of feed additives in feeds. Concomitant with the need for better aquafeed production practices is the need to distribute better feed management practices to the farmers using farm-made aquafeeds. These have already been developed by the commercial feed producers and distributed by the feed dealers to those farmers using commercial aquafeeds. However, the dealers of farm-made feed ingredients and feed producers are not supplying BMPs to the farmers using farm-made feeds. The development and distribution of feed BMPs would likely improve feed performance for these farmers.

2. Establishment of a farm-made feed producers association

Currently, the farm-made feed producers do not have any formal representation that enables them to interact with government and the new regulatory dispensation that will come into force as a result of the Fish Feed and Animal Feed Act (2010) and its regulations. A producers association would not only provide a formal forum for the DoF to interact with the feed processors, it would also provide a forum for training and extension and the distribution of extension materials – better feed manufacturing and feed management practices.

3.5 Feed dealers/traders

Farmers access their feed and feed ingredients through a network of dealers. There is considerable variation in the types of services that are available to the

farmers. In general, those farmers that purchase commercially manufactured aquafeeds tend to have access to dealership services that are not available to those farmers that purchase products from feed ingredient dealers and make their own farm-made feeds. While the services vary between dealers, it is evident that many of the commercially produced aquafeed dealers form long-term relationships with their feed suppliers and farmers, often providing both extension materials and finance to the farmers. The extension materials are developed by the feed manufacturers and are designed to optimize the farmers' use of their purchased feeds by improving their feed management practices, providing feed tables and promoting record-keeping activities. The feed dealers are used as the conduits for the distribution of these materials. In contrast, those purchasing feed ingredients to make farm-made feeds are not supplied with this type of information and appear not to have access to these types of extension materials. Nevertheless, some feed ingredient dealers provide some limited formulation advice.

Finance is available to some famers, but again this is primarily available to those farmers that are using commercially produced aquafeeds. Finance terms and availability varies between dealerships and the relationship between the feed dealers and the farmers. For example, one feed dealer (Mr M. Billah, Comilla) who deals with eight feed companies reported supplying in the region of 300 farmers. Two hundred of these farmers have sufficient capital to fund their feed costs, however, the remaining 100 farmers require loans; in this case 50 percent of total feed costs per production cycle were usually provided on credit. Other dealers reported credit lines of 20–70 percent of feed costs (S. Oslam, Brac, personal communication, 2012). Alternatively, credit is provided to farmers who run out of money to pay for feeds towards the end of their production cycles. While collateral is not required to secure these loans, the dealer visits the farmers to assess their infrastructure, farming skills, wealth and ability to repay the loan. Evidently, the loans are based the development of long-term (± 5 year) relationships with the farmers, such that in the event of a crop failure, the dealer either extends the line of credit (payment terms) or in some cases, the loan is repaid from the profits from the next crop. The credit provided can be substantial. One feed dealer reported that an average farmer that he supplied would require in the region of USD750 worth of feed per month. Over a three-month period, this would equate to a feed bill of USD2 250. If it is assumed that he purchases half of this feed on credit, he would require a credit line of USD1 125 over a three-month period – this is a considerable amount of money for what is essentially an unsecured loan.

Loans are generally short term with credit periods ranging from 3 months for tilapia and pangas to 6–7 months for the carps (S. Oslam, Brac, personal communication, 2012). Some dealers report charging interest (up to 15 percent was reported), while others provide the loans free of charge. The feed manufacturing companies are also aware that the costs of their feeds are becoming increasingly problematic for many farmers. In response, some of them have extended lines of credit or provided feed on credit to the dealers, enabling them to pass credit services on to the farmers. The credit terms varies between the companies and dealers. While Brac Feed Enterprises are responding to the affordability issues

by setting up a pilot credit facility – at present, 15–20 tonnes of feed per month is provided on credit to 12 selected dealers (S. Oslam, Brac, personal communication, 2012), other dealers reported more substantial loans. For example, one dealer indicated that that while the CP Feed Company provided him with an annual credit line, the other companies that he dealt with limited their credit to 200 tonnes of feed a month.

Proposed Interventions

1. Improve access to finance/development of appropriate financial models to enable farmers to purchase commercial aquafeeds and feed ingredients

The private sector is increasingly addressing the issue of feed use and affordability, and many feed manufacturers and dealers provide the farmers with extension services and access to financial products that enable them to purchase feeds. However, it would appear that access to the financial products is dependent upon a number of factors, including the farmers' wealth and resources, type and intensity of the farming operation, and the relationship with the feed dealer. While it was not possible to determine numbers, it is likely that access to finance remains a significant constraint to many farmers that are using commercially produced aquafeeds. Furthermore, it appears that the feed ingredient dealers are not providing finance or extension materials to those famers that purchase feed ingredients for formulating farm-made feeds.

While it is important to support the existing private-sector initiatives, there is a need to identify the scale of the lending arrangements and where necessary, improve access to finance to those famers that are currently unable to access finance. In addition, there is a need provide finance and extension materials (BMPs for farm-made feed production and feed management practices) to those farmers that purchase feed ingredients for farm-made feeds. Concomitant with the commercial feed suppliers, the potential to use the feed ingredient suppliers to support the farmers in the terms of supplying extension materials/loans could be considered.

At present, there is insufficient information pertaining to the financial assistance (e.g. loan sizes, funding periods, terms and conditions) that would be required to enable farmers to access adequate feed and feed ingredients. Amongst others, funding requirements will depend upon the culture species, production systems, feed type, cost, use, and farmer resources/wealth. It would therefore be appropriate to develop a better understanding of the aquafeed value chain, with particular emphasis on feed/ingredient availability/costs, funding requirements and how these change according to species, grow-out periods and the technologies in use. This would provide the primary information that could be used to develop funding models. These models could then be trialed through appropriate funding agencies – possibly micro-finance institutions, feed dealers, farmer groups/associations, etc.

3.7 Feed additives

At present, there is very little information pertaining to the use of feed additives and the extent that they are being used by farmers. The exception is the use of the antibiotic nitrofuran that in the past has led to the rejection of a number of shipments of freshwater prawn (*Macrobrachium rosenbergii*) to the European Union. This issue has since been resolved and diagnostic and traceability protocols have been developed to monitor nitrofuran use in the shrimp sector. Discussions with Dr Z. Ali (Nutritionist, BFRI) suggest that at present, minimal feed additives are being used in the freshwater sector and banned substances such as antibiotics and hormones are not in use. Nevertheless, there is some concern that banned substances may be present in some of the feed ingredients that are imported into the country, specifically antibiotics in the meat and bone meal. Discussions with the feed and feed ingredient dealers in Comilla and Bogra indicated that while some feed additives are being sold for use in farm-made feeds and to improve pond culture conditions, banned substances are not currently in use. A rapid review of the chemicals that were on sale at the feed dealerships indicated that the chemicals available comprised vitamin and mineral mixes and probiotic formulations for use in farm-made feeds, and chemicals to alleviate pond water quality issues (e.g. resolve low dissolved oxygen levels, hydrogen sulphide). While the use of appropriate levels of vitamin and mineral mixes is appropriate, the efficacy of the probiotics and chemical additives available could not be confirmed, and thus it could not be established whether the farmers are using legitimate products or are wasting their resources.

The widespread adoption of commercial feeds and the concomitant increase in the intensification of production systems in some sectors (e.g. pangas), suggests that in the future, water quality issues and disease may become a problem for some farmers. If this is the case, it is reasonable to suggest that many farmers may resort to using banned chemicals to alleviate their production problems.

Proposed Intervention

1. Develop a monitoring and response programme for feed additives and determine their efficacy

While our current understanding of the use and efficacy of feed additives/chemicals is limited, it would be appropriate to establish the efficacy of those chemicals that are available in the market to determine whether they are cost effective and whether farmers should be using them. In addition, consideration should be given to assisting the DoF to set up a programme to monitor and map chemical use, and develop a response programme that addresses the misuse of feed additives, should this occur. A comprehensive monitoring programme will require the use of a sophisticated diagnostic laboratory (i.e. for hormones, antibiotics assays etc.). While the testing required would be beyond the diagnostic capacity of the proposed DoF Feed Unit laboratory, the FAO Food Safety Project GCP/BGD/047/NET has installed appropriate diagnostic facilities to undertake these types of assays. Synergies between the two programmes should therefore be explored.

3.8 Summary of proposed recommendations and actions

Issues and recommendation	Actions
Regulatory issues	
1. Provide assistance to the DoF to implement its mandate to regulate the aquafeed production sector	• Set up a Feed Unit at the DoF and train staff in the implementation of the Fish Feed and Animal Feed Act (2010) and regulations • Set up a feed diagnostic laboratory at the DOF (analytical and training of personnel) • Upgrade the feed laboratory at the BRFI as a secondary diagnostic laboratory • Develop sampling schedules and protocols for monitoring feed ingredients and aquafeeds • Train feed inspectorate (secure sampling, chain of custody)
Commercial aquafeed issues	
1. Develop a commercial aquafeed producers association	• Register commercial aquafeed producers • Hold consultations to develop a charter/agreement of association • Develop an organizational structure • Develop long-term funding mechanisms
2. Develop an aquafeed certification programme	• Initiate stakeholder discussions between the commercial aquafeed producers and the DoF – identify lead agent • Develop a certification programme (standards, monitoring, funding and financial arrangements)
3. Promote a migration from farm-made feeds to commercially produced feeds	• Design a production model (economic model, volumes required, farmer numbers, etc.) • Map commercial producers and farmers/farmer groups using farm-made feeds that are willing to participate in a programme • Develop a funding model to improve farmer access to feed ingredients for extrusion in commercial feed mills • Trial a production programme that migrates farmers from their traditional practice of producing farm-made feed to extruding their feed ingredients at commercial production facilities
Farm-made feed issues	
1. Improve the technical capacity to improve the quality of f arm-made feeds	• Develop better aquafeed production/feed management practices (BMPs) • Distribute BMPs to feed ingredient suppliers and farm-made feed manufacturers/farmer groups
2. Establish a farm-made feed producers association	• Identify farm-made feed producers • Hold consultations to develop a charter/agreement of association • Develop an organizational structure Develop long-term funding mechanisms

Issues and recommendation	Actions
Feed dealer issues	
1.Improve access to finance/ develop appropriate financial models	• Undertake value-chain analysis of commercial and farm-made feeds • Develop small-scale financial models to improve famer access to commercial and farm-made feeds/feed ingredients • Promote and trial financial models through appropriate financing institutions/feed/feed ingredient dealers, etc. • Approach feed ingredient dealers that supply products to those farmers using farm-made feed ingredients and promote the distribution and adoption of better feed management practices
Feed additive issues	
	• Undertake a survey to establish the current use of feed additives across all subsectors • Provide assistance to the DoF to develop a monitoring and response programme to monitor the use of feed additives across all the subsectors, possibly in collaboration with the existing FAO food safety programme (FAO Project GCP/BGD/047/NET). • Undertake trials to establish the efficacy of the feed additives currently in use, determine their efficacy, and advise farmers of the appropriateness of their use

4. References

Barman, B.K. & Karim, M. 2007. Analysis of feeds and fertilizers for sustainable aquaculture development in Bangladesh. *In* M.R. Hasan, T. Hecht, S.S. De Silva & A.G.J. Tacon, eds. *Study and analysis of feeds and fertilizers for sustainable aquaculture development*, pp. 113–140. FAO Fisheries Technical Paper No. 497, Rome, FAO.

Belton, B., Karim, M., Thilsted, T., Murshed-E-Jahan, K., Collis, W. & Phillips, M. 2011. *Review of aquaculture and fish consumption in Bangladesh.* Studies and Reviews 2011-53. Dhaka, WorldFish Center.

BFRI. 2011. *Evaluation of nutrient quality and shelf life of commercial feed ingredients and feeds on aquaculture production in Bangladesh.* Annual Progress Report 2009–2010. Mymensingh, Bangladesh Fisheries Research Institute.

DoF. 2012. *Fisheries statistical yearbook of Bangladesh 2010–2011.* Fisheries Resources Survey System (FRSS). Volume 28, 46 pp. Dhaka, Department of Fisheries, Ministry of Fisheries and Livestock.

This document presents the findings of an FAO TCPF Project "Identification and understanding of key technical, economic and social constraints to seed and feed production and management in Bangladesh". The objectives of this project were to investigate the status and constraints of the aquaculture seed and aquafeed subsectors.

The project identified the key technical, economic and social constraints hindering the development of the aquaculture seed and feed production and management subsectors in Bangladesh. They also provided recommendations related to improving the four key areas of improved seed quality, improved aquafeed quality, strengthened capacities of farmers to utilize feed efficiently, and increased technical efficiencies of small-scale aquafeed producers.

The recommendations contained in this document should lead to a sustained improvement in technical and economic efficiencies of the main players in aquaculture seed and aquafeed subsectors in Bangladesh, from the raw material suppliers to the farmers and is expected to improve their productivity and economic returns and assure the sustainable growth of the country's aquaculture sector.

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