Aquaculture technologies in Bangladesh: An assessment of technical and economic performance and producer behavior

AQUACULTURE TECHNOLOGIES IN BANGLADESH: AN ASSESSMENT OF TECHNICAL AND ECONOMIC PERFORMANCE AND PRODUCER BEHAVIOR

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BDT	Bangladesh taka (1 USD = BDT 78)
BRDB	Bangladesh Rural Development Board
CSISA	Cereal Systems Initiative for South Asia
FTE	full-time equivalent
GDP	gross domestic product
ha	hectare(s)
HH	household
HS	homestead
kg	kilogram(s)
NGO	nongovernmental organization
PCR	polymerase chain reaction
SIS	small indigenous species
t	metric ton(s)
USAID	United States Agency for International Development
yr	year(s)

EXECUTIVE SUMMARY

Introduction

Bangladesh is the fifth largest aquaculture producer in the world. Aquaculture in Bangladesh has grown rapidly over the last three decades, at an average annual rate of 10.2%, and makes a significant contribution to the country's rural economy through farm incomes and on- and off-farm employment. Aquaculture also makes an important contribution to food and nutrition security in a national context where fish is by far the most frequently consumed nutrient-rich food. Despite this impressive growth, the characteristics of aquaculture in Bangladesh (technical, economic, and in terms of environmental performance and producer behavior) remain poorly understood by researchers and policymakers. This is due in part to the rapidity of change and development in the sector, and to the diversity of specialized production technologies that have emerged in response to local comparative advantages in different regions of the country. Research on the technical characteristics of aquaculture production, the socioeconomic characteristics of aquaculture producers, and the broader impacts of the activity on communities and the environment in Bangladesh has focused on a limited number of technologies (primarily traditional homestead ponds and the shrimp farming systems of southwest Bangladesh). However, these production systems now account for only a small fraction of Bangladesh's total aquaculture output. A variety of newer commercial technologies now account for the majority of production, but remain underreported or unrecognized in the literature.

Methodology

The study was designed based on the logic that in order to develop effective policy and field-based interventions in support of positive aspects of aquaculture development, it is necessary to fully understand the sector's characteristics. Surveyed farms were located in a total of 16 districts in 6 geographical hubs and in 4 outlying districts. These field sites covered most of the main aquaculture clusters in the country. The main aquaculture technologies practiced in each hub were identified through a process of rapid appraisal with local key informants. Fourteen distinct production technologies were identified in this way. Villages with high concentrations of households practicing each technology were identified through key informant interviews and subsequent follow-up visits. A census of households practicing aquaculture was conducted in each of the selected villages, and farm households were selected at random from this list for interview. A total of 2678 farmers were surveyed using a structured questionnaire. To our knowledge, the study is the largest in-depth survey of the behaviors of aquaculture producers ever conducted in Bangladesh, and perhaps the world.

In the following analysis, farming technologies are subdivided, for analytical purposes, into commercial and noncommercial (homestead pond-based) technologies. Commercial technologies are further subdivided by the type of waterbody in which they are practiced, with ponds and *ghers* (modified rice fields found in southern Bangladesh) being the two most important.

Socioeconomic characteristics of fish farmers

Asset endowments: The landholdings of homestead pond farmers were considerably smaller than those of farmers practicing commercial technologies, but larger than the national average operated area of farm holdings, indicating that aquaculture producers possess better-than-average resource endowments, irrespective of the technology practiced. Fish producers were also better educated than the general population on average, with commercial farmers displaying higher levels of literacy than noncommercial producers. About 13% of the area of land operated by noncommercial (homestead pond) farmers was allocated for fish farming. Between commercial pond and *gher* farmers, the share of land allocated to aquaculture varied from 16% to 57% and 62% to 84% respectively. The Bangladesh Bureau of Statistics groups farms by four size categories (marginal = <0.20 hectares [ha]; small = 0.21–1.00 ha; medium = 1.01–3.00

ha; large = >3.00 ha). With a small number of exceptions, the largest share of farmers across technologies operated landholdings within the small farm category. Between a third and one-half of all farmers fell within the medium category. Only a small portion of the farmers operated landholdings falling in the marginal category (16% of homestead pond farmers, and 6% or less of all commercial producers).

Economic status: The average monthly income of the sampled households ranged from BDT 2002 to BDT 2500 for homestead pond farmers, from BDT 3445 to BDT 13,110 for commercial pond farmers and from BDT 4005 to BDT 6993 for commercial *gher* farmers. The average monthly income per person of homestead pond farmers is similar to that of the rural population of Bangladesh, while the per capita monthly incomes of commercial *gher* and pond farmers exceed the national average by several times. Hossain et al. (2013) identify per capita income thresholds at which households in Bangladesh may be considered poor, lower middle income, upper middle income or higher income. For most commercial technologies, the major share of farmers (between 46% and 73%) earned incomes placing them within the higher-income category (>BDT 4000 per person per month). Households with per capita monthly incomes placing them within the lower-middle-income group (BDT 1131–3000) accounted for the greatest share of homestead pond farmers. While 19% of homestead pond farmers were categorized as poor, less than 7% of households practicing most commercial and rice-fish technologies fell into this income group.

Income composition: For noncommercial (homestead pond) farmers, aquaculture contributes only 4%–5% of total household income on average. This contribution increases to 24%–72% for commercial ponds and 38%–63% for commercial *gher*-based technologies respectively. Agriculture contributed between approximately one-quarter and one-half of total household incomes for farmers practicing semi-intensive and extensive aquaculture technologies, but a smaller share for those practicing intensive aquaculture technologies—e.g. farming koi and pangas, for which aquaculture accounted for more than 70% of household income. The share of non-farm income in household income was greatest for households operating noncommercial technologies. Across the whole sample, the share of non-farm income in total income was rather low (less than 25%) as compared to a national average for rural areas, suggesting that incomes from commercial aquaculture are often large enough to offset the need to seek non-farm employment.

Production practices, productivity and returns

Waterbody characteristics and tenure arrangements: The majority of waterbodies used for aquaculture held water year round. The average culture period (production cycle) of these technologies varied from 234 to 336 days. The majority of the waterbodies used for aquaculture were operated by a single individual ("single owned"), and 16% of homestead ponds were owned and operated by more than one individual ("joint owned"). However, joint ownership was rare for commercially managed waterbodies, ranging from 1% to 5%. Leasing in land for aquaculture was a significant arrangement for many commercial pond and *gher* operators (7%–28% and 31%–43% of farms respectively). Accessing land through lease arrangements was approximately two to three times more common in commercial aquaculture than in agriculture as a whole.

Homestead ponds have multiple uses besides fish farming. Approximately three-quarters of homestead ponds were used for washing and bathing. Water from commercially managed ponds was generally not used for domestic purposes. Drinking water from waterbodies used for aquaculture was very rare, being reported for only 1% of homestead ponds. The use of dikes surrounding waterbodies for the production of vegetables, timber trees and fruits was very widespread, and can be considered the second most important overall function of these waterbodies after fish production. Dikes were used mainly for growing timber trees, followed by vegetables and short-growing fruits (e.g. papaya and banana).

Management practices: Fertilization is used to stimulate production of natural feed in the pond. The vast majority of farmers followed this practice, except those practicing intensive technologies (e.g. koi and pangas culture in ponds) in which the majority of fish nutrition was derived from pelleted feeds. Supplementary feeding was common across all technologies. Most farmers used raw ingredients (e.g. rice bran, wheat bran, mustard oil cake, etc.) rather than pelleted feeds. The main exceptions were intensive commercial pangas and koi culture in ponds (reliant mainly on pelleted feeds) and extensive shrimp culture in *ghers* (for which few, if any, supplementary feed inputs were used).

Investment and operating costs: Investment costs for aquaculture can be substantial. The highest level of investment per unit area was found in commercial koi culture in ponds at BDT 2,900,000/ha per year (yr), or approximately USD 37,000/ha/yr at current exchange rates (USD 1 = BDT 78), followed by pangas in ponds (BDT 1,840,000/ha/yr). Investment in other commercial technologies in ponds (carp, tilapia, and carp and prawn) varied from BDT 178,286/ha/yr to 517,899/ha/yr. The investment for commercial fish and for shrimp and prawn-based *gher* systems ranged from BDT 179,850/ha/yr to 214,636/ha/yr. Per unit area investment costs for shrimp-based *ghers* and rice-fish systems were lower, at around BDT 100,000/ha/yr. Investment in homestead ponds was lower than any other system at BDT 76,610/ha/yr. The share of operating costs in total costs varied from 76% to 98% among technologies. Fish seed, feed and labor were identified as the three major operating costs for fish production. Fish seed was the major expense in homestead pond technologies, contributing 46% of total costs. Feed was the major cost item in commercial technologies in ponds. In terms of contribution to overall costs, koi culture in ponds was the most feed-intensive commercial pond-based technology (feed: 80%; seed: 12%; labor: 3%), followed by pangas (feed: 75%; seed: 14%; labor: 4%), tilapia (feed: 52%; seed: 18%; labor: 12%) and carp (feed: 31%; seed: 25%; labor: 16%).

Fish seed: Almost 100% of homestead-based pond farmers stocked carp species. The main source of fingerlings for homestead pond farmers was mobile fish traders (87%), followed by nurseries (30%), hatcheries (28%) and neighboring farmers (10%). A small proportion of homestead-based pond farmers also stocked pangas (4%), koi (2%), shing (2%) and tilapia (41%). Small indigenous species were stocked by 5% of homestead pond farmers. Carp were commonly stocked in all commercial pond-based systems, with the exception of koi culture in ponds. The main source of fingerlings for commercial pond farmers was hatcheries (55%–65%), followed by nurseries (36%–87%) and mobile fish traders (8%–75%).

Feed use: The most commonly used feed items in homestead fish ponds were rice bran (62%–91%), mustard oil cake (27%–46%) and rice products, including boiled rice (36%–40%). The use of commercial pelleted and farm-made feeds was common among farmers practicing intensive pond-based technologies (pangas, koi and tilapia). The contributions of commercial pelleted (sinking), commercial pelleted (floating), homemade pelleted and homemade (mash) feeds to total feed costs in commercial pangas culture in ponds were 46%, 12%, 26% and 15% respectively. Farmers of koi and tilapia were somewhat more dependent on commercially manufactured pelleted feed, which comprised about 99% and 85% of total feed costs respectively. Results show that 57% and 22% of pangas, 80% and 31% of koi, and 26% and 43% of tilapia farmers used the commercial sinking and commercial floating feeds, respectively.

Labor and gender: Labor was the third most important cost item in the aquaculture systems studied. Total annual labor use in noncommercial homestead ponds stood at 208 person-days/ha. As the average size of these resources was very small, this amounted to just 13 person-days of labor per household. Feeding, followed by harvesting and marketing, collection of inputs, pond preparation, and application of nonfeed inputs were the major work activities for homestead ponds. Together these accounted for 95% of total labor use in fish production. Among commercial aquaculture technologies, the highest annual labor requirement was for commercial koi farming (643 person-days/ha), followed by pangas in ponds (514 person-days/ha). All other commercial technologies used approximately 220 to 300 person-days/ha. Feeding, guarding, harvesting and marketing, and pond or plot preparation were the four activities with the highest labor requirements among all commercial technologies, except in the case of shrimp production in *ghers*, for which there were minimal labor requirements for feeding. The family was the main source of labor across all technologies, with the exception of pangas culture in *beels*. The share of family labor ranged from 89% in homestead ponds to 68%–87% in commercial ponds and 51%–72% in commercial *gher* technologies. Participation of women in aquaculture was lower than men. Women household members provided 22% of total labor for homestead ponds and 5%–24% in several semi-intensive pond-based technologies. However, the contribution of female family labor was very small in intensive pangas and koi culture (2%). Use of female hired labor in pond-based aquaculture technologies was virtually nonexistent. Among *gher*-based technologies, the contribution of women's work to total labor was similar to pond-based technologies, but hired female labor accounted for a greater share of women's labor than female family labor. The total contribution of female labor in *gher*-based technologies ranged from 6% to 17%.

Yields: Homestead ponds generated yields and gross returns of 1759 kilograms (kg) and BDT 150,841 per hectare, and 95 kg and BDT 8114 per household, with carp contributing 87% and 86% of fish biomass and returns, respectively. Among pond-based commercial aquaculture technologies, koi farming was the most productive and generated the highest returns (33,036 kg/ha and BDT 3,504,941/ha), followed by pangas (32,688 kg/ha and BDT 2,421,458/ha), tilapia (8856 kg/ha and BDT 783,843/ha) and carp (4754 kg/ha and BDT 567,282/ha). Among *gher*-based technologies, fish was the most productive in terms of volume (3275 kg/ha), followed by prawn-based systems (1600–1700 kg/ha) and shrimp (approximately 860 kg/ha). However, in terms of value, prawn-based *gher* systems generated the highest gross returns (BDT 465,000/ha–510,000/ha), with shrimp technologies generating approximately BDT 200,000/ha. Regardless of the technology deployed, on average all types of farm were able to generate profits. The highest gross margin came from koi culture in ponds (BDT 678,357/ha), and the lowest from homestead ponds (BDT 74,000/ha).

Marketed surplus: The share of fish sold was more than 75% of the total harvest across all commercial technologies. The opposite scenario was observed for homestead ponds, for which 55% of total production was consumed by the household, 41% was sold and 4% was given away.

Farmer attitudes and access to information

Motivation: Eighty percent of homestead pond farmers reported that their primary objective was to help meet household subsistence needs through producing fish for home consumption. For farmers practicing commercial technologies, the status of fish farming as a profitable business was by far the most important reason for practicing fish culture, and was cited by almost all farmers.

Access to information: Friends and neighbors practicing fish farming were the main source of knowledge and information about aquaculture technologies, identified as such by 68%–88% of farmers across all but one technology (production of small indigenous species in homestead ponds, which had been introduced through a WorldFish-supported project). Most farmers reported that they shared their experiences with fellow farmers, and identified social gatherings and face-to-face interactions as the most common means of technology dissemination.

Extension: Commercial farmers had better access to government extension agencies than homestead pond farmers did. Between 11% and 39% of farmers had received formal extension support from a Department of Fisheries *upazila* fisheries officer. Access to *upazila* fisheries officers by noncommercial farmers was lower, at 8%. The level of contact between nongovernmental organization (NGO) staff and aquaculture producers was greater than with the Department of Fisheries, ranging from 24% for homestead pond farmers to 7%–58% for commercial pond farmers and 26%–44% for *gher* farmers. However, the NGO staff with whom farmers interacted were mainly involved in providing microcredit, with very little provision of training. As a result, among the general population of farmers, the proportion who had ever received training organized by a project was reported to be very low, at less than 4% for all technologies.

Perceptions of aquaculture: Farmers were asked about their reasons for adopting fish culture, as well as the extent of their agreement or disagreement with a variety of statements regarding aquaculture, evaluated using a five-point Likert scale. A high level of agreement and consensus was observed across all technologies with the statement "fish culture is enjoyable." Most farmers, except those practicing intensive pangas and koi culture in ponds, also agreed that fish culture techniques were easy to learn. A divergent pattern was noted in responses to the statements "fish culture doesn't interfere with my leisure time" and "fish culture is time consuming." A higher level of agreement with the former and higher level of disagreement with the latter statement was provided by noncommercial homestead-based pond farmers as compared to those practicing commercial technologies. This tendency was especially strong among commercial pangas, koi and tilapia farmers. These results demonstrate clearly that noncommercial aquaculture is motivated by a different set of incentives and involves a different set of behaviors and risks than entrepreneurial forms of commercial farming. There was a high level of agreement among commercial farmers that fish culture is capital intensive and risky. Noncommercial farmers tended to take the opposite view. However, most respondents across all technologies felt that fish farming provided greater economic returns and other benefits than other agricultural activities. The balance of perceived tradeoffs between potential risks and benefits was reflected in scores just under 3.0 in response to the statement "fish culture has made me more vulnerable to shocks," indicating farmers' ambiguity about the statement or slight disagreement. There was strong agreement about the complementarity of fish culture with other agriculture practices across the technologies. Most farmers also felt that practices such as dike cropping and rice-fish integration minimized risk.

Credit and marketing

Access to credit: Among commercial fish farmers, 92% of pangas farmers operating in *beels* and 80% of koi farmers reported accessing credit in order to fund their operations, as compared to 21% of tilapia (pond) and 16% of carp (pond) farmers. Only 1% of homestead pond farming households did so. Commercial pond farmers accessed cash loans primarily from banks, NGOs, and relatives or neighbors. Among commercial pond farmers who took loans, the majority accessed them from banks (33%–64%), followed by NGOs (23%–33%) and relatives or neighbors (18%–33%). Less than 10% took loans from informal moneylenders. Among *gher* farmers who accessed credit, the majority took loans from NGOs (56%–68%), followed by banks (26%–40%), relatives or neighbors (5%–15%), and moneylenders (3%–15%). Loans from wholesalers accounted for less than 5% of the total. The usual mode of repayment was in cash, although a few farmers practicing *gher*-based technologies repaid both in cash and in kind (harvested shrimp or prawn). Thus, the vast majority of informal credit supplied for aquaculture was not output-tied. Rates charged on loans varied widely among sources. Rates of interest on loans from formal financial institutions ranged from 10% to 14% per year. The interest rates paid to moneylenders, wholesalers, relatives or neighbors, and NGOs were higher and more variable, ranging from 12% to 48%, 21% to 29%, 4% to 27% and 15% to 21% per annum, respectively. Input suppliers were often willing to supply the inputs in kind as a form of credit during the production cycle if farmers did not have cash available. About 16% of farmers had taken an in-kind loan during the survey year. Loans in kind were taken most frequently by commercial farmers. No noncommercial farmers were found to obtain in-kind loans. The highest percentage of farmers taking loans in kind was found in technologies utilizing large quantities of commercial pelleted feeds. Pelleted feed was the most widely loaned input, followed by seed. Farmers usually repaid these loans in cash at 2.5%–5% above the market value. These findings indicate that access to credit has improved considerably in recent years and that agricultural credit and output markets in rural Bangladesh have become highly competitive and are no longer interlocked to any significant degree.

Harvesting and marketing: Decisions concerning the quantity of fish to be harvested for sale were usually made by the male household head (72%–95% across all technologies). Joint decision making regarding the harvest of fish for home consumption was somewhat more common, ranging from 2% to 40% across technologies. Decisions regarding choice of marketing channel depended mainly on distance to market and quantity of fish harvested. The majority of farmers across all technologies sold fish directly to a wholesaler in a market (58%–99% of sales for commercial technologies). *Faria*, who collect fish from producers in small quantities and sell to wholesalers or retailers, also played a significant role in marketing products across all technologies (2%–39% of sales). The role of *faria* was most important when the amount of fish harvested was not sufficiently large to justify the time and cost to the farmer of delivering to a wholesale market. Depot owners acted as important intermediaries in the case of shrimp and prawn marketing, buying these products from producers in order to supply them to processing factories (8%–37% of sales). The main role of fish-harvesting teams was to harvest fish for farmers, but they often also acted as traders, buying harvested fish from farmers. The role of harvesting teams in trading fish was particularly important for homestead ponds, for which they accounted for 29% of sales, but was relatively minor among commercial technologies.

Shocks, environmental impacts, conflicts and constraints

Climate shocks: Aquaculture producers confront a variety of risks and shocks similar to those affecting agriculture. The most important of these was flooding, which affected 1%–8% of farmers across technologies within the last 12 months, and 1%–43% during the last 5 years, with tilapia production in ponds and *gher*-based farming systems most heavily affected. Cyclones were the next most important climate shock, again having the greatest impacts on *gher*-based farming systems and tilapia production in ponds, likely corresponding to the prevalence of these systems in southern Bangladesh. The impacts of drought were minor, affecting fewer than 4% of farms across all technologies within the last 5 years.

Disease: Surveyed farmers reported being vulnerable to high levels of stock mortality as a result of disease, constituting an important shock. Between 38% and 29% of farms producing shrimp or prawn, respectively, experienced disease problems in the year preceding the study, as did 11% of pangas and 21% of koi farmers. This reflects the high susceptibility of crustaceans (particularly shrimp) to disease, as well as the increasing likelihood of disease outbreaks at high production intensities, as in the case of koi and pangas. The share of shrimp and prawn farms affected by disease stood at between 50% and 64% over the 5 years preceding the survey. During this period, about 35% of pangas farmers and 45% of koi farmers were impacted by disease outbreaks. The share of affected farms varied from 16% to 22% across all other technologies.

Farmer perceptions of environmental impact: Farmers were asked about their perceptions of the environmental impacts of their activity. They identified a range of positive and negative effects. A widely reported positive impact across technologies was the increased availability of indigenous fish species from pond and *gher* farming systems. Increased rice productivity and reduced use of fertilizer and pesticides were identified by farmers integrating fish with rice cultivation. The ability to produce vegetables and short-growing fruits on pond or *gher* dikes with minimal use of fertilizers was another positive aspect reported by 10%–28% of farmers across technologies. With regard to perceptions of negative impacts, intensive koi (10%), pangas (8%) and tilapia (5%) farmers raised concerns over the impacts of waste discharges on crop production and nearby waterbodies. A significant share of shrimp farmers (26%–38%) also reported concerns about the negative impacts of their activity, based on their observation of the environment surrounding their farms. The major area of concern was increasing salinity levels, which they reported resulted in reduced rice yields, a decline in trees and vegetation, and reduced numbers of poultry and livestock due to reductions in the area of grazing land in shrimp-producing localities. These observations are supported by numerous other studies. Waterlogging in the areas surrounding ponds as a result of seepage or obstruction of drainage due to poorly planned pond or *gher* construction was also identified as a negative environmental impact by shrimp, pangas and koi farmers.

Conflicts: The majority of farmers did not report experiencing conflicts related to aquaculture. Conflicts that did occur were mainly reported in intensive pond-based technologies such as koi (11%), pangas (12%) and commercial carp farming (5%), as well as in shrimp farming areas (9%–18%). Many of the conflicts identified were associated with the types of negative environmental impacts discussed above.

Constraints: High capital requirements were emphasized by both homestead and commercial farmers as the most important constraint to achieving higher levels of fish production. Good production requires regular use of feed, fertilizer and other inputs, which can mean that farmers require better access to finance than is presently available to them. Half of shrimp farmers, 31% of koi farmers, 22% of pangas farmers and 8%–17% of all other farmers reported disease to be the main obstacle to good levels of production. For shrimp farmers, diseases such as white spot disease were serious, as they usually caused large mortalities. However, for finfish, the main effect of disease was usually reduced fish growth. Lack of access to good-quality seed was reported by 9% of homestead pond farmers, 14%–25% of commercial pond farmers and 13%–29% of *gher* farmers as a constraint that resulted in suboptimal levels of production. The limited availability and high price of good-quality feed was also recognized as a constraint by some producers. Continuous increases in the price of feed ingredients and formulated feeds as compared to fish prices, which were often static or declining in real terms, also represented a problem for commercial farmers.

Policy implications: Aquaculture is the fastest-growing food-producing sector in Bangladesh and has demonstrated continuous increases in production over recent decades. Evidence presented in this study shows clearly that aquaculture, in particular in its commercial forms, has great potential to create income and employment opportunities and contribute to food security. However, much of aquaculture's potential to contribute to improving food security and rural livelihoods remains to be harnessed. Addressing a number of critical social, economic and policy constraints could contribute a great deal to achieving these goals.

This study demonstrates that, with the partial exception of homestead pond-based production systems, direct participation in aquaculture by resource-poor households was limited. Further institutional innovations are required to make small ponds and other waterbodies located close to homesteads (to which the resource-poor have some access) more productive and profitable. Public services should be more effectively targeted to ensure that poorer households gain better access to extension services.

The study also shows that small indigenous fish species rich in Vitamin A, calcium, iron and zinc, and other micronutrients can be successfully introduced to traditional polyculture systems without hampering the production of other fish species. However, at present technologies for small indigenous species production remain concentrated in a limited geographical area, and their adoption is linked mainly to project-based facilitation efforts. Furthermore, the reproductive biology of small indigenous species and hatchery techniques for seed production of many small indigenous species are still poorly understood, meaning that production of these species is reliant mainly on the collection of wild seed, representing a critical bottleneck that presently inhibits further commercial expansion of the technology. Future research should therefore prioritize the development of hatchery production technologies of small indigenous species. Mass awareness-raising activities are also needed to educate potential producers and consumers of the nutritional value of small indigenous species.

Although many of the inputs required for aquaculture production (feed, seed, fertilizer and labor) are widely available, participants identified the timely availability of good-quality inputs, most importantly seed and feed, as constraints. The government should continue its efforts to improve input quality (e.g. through support for genetic improvements in seed quality and stricter regulation of feed production and marketing), but also pay attention to developing the efficiency of distribution channels (e.g. through further investments in transport infrastructure) so that seed and feed are available when farmers need them.

Capacity development for market intermediaries and the development of links between resource-poor rural producers and input suppliers will also be important for ensuring that producers are able to access quality inputs in time and sell their produce at higher prices. The study shows that most homestead pond producers and many commercial farmers are unaware of the importance of ensuring adequate postharvest handling of fish. Concerted efforts are needed to upgrade producer capacity in postharvest methods and raise awareness of their importance.

The study points to limited participation by women in most aquaculture technologies, as both family and hired labor, with a small number of partial exceptions. Gender disparities in wage rates of 10%–20% were also observed. Women in rural Bangladesh are, to a great extent, subjected to a restrictive gender-based division of labor and social taboos, which limit mobility and reduce their participation in income-generating activities beyond the homestead. To overcome these obstacles, development projects and government agencies should work together with social development and gender experts to develop gender-sensitive approaches in consultation with communities, while creating greater space for women's agency through skills development to support participation in income-generating activities.

Lack of financial capital was identified by producers as a major constraint to commercialization of aquaculture. Measures that result in improved access to rural credit are necessary for facilitating technology adoption, stimulating productivity increases, generating employment and increasing producer incomes. Considering both formal and informal sources, only 30% of farmers obtained credit for aquaculture. Farmers reported that the collateral requirements of public and commercial banks, and the high interest rates and inflexible repayment schedules of microfinance providers, were major obstacles to utilizing formal credit. Special attention to farmers' practical needs and a supportive policy framework are required to develop appropriate financial instruments that increase the volume of affordable credit flows to fish producers.

Finally, aquaculture development must be compatible with the environment and surrounding communities if it is to be sustainable over the long term. Proper planning in consultation with community members and other relevant stakeholders is urgently needed to avert or resolve current and potential environmental problems and associated conflicts. These are related mainly to intensive pond-based commercial aquaculture systems and saline *gher*-based shrimp farming technologies, which are shown to result in problems related to effluent discharge, saline intrusion and waterlogging.

Currently, the impacts of climate change on aquatic ecosystems and aquaculture are not well understood. The study indicates that climate shocks such as more frequent and severe floods and cyclones can have serious negative impacts on aquaculture. The overarching need in these instances is to develop adaptation and mitigation measures that will improve the ability of producers to quickly respond to the threats to livelihoods and food security posed by climate change, as well as to the opportunities it may provide. Disease was also shown to be a critical risk, most importantly for producers of shrimp and prawn, but also for carp, tilapia, pangas and koi producers. Greater investment in targeted research and effective veterinary services is needed to develop effective preventative and mitigation strategies against fish disease.

INTRODUCTION

Bangladesh is the fifth largest aquaculture producer in the world (FAO 2014). The fisheries sector makes an important contribution to the economy of Bangladesh, generating 4.4% of national gross domestic product (GDP), 22.2% of agricultural GDP and 2.7% of foreign exchange earnings in 2010–11 (DOF 2014). Historically, Bengali people have had a strong preference for fish, which forms an important part of their customs and culture. Per capita fish consumption in Bangladesh is now close to the global average, at 49.5 grams (g) per day, or 18.1 kg per year. However, there is a significant difference in fish consumption between rural and urban households. In rural areas, average daily consumption of fish per capita is 45.8 g, while in urban areas it is higher, at 59.9 g (Apu 2014). As the main animal-source food consumed in Bangladesh, accounting for 60% of animal protein intake (DOF 2014) and being by far the most frequently consumed nutrient-rich food (Toufique and Belton 2014), fish has an extremely important role to play in ensuring national food and nutrition security.

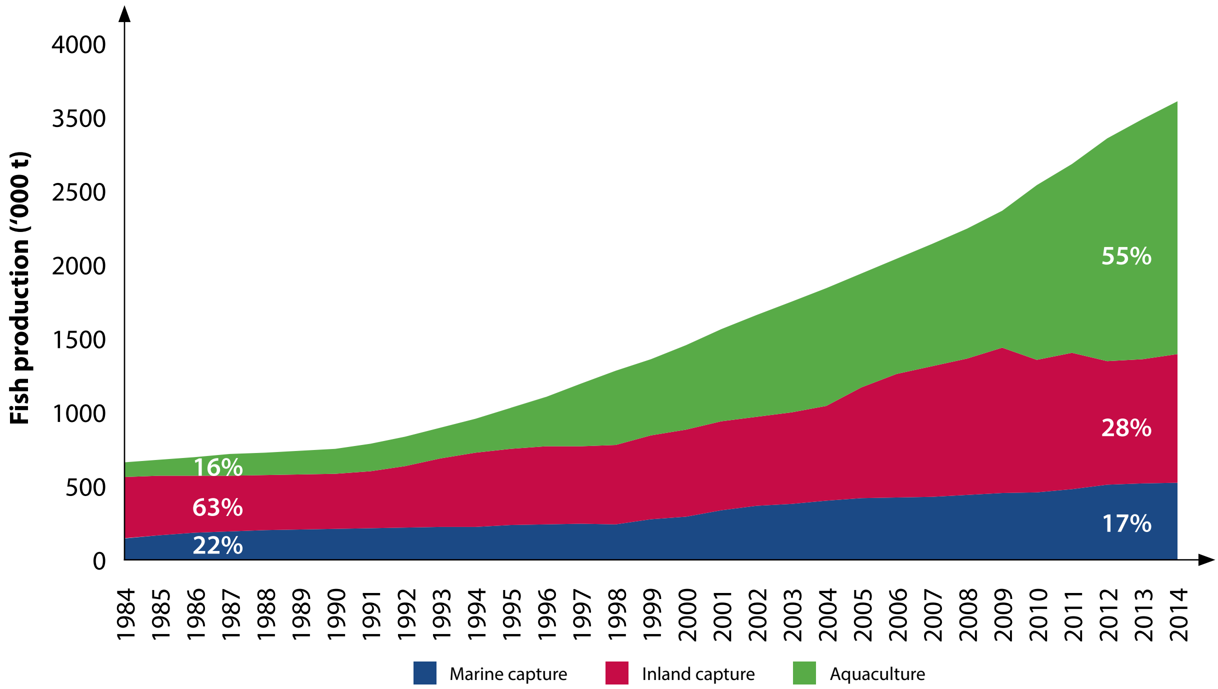
Fish in Bangladesh originates from three sources: marine capture fisheries, inland capture fisheries and aquaculture. Aquaculture plays an increasingly significant role, contributing 55% of the country's 3.55 million metric tons (t) of total fish production in 2014, up from 0.12 million metric tons (16%) in 1985. Production from aquaculture has surpassed the growth of inland and marine capture fisheries (Figure 1). Widespread development of hatchery production of new fish species, both exotic and indigenous; increasing use of a range of feeds and fertilizers; and improvements to and modifications of farming systems to meet evolving market demand and local environmental conditions have resulted in an extremely diverse sector in terms of the production technologies deployed, and have helped aquaculture to maintain its high growth rate (Belton et al. 2011). The slower growth of capture fisheries is mainly due to progressive physical degradation of the environment, shrinkage and pollution of natural water bodies, and overexploitation of fisheries resources. Therefore, aquaculture will have to play a major role in meeting growing demand for fish in the country in coming years.

Despite, or perhaps because of, the pace and diversity of this growth, there has never been any systematic attempt to document the range of production systems in operation and study their characteristics in terms of the socioeconomic profile of farmers, yields and profitability; access to information; and farmer rationales for engaging in production. In fact, studies documenting the characteristics of aquaculture technologies in Bangladesh are limited to a handful of systems and species. Accurate knowledge of these factors is particularly important for the design of more responsive and effective interventions to improve the performance of the sector, particularly in terms of addressing poverty and nutrition outcomes.

To these ends, this study presents data collected by WorldFish on the performance of 14 distinct aquaculture systems, practiced in 16 districts, belonging to 6 geographical hubs (groups of districts with similar agroecology). The specific objectives of the study are as follows:

- to identify socioeconomic characteristics of fish farmers practicing a variety of technologies
- to delineate differences in production practices and productivity across technologies
- to estimate production costs, revenues and profits generated from fish culture
- to identify rationales and incentives in farmer decision making about aquaculture
- to identify risk factors, environmental impacts, conflicts and constraints related to aquaculture development.

This report is comprised of nine chapters, including this introduction. The second chapter outlines the analytical framework for the study and provides a brief description of the different aquaculture systems surveyed and their locations. Chapter three presents findings by production technology on the characteristics of farm households (demography, livelihoods, incomes and landholdings). Characteristics of aquaculture holdings (farm size, plot characteristics, tenure and integration) and farmers' access to knowledge and extension services and fish management practices are discussed in chapter four. Chapter five evaluates farmers' perceptions about aquaculture technologies. Chapter six presents production performance, by technology. This includes costs and returns, with special attention to the costs of feed, stocking and labor, which are identified as the major costs for aquaculture production. Chapter seven explores credit and marketing arrangements. Chapter eight discusses social and environmental conflicts, positive and negative environmental aspects, and farmer perceptions of welfare impacts and constraints to adoption. Chapter nine elaborates on the broader findings of the research on aquaculture systems and offers concluding remarks.



Source: DOF (1994; 1997; 2006; 2015).

Figure 1. Changes in the composition of fisheries production in Bangladesh, 1984 to 2014.

METHODOLOGY

All data used in the study is from a field survey of fish producers. This chapter describes the research process used to assess the performance of the aquaculture technologies practiced in different geographical locations around Bangladesh. This description includes the design of the research framework, the identification of aquaculture technologies and locations to be surveyed, and the development of survey tools. The survey design and implementation process is outlined in greater detail below.

Study area

The research was initiated under the USAID-funded CSISA-BD project, in which WorldFish was an implementing partner. CSISA-BD worked in six geographical "hubs" covering most of the major aquaculture-producing areas in the country. A rapid appraisal based on interviews with key informants was conducted in each hub in order to identify the main aquaculture technologies practiced and where the highest concentrations of each type of technology were. Four additional districts located outside the CSISA-BD hubs, where informants reported there to be large clusters of aquaculture operations, were also visited. A brief description of the hubs is given below (see also Figure 2).

Barisal hub covers Barisal Division in southern central Bangladesh. The hub is comprised of Barisal, Patuakhali, Barguna, Pirojpur, Jalokhati and Bhola districts. The districts of this hub lie within the coastal belt, and the entire hub is crisscrossed with thousands of rivers and canals. Large numbers of rural people from these districts have migrated to cities after becoming homeless due to river erosion and other natural disasters. According to the poverty map of Bangladesh, Barisal hub has higher poverty rates than any hub other than Rangpur (World Bank et al. 2010). There are huge numbers of small ponds in these districts, covering a reported area of 31,664 ha, and large numbers of semiclosed waterbodies, which offer good potential for aquaculture production (DOF 2015). However, fish yields from aquaculture in Barisal are below the national average. Inadequate technical skills and knowledge among fish farmers, as well as poor access to input and output markets, were identified as major causes of low productivity in the hub.

Faridpur hub is located in central Bangladesh in Dhaka Division, to the south of the capital city, Dhaka. The hub consists of the districts Faridpur, Gopalganj, Madaripur and Shariatpur. Districts in this hub lie on the floodplain of the Padma River, also called the lower Ganges, providing the region with good opportunities for agriculture due to high soil fertility. However, seasonal migration away from the area is also very high due to its flood-prone nature and exposure to river erosion. There are reported to be 12,333 ha of ponds and *ghers* in the hub (DOF 2015), but fish yields are below the national average. Limited supporting infrastructure (e.g. hatcheries and nurseries) limits access to quality inputs, and poor communication networks hinder the development of aquaculture. Homestead-based pond aquaculture (carp polyculture) is the main aquaculture technology practiced in the hub, but a variety of fish species are also cultured in ponds on a commercial basis.

Jessore hub is located in Khulna Division in southwest Bangladesh, and encompasses Jessore, Jhenaidah, Narail, Magura, Chuadanga and Meherpur districts. Jessore hub is an important area for freshwater aquaculture because of its favorable conditions, including a high concentration of hatcheries, low-lying agricultural lands, a warm climate, fertile soil, and cheap and abundant labor. Jessore is one of the most diverse and dynamic areas for aquaculture in the country, and was one of the first fish seed production hubs in the country. Rural communication and infrastructure is better developed than in many other parts of Bangladesh. Homestead ponds and commercial polyculture of carp, tilapia and freshwater prawn in ponds and *ghers* make Jessore a prominent area for fish production.

Khulna hub is located in southwest Bangladesh, and is the most important area of the country for giant freshwater prawn (*Macrobrachium rosenbergii*) culture and brackish-water tiger shrimp (*Penaeus monodon*) production. The hub is comprised of the coastal districts of Khulna, Bagerhat and Satkhira, and is prone to natural disasters and vulnerable to the effects of climate change. Cyclones, salinity, tidal surges, flash floods, arsenic-contaminated groundwater and repeated waterlogging are common in this part of Bangladesh, shaping the lives and livelihood patterns of the people living there. Agriculture and shrimp and prawn farming are major providers of employment and livelihoods in the southwest coastal districts. The hub has approximately 204,052 ha of *ghers* used for shrimp and prawn production (DOF 2015).

Mymensingh hub is located in Dhaka Division and includes the districts of Mymensingh, Jamalpur and Tangail. Mymensingh is the most important district in Bangladesh for commercial freshwater aquaculture. Mymensingh District is ranked first among the districts for pond fish production in Bangladesh, producing 301,425 t/yr, which is 20% of Bangladesh's total pond production (DOF 2015). Aquaculture is commonly regarded as part of the area's cultural heritage by the people of the Mymensingh hub. Mymensingh is an important area for freshwater aquaculture because of the availability of hatchery-produced fry, favorable climatic conditions, low-lying agricultural land, a warm climate, fertile soil and abundant labor (Ahmed and Toufique 2015).

Rangpur hub in the northwest consists of districts ranging from drought-prone areas in the old Himalayan piedmont plain to flash-flood-prone areas east and northeast of Dinajpur. The greater Rangpur hub has historically been one of the poorest areas in Bangladesh, and the incidence of extreme poverty remains proportionally higher than the rest of the country. In 2010, 42.3% of Rangpur's population fell below the upper poverty line and 27.7% below the lower poverty line (World Bank et al. 2010). The hub has approximately

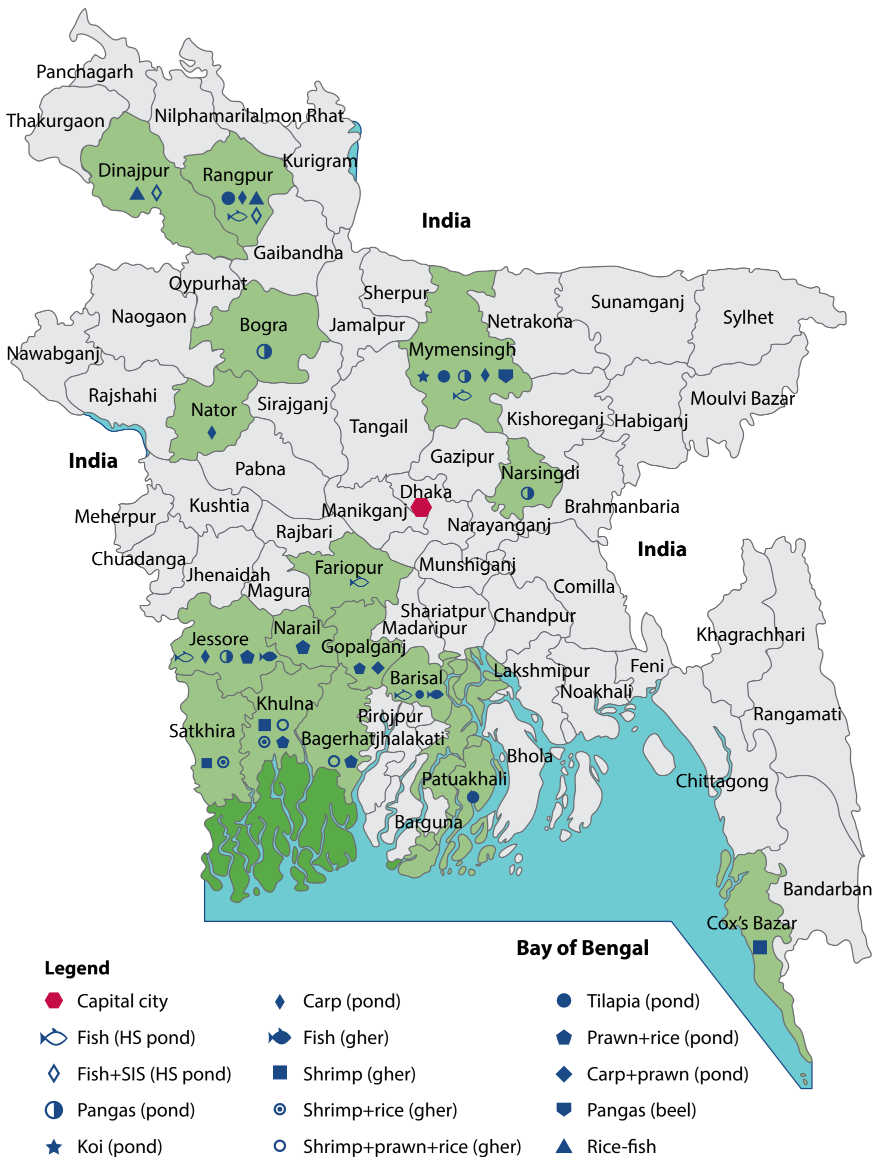


Figure 2. Aquaculture technologies by district.

24,416 ha of ponds used for fish production (DOF 2015) and is the most important area of the country for integrated rice-fish production. Carp-based aquaculture technologies are commonly practiced throughout the hub.

Areas surveyed outside the CSISA hubs consisted of the districts of Bogra, Natore, Cox's Bazar and Narsingdi. These districts were selected on the basis of their importance for aquaculture, as identified by key informants during the exploratory stage of the research. All of these districts are categorized in the study as outside hubs.

Bogra is a northern district of Bangladesh located in Rajshahi Division, referred to as the gateway to North Bengal. Bogra is an industrial city housing many small and midsized industries. A large number of private fish seed hatcheries and aquafeed industries have developed in Bogra, making it a suitable location for fish farming. Commercial pangas farming is the most important type of aquaculture practiced there.

Natore is also located in northern Bangladesh in Rajshahi Division. The district is famous for commercial carp polyculture, especially for production of large rohu and catla. Ponds in Natore are mostly perennial. A large number of nurseries have been established in this district to supply large fingerlings to commercial carp farmers. Natore is also an important area for commercial agriculture.

Cox's Bazar is located in Chittagong Division and is a popular tourist destination due to its wide, sandy beaches. In addition to tourism, marine fishing and collecting seafood and marine products are activities that employ many people. Cox's Bazar is also famous for brackish-water shrimp farming. The first shrimp hatchery in Bangladesh was established by the Department of Fisheries at Cox's Bazar in 1987. At present, 57 shrimp hatcheries supply shrimp seed to all other shrimp-growing areas in Bangladesh (Debnath et al. 2015).

Narsingdi is a district in central Bangladesh, in Dhaka Division. A favorable climate, numerous waterbodies, and good road communications with Dhaka city and the urban centers in the east of the country make Narsingdi a good location for fish farming. Farmers in the district produce pangas, tilapia and carp on a commercial basis.

Sample design

The purpose of the study was not to provide a nationally representative overview of the entire aquaculture sector of Bangladesh, but rather to identify and analyze the most important production systems. A purposive sampling strategy was thus adopted, as aquaculture development in Bangladesh occurs in a highly geographically clustered manner, which makes it very difficult to sample representatively over a broad area.

Sampling followed a multistage process. The first step was to identify the most important aquaculture systems present in each hub. WorldFish recruited and trained research staff to organize informal discussions with key informants in each hub (e.g. government officers, hatchery owners, seed sellers, feed dealers and development project officials) to identify the main aquaculture production technologies present. Districts with high concentrations of aquaculture, as well as the major technologies practiced in each, were identified at this stage.

In the second phase, a further round of informal discussions was organized with key informants at district level. The objective of these discussions was to crosscheck findings and identify the locations with the highest concentrations of farmers practicing each of the aquaculture technologies identified. *Upazilas* (third-level administrative units), unions (lowest-level administrative units, comprised of 10–25 villages on average) and, in some cases, villages, with the highest concentrations of each major technology were identified at this stage. This was followed by field visits and village-level focus group discussions for further validation. Once the farming systems and areas were identified, study villages were selected at random from a list of potential villages. For villages that were very small, two or three nearby villages were selected to form a cluster.

During the third phase, research staff conducted reconnaissance visits to all the villages selected. Group discussions were organized in each to develop village profiles, and a census was conducted to identify the location of each individual aquaculture producer and provide a sample frame for the structured household survey that followed. As the initial stages of the sampling procedure were selective, the number of households sampled per technology was not representative of the total population of households practicing that type of aquaculture, but we consider this approach adequate for providing data on the characteristics of each technology.

A total of 14 production systems were identified during the survey. These systems and the locations where they were surveyed are shown in Table 1 and Figure 2. Data was collected from 12 districts in these hubs: Jessore and Narail districts in Jessore hub; Khulna, Bagerhat and Satkhira districts in Khulna hub; Faridpur and Gopalganj districts in Faridpur hub; Barisal and Patuakhali districts in Barisal hub; Mymensingh District in Mymensingh hub, Dinajpur and Rangpur districts in Dinajpur hub; and the four additional districts Natore, Bogra, Narsingdi and Cox's Bazar from outside the hubs. Aquaculture systems were defined as being based on a distinct production technology (Table 4) based on a combination of characteristics, including the intensity of production, the type of waterbody in which production took place, the combination of species stocked, the management practices, the market orientation of production, and whether or not production was integrated with agriculture (see Tables 1, 2 and 3 for a complete elaboration of these points). For the purposes of brevity, in the analysis that follows, the 14 production systems are grouped in 6 categories based on their similarities.

Study period and analytical methods

This survey was done from November 2011 to June 2012. Twenty-four enumerators were hired for the survey. The team was divided into six groups and each group was posted to a hub. The research team stayed 8–10 days in each survey location (village). A total of 2678 farmers were selected at random from the farm census list compiled in each aquaculture cluster. Data collected from respondents was tabulated and analyzed in accordance with the objectives of the study.

Survey instrument

A set of preliminary questions was prepared for the questionnaire based on the objectives of the study. The first part of the questionnaire focused on fish farmers' socioeconomic characteristics and the characteristics of waterbodies utilized for aquaculture. The second part of the questionnaire focused on technical and economic performance by collecting detailed input and output data. The third part of the questionnaire addressed contextual issues, including the extent of and reasons for farmers' adoption of fish management practices; credit and marketing; social and environmental issues related to fish farming; and the identification of constraints and potentials. The questionnaire was comprised of a mix of closed and open questions. A 2-week training workshop was organized for enumerators and survey supervisors prior to the implementation of the survey. Questionnaires were pretested and revised on an iterative basis following repeated discussions of the data collection tools and their application. Open-ended questions were post-coded during the data cleaning process.

Summary

This study identified 14 distinct commercial and subsistence aquaculture systems located across a wide geographical area in Bangladesh. Some of the systems and cluster locations identified are not widely known about, even among aquaculture experts. This suggests that rapid and highly dynamic private-sector-led development of aquaculture systems has taken place. So far, very few of these systems have been the subject of detailed studies on their economic and technical characteristics, and only homestead pond and pangas aquaculture systems have received any significant degree of attention from researchers in this regard. This study therefore represents by far the most comprehensive attempt to date to explore these issues.

Serial no.	Technology	Abbreviated name	Barisal	Dinajpur	Faridpur	Jessore	Khulna	Mymen -singh	Outside hub	Total
Homestead aquaculture in pond										
1	Fish polyculture	Fish (HS pond)*	40	80	95	78	-	88	-	381
2	Fish polyculture with small indigenous species	Fish+SIS (HS pond)	-	137	-	-	-	-	-	137
Commercial aquaculture in pond										
3	Pangas culture	Pangas (pond)	-	-	-	78	-	130	75	283
4	Carp culture	Carp (pond)	-	80	88	10	-	71	99	348
5	Tilapia culture	Tilapia (pond)	51	13	53	-	-	31	-	148
6	Koi culture	Koi (pond)	-	-	-	-	-	97	-	97
7	Carp and prawn polyculture	Carp+prawn (pond)	96	-	60	-	-	-	-	156
Commercial aquaculture in *gher*										
8	Fish polyculture	Fish (*gher*)	86	-	-	135	-	-	-	221
9	Shrimp culture	Shrimp (*gher*)	86	-	-	-	138	-	44	268
10	Shrimp culture and rice farming	Shrimp+rice (*gher*)	-	-	-	-	128	-	-	128
11	Shrimp and prawn culture and rice farming	Shrimp+prawn+rice (*gher*)	-	-	-	-	134	-	-	134
12	Prawn culture and rice farming	Prawn+rice (*gher*)	-	-	10	109	93	-	-	212
Commercial aquaculture in *beel*										
13	Pangas culture	Pangas (*beel*)	-	-	-	-	-	37	-	37
Rice-fish culture										
14	Rice-fish culture	Rice-fish	-	128	-	-	-	-	-	128
Total			359	438	306	410	493	454	218	2,678

* HS stands for homestead. See Annex 1 for the common, Bengali and scientific names of all fish species.

Table 1. Distribution of sample households by technology and hub.

Waterbody type	Description
Homestead pond	A pond, usually small, constructed close to the homestead area and used for a range of domestic purposes such as drinking water, bathing, washing clothes, etc.
Gher	A rice field in southern Bangladesh modified by deepening it to provide sufficient water to hold fish and/or crustaceans and raising dikes to prevent their escape. Often, though not always, it is integrated with rice cultivation, either concurrently or in consecutive seasons.
Commercial pond	A pond excavated with the intention of year-round production of fish primarily destined for sale. It is usually, but not always, on land formerly used for rice cultivation.
Beel	A large, naturally occurring depression holding water for all or part of the year, made suitable for fish culture by enclosing it with high dikes to retain water and prevent flooding. Typically, *beels* are formed by inundation of low-lying lands during flooding, where some water gets trapped even after floodwaters recede from the floodplain. *Beels* may also be caused by filling up of low-lying areas during rains, especially during the monsoon season.
Rice-fish plot	A rice field in northern Bangladesh modified by deepening it to provide sufficient water to hold fish and raising dikes to prevent their escape. Rice cultivation is practiced concurrently with fish production or in consecutive seasons.

Table 2. Definitions of aquaculture waterbodies.

Farming system	Characteristics
Extensive	• depend mainly on the natural productivity of the waterbody for fish growth • minimal or occasional use of low-quality supplemental feeds such as farm byproducts, including rice bran, rice products and mustard oil cake • irregular use of fertilizer, particularly organic fertilizer (e.g. cow dung) • low level of control over stock management • low stocking density (below 15,000 fingerlings/ha) • low level of fish productivity (below 3 t/ha).
Semi-intensive	• fish nutrition derived from both natural feeds produced in the pond (phytoplankton and zooplankton) and external inputs of supplemental feed such as homemade feed and commercially produced pelleted feed • control of stock management • intermediate level of stocking density (15,000–35,000 fingerlings/ha) • regular use of fertilizers, particularly inorganic fertilizers (urea, triple superphosphate, diammonium phosphate) • occasional exchange of pond water • moderate to high level of productivity (4–20 t/ha).
Intensive	• all fish nutrition derived from external feed inputs, most commonly in the form of formulated pelleted diets • control of stock management • high stocking density (above 35,000 fingerlings/ha) • regular pond monitoring • frequent exchange of pond water • high level of productivity (above 20 t/ha).

Table 3. Definitions of aquaculture management practices.

Technology	Surveyed location (districts)	Market orientation (% fish sold to market)	Integration with agriculture	Type of waterbody	Culture techniques and management practices
Fish (HS pond)	Barisal, Faridpur, Jessore, Mymensingh and Rangpur	At least 25%–40% of total fish harvested sold to the market	Often integrated with pond dikes for dike cropping	Homestead pond	**Fish species cultured:** Carp polyculture with tilapia and local indigenous fish species (often self-recruited from open water). **Culture period:** Varies between locations. Generally, farmers stock in April–May and harvest in March–April. **Management practices:** Extensive.
Fish+SIS (HS pond)	Dinajpur and Rangpur	At least 25%–40% of total fish harvested sold to the market	Often integrated with pond dikes for dike cropping	Homestead pond	**Fish species cultured:** Carp and small indigenous species (*mola*, *dhela*, *darkina*, *puti*, prawn and *gura chingri*) polyculture with tilapia and other nonstocked indigenous fish species. **Culture period:** Varies between locations. Generally, farmers stock in April–May and harvest in March–April. **Management practices:** Extensive.
Pangas (pond)	Bogra, Jessore, Mymensingh and Narsingdi	At least 80%–90% of total harvested biomass sold to the market	Occasionally integrated with pond dikes for dike cropping	Commercial pond	**Fish species cultured:** Target species is pangas polyculture with carp and tilapia. **Culture period:** Varies between locations. Generally, farmers stock in March–April and harvest in November–December. **Management practices:** Intensive.
Koi (pond)	Mymensingh	At least 80%–90% of total harvested biomass sold to the market	Occasionally integrated with pond dikes for dike cropping	Commercial pond	**Fish species cultured:** Target species is koi (climbing perch) polyculture with shing, carp and tilapia. **Culture period:** Two consecutive cycles. Generally, farmers stock in March–April and harvest in June–July in the first cycle and again stock in July–August and harvest in September–October in the second cycle. **Management practices:** Intensive.
Tilapia (pond)	Barisal, Gopalganj, Mymensingh and Rangpur	At least 80%–90% of total harvested biomass sold to the market	Often integrated with pond dikes for dike cropping	Commercial pond	**Fish species cultured:** Main species is tilapia, stocked in polyculture with carp and shing. **Culture period:** Farmers stock in March–April and harvest in November–December. **Management practices:** Semi-intensive.
Carp (pond)	Dinajpur, Faridpur, Jessore, Mymensingh, Rangpur and Natore	At least 80%–90% of total harvested biomass sold to the market	Often integrated with pond dikes for dike cropping	Commercial pond	**Fish species cultured:** Main species is carp, stocked in polyculture with tilapia and local small fish species. **Culture period:** Generally, farmers stock in April–May and harvest in March–April. **Management practices:** Semi-intensive.
Carp+prawn (pond)	Gopalganj and Patuakhali	At least 80%–90% of total harvested biomass sold to the market	Integrated with pond dikes for dike cropping	Commercial pond	**Fish species cultured:** Target species are carp and prawn polyculture with tilapia and local small fish species. **Culture period:** Generally, farmers stock in April–May and harvest in March–April. **Management practices:** Extensive to semi-intensive.
Fish (*gher*)	Barisal and Jessore	At least 80%–90% of total harvested biomass sold to the market	Integrated with *gher* dikes for dike cropping and alternate rice production	*Gher*	**Fish species cultured:** Target species is carp polyculture with tilapia and prawn. **Culture period:** Generally, farmers stock in March–April and harvest in November–December. Fish is cultured concurrently with rice or after harvesting of rice (alternate system). **Management practices:** Extensive to semi-intensive.
Shrimp (*gher*)	High-saline areas of Khulna, Satkhira, Patuakhali and Cox's Bazar	At least 80%–90% of total harvested biomass sold to the market	No integration due to high salinity	*Gher*	**Fish species cultured:** Target species is shrimp polyculture with carp, tilapia and euryhaline brackish-water species. **Culture period:** Varies between locations. Generally, farmers stock in January–February and harvest in December–January. **Management practices:** Extensive.
Shrimp+rice (*gher*)	High-saline areas of Khulna and Satkhira	At least 80%–90% of total harvested biomass sold to the market	Alternate rice production when salinity becomes low; integrated with dikes for dike cropping	*Gher*	**Fish species cultured:** Target species is shrimp polyculture with carp, tilapia and euryhaline brackish-water species. Cultivation of a slightly salt-resistant transplanted Aman paddy in the elevated parts of the fields. **Culture period:** Generally, farmers stock in February–March and harvest in September–October. **Management practices:** Extensive.
Shrimp+prawn+rice (*gher*)	Medium-saline areas of Khulna and Bagerhat	At least 80%–90% of total harvested biomass sold to the market	Starts with shrimp and during rainy season integrates prawn and rice for concurrent practice; integrated also with dikes for dike cropping	*Gher*	**Fish species cultured:** Target species are shrimp and prawn polyculture with carp, tilapia and some nonstocked fish species. Cultivation of rice in the elevated parts of the fields. **Culture period:** Varies between locations. Generally, farmers stock in March–April and harvest in November–December. **Management practices:** Semi-intensive.
Prawn+rice (*gher*)	Khulna, Bagerhat, Jessore, Narail and Gopalganj	At least 80%–90% of total harvested biomass sold to the market	Integrated prawn and rice (both concurrent and alternate practice); integrated also with dikes for dike cropping	*Gher*	**Fish species cultured:** Target species is prawn polyculture with carp, tilapia and some nonstocked fish species. Small prawn is reared in the trench during rice farming. **Culture period:** Varies between locations. Generally, farmers stock in March–April and harvest in November–December. **Management practices:** Semi-intensive.
Pangas (*beel*)	Mymensingh	At least 80%–90% of total harvested biomass sold to the market	Sometimes integrated with horticulture on *beel* dikes	*Beel*	**Fish species cultured:** Target species is pangas polyculture with carp, tilapia and some nonstocked fish species. **Culture period:** Generally, farmers stock in April–May and harvest in March–April. **Management practices:** Semi-intensive to intensive.
Rice-fish	Dinajpur and Rangpur	At least 80%–90% of total harvested biomass sold to the market	Integrated fish and rice cultivation (concurrent or alternate); sometimes integrated with horticulture on rice plot dikes	Rice-fish plot	**Fish species cultured:** Target species is carp polyculture with tilapia and some nonstocked fish species. **Culture period:** Varies between locations. Generally, farmers stock in February–March and harvest in November–December. **Management practices:** Extensive.

Table 4. Defining characteristics of the aquaculture systems identified and surveyed.

METHODOLOGY

THE SOCIOECONOMIC CHARACTERISTICS OF AQUACULTURE PRODUCERS

This chapter summarizes the demographic and socioeconomic characteristics of households practicing aquaculture, including gender, landholdings and income. The first section deals with the demographic characteristics of producer households. The second section addresses the socioeconomic characteristics of the sampled aquaculture households. Farmers' perceptions about different aquaculture technologies, their knowledge and experience levels, and their perceptions of the benefits of fish farming are discussed in the third section.

Demographic characteristics of the sample households

Sample distribution by interviewee type and gender

Eighty-seven percent of respondents were the owners and/or operators of the aquaculture resource in question, 8% were farm managers, and the remainder were hired technicians. Farm managers and technicians were only asked questions relating to the fish farming operation. In these cases, contact was made with the absentee owner by mobile phone, and socioeconomic and other contextual information was collected from the pond owners, either by phone or following short meetings fixed with the owner for this purpose. In the vast majority of cases, interviewees reported that the individual with legal title to the aquaculture resource in question (i.e. pond, *gher*, etc.) was a man (98%–100%). (See Table 5.)

Demographic characteristics

Average farmer age varied from 35 to 46 years across technologies, with 95% falling within the productive age of 18–60 years, and 36% to 55% of farmers being within the ages of 31–45 (Table 5). This indicates that the average age of entrants into aquaculture is relatively young, suggesting it is an attractive livelihood option. Across technologies, the largest share of farmers was educated to secondary level, and the second largest share had received primary-level education. Commercial farmers were better educated on average than farmers with homestead ponds (Table 5). Between 10% and 14% of commercial farmers were illiterate. Among farmers practicing aquaculture technologies, the proportion of illiterate farmers was highest for the least commercial technologies, at 36%, 26% and 23% for the fish+SIS (HS pond), carp+prawn (pond) and fish (HS pond) technologies, respectively. There were no illiterate farmers practicing the commercial pangas (*beel*) technology. The illiteracy rate varied from 4% to 18% among the farmers of other commercial technologies. Among the rural population as a whole, only 29% of men aged over 25 have received primary education, and only 8% have received secondary education; the literacy rate is just 42% (Ahmed et al. 2013). This suggests that the socioeconomic status of households engaged in aquaculture is considerably higher than that of the general population.

The average household size of the fish+SIS (HS pond), rice-fish and prawn+rice (*gher*) technologies was 4.4, 4.4 and 4.7, respectively. The family size across all other technologies varied from 5.0 to 5.8. Among the rural population as a whole, average household size is 4.5 (BBS 2010). The average size of aquaculture households thus appeared to be slightly higher than the national average. Table 5 shows that the majority of household members engaged in aquaculture also engaged in agricultural activities such as crop farming and poultry and livestock rearing. On average, 43%–65% of the sampled aquaculture household members were also involved in agricultural activities. The share of household members engaged only in aquaculture varied from 25% to 57%.

Socioeconomic characteristics of households practicing aquaculture

Distribution of landholdings

The average size of operated landholdings (i.e. including all land owned, leased in, and shared in for agricultural and other uses) by households practicing fish farming averaged 0.65–0.71 ha, 1.30–1.67 ha, 1.25–4.09 ha, and 1.49 ha for homestead pond, commercial pond, commercial *gher* and rice-fish technologies, respectively (Table 6). Pangas (*beel*) farmers had the largest landholdings out of all technology groups, averaging 7.59 ha. The landholdings of homestead pond farmers were considerably smaller than those of farmers practicing commercial technologies, but larger than the national average operated area of farm holdings, with 0.60 ha (BBS 2010). These results indicate that aquaculture producers possess higher-than-average resources, irrespective of the technology practiced. Similar observations are made by Belton et al. (2014) and Belton and Azad (2012). About 13% and 8% of the area of land operated by fish (HS pond) and fish+SIS (HS pond) farmers, respectively, was allocated for fish farming (Table 5). Among commercial pond and *gher* farmers, the share of land allocated to aquaculture varied from 16% to 57% and 62% to 84%, respectively. The allocation of operated land to aquaculture was 79% and 36% for pangas (*beel*) and rice-fish farmers, respectively. The fact that farmers engaged in commercial aquaculture allocated a large share of their agricultural land to the activity suggests that it is an attractive enterprise.

The Bangladesh Bureau of Statistics groups farms by four size categories (marginal: <0.20 ha; small: 0.21–1.00 ha; medium: 1.00–3.00 ha; large: >3.00 ha). With the exception of tilapia (pond), carp (pond), pangas (*beel*) and rice-fish farmers, the largest share of farmers for all technologies operated landholdings of a size that placed them within the small farm category. The shares of farmers within the small farm category were tilapia (pond) at 36%, carp (pond) at 43%, pangas (*beel*) at 3% and rice-fish at 41%. Between a third and one-half of all farmers fell within the medium category. Only a small portion of the farmers operated landholdings falling in the marginal category: 16% for fish (HS pond), 19% for fish+SIS (HS pond), and 6% or less for all other commercial and rice-fish farmers. Among farmers producing pangas (*beel*), 58% were in the large category.

Distribution of income

The average monthly income of sampled households ranged from BDT 2002 to BDT 2500 for homestead pond farmers; from BDT 3445 to BDT 13,110 for commercial pond farmers; and from BDT 4005 to BDT 6993 for commercial *gher* farmers. Average monthly income was BDT 30,446 and BDT 3653 for pangas (*beel*) and rice-fish farmers, respectively (Table 6). The average monthly income per person of homestead pond farmers is similar to that of the rural population of Bangladesh, which stands at BDT 2130 per person per month (BBS 2010). However, the per person monthly income of commercial *gher* and pond farmers is much higher, and that of *beel* farmers is about 15 times higher compared to farmers practicing homestead pond-based technologies. This supports the finding by Belton et al. (2014) that large-scale aquaculture in *beels* is capital intensive and is often carried out by wealthy and politically connected business people.

Hossain et al. (2013) identify per person income thresholds at which households in Bangladesh may be considered resource-poor, lower middle income, upper middle income or higher income. For most commercial technologies, except for carp+prawn (pond) and shrimp+rice (*gher*), the majority of farmers (between 46% and 73%) earned incomes placing them within the higher income category (>BDT 4000 per person per month). Households with per person monthly incomes placing them within the lower middle income group (BDT 1131–3000) accounted for the greatest share of fish (HS pond), fish+SIS (HS pond), carp+prawn (pond), shrimp+rice (*gher*) and rice-fish farmers. Nineteen percent and 31% of fish (HS pond) and fish+SIS (HS pond) farmers, respectively, were categorized as resource-poor, while less than 7% of households practicing most commercial and rice-fish technologies fell into this income group. All (100%) of farmers producing pangas (*beel*) were in the higher income group. (See Table 6.) This may be because the size of investments required to engage in commercial aquaculture means that only relatively better-off farmers can enter production, but may also reflect the fact that commercial forms of aquaculture are able to generate substantial returns (Belton et al. 2014).

Aquaculture's contribution to household incomes

For noncommercial farmers—fish (HS pond) and fish+SIS (HS pond)—aquaculture contributes only 4%–5% of total household income on average. This contribution increases to 28% among rice-fish farmers, and varies from 24% to 72% for commercial pond and 38% to 63% for commercial *gher*-based technologies, respectively. The contribution of fish income to total household income is 83% for pangas (*beel*).

Item	Fish (HS pond)	Fish+SIS (HS pond)	Pangas (pond)	Koi (pond)	Tilapia (pond)	Carp (pond)	Carp+prawn (pond)	Fish (*gher*)	Shrimp (*gher*)	Shrimp+rice (*gher*)	Shrimp+prawn+rice (*gher*)	Prawn+rice (*gher*)	Pangas (*beel*)	Rice-fish
Respondent type (%)														
Owner	100	100	100	99	100	100	100	99	100	100	95	97	95	100
Farm manager	-	-	-	1	-	-	-	1	-	-	5	3	5	-
Gender of the owner (%)														
Male	99	98	100	100	100	100	99	100	100	99	99	100	100	98
Female	1	2	-	-	-	-	1	-	-	1	1	-	-	2
Average age (years)	**43**	**46**	**41**	**35**	**40**	**42**	**41**	**42**	**41**	**45**	**41**	**41**	**39**	**44**
Age category (%)														
18–30 years	18	10	23	48	28	23	21	21	25	18	27	27	18	16
31–45 years	40	47	42	36	43	39	45	47	37	38	44	37	55	45
46–60 years	30	34	27	12	21	31	22	23	30	28	21	31	26	28
>60 years	11	9	8	3	9	7	12	10	7	16	8	5	-	11
Education category (%)														
Illiterate	23	36	13	4	5	18	26	11	6	6	11	18	-	15
Primary	33	23	24	27	30	26	37	27	27	34	28	21	26	35
Secondary	38	35	47	55	49	44	35	50	54	52	44	52	50	38
Graduate	6	5	13	14	16	12	3	9	12	8	10	9	18	13
Other (nonformal)	1	-	1	-	1	0.29	-	4	1	-	6	0.47	5	-
Average household size (no.)	5.03	4.39	5.02	5.37	5.54	5.01	5.58	5.14	5.21	5.07	5.82	4.74	5.34	4.41
% of household members involved in agriculture	59	54	52	48	55	54	65	54	38	53	50	63	43	61
% of household members involved in aquaculture	42	39	38	31	47	43	55	38	34	41	49	50	25	57

Table 5. Demographic characteristics of sample households.

Item	Fish (HS pond)	Fish+SIS (HS pond)	Pangas (pond)	Koi (pond)	Tilapia (pond)	Carp (pond)	Carp+prawn (pond)	Fish (*gher*)	Shrimp (*gher*)	Shrimp+rice (*gher*)	Shrimp+prawn+rice (*gher*)	Prawn+rice (*gher*)	Pangas (*beel*)	Rice-fish
Average operated landholdings for farming (ha)	0.71	0.65	1.52	1.30	1.67	1.52	1.48	2.65	4.09	1.50	1.25	1.25	7.60	1.49
Average operated area for aquaculture (ha)	0.09	0.05	0.86	0.59	0.46	0.61	0.24	1.87	3.23	1.25	0.90	0.77	6.01	0.54
Aquaculture area as a share of operated landholdings (%)	13	8	57	45	28	40	16	70	79	84	73	62	79	36
Farm category, based on operated landholdings (%)*														
Marginal (< 0.20 ha)	16	19	4	1	1	2	6	1	4	3	3	3	-	1
Small (0.21–1.00 ha)	67	60	46	51	36	43	43	44	38	50	54	52	3	41
Medium (1.01–3.00 ha)	14	20	41	42	51	45	40	38	25	35	33	37	39	48
Large (> 3.00 ha)	3	1	9	6	12	9	11	16	33	12	10	8	58	11
Average monthly income (BDT/per capita)	**2,500**	**2,002**	**13,110**	**11,590**	**6,548**	**6,338**	**3,445**	**5,401**	**4,915**	**4,005**	**5,931**	**6,993**	**30,466**	**3,653**
Income category (%)**														
Resource-poor (≤BDT 1130)	19	31	1	4	6	4	4	7	8	9	7	3	-	4
Lower middle income (BDT 1131–3000)	55	53	14	12	34	27	53	34	37	37	33	23	-	52
Upper middle income (BDT 3001–4000)	11	7	12	12	14	13	18	11	13	23	13	16	-	21
Higher income (>BDT 4000)	15	9	73	71	46	56	25	48	41	32	48	58	100	23

* HIES (2010) is used to present the landholding category. Some of the categories are merged in this report.

** Different groups are defined in terms of per person income by adjusting ratio of population under each category (particularly resource-poor) based on HIES 2010 (Hossain et al. 2013).

Table 6. Distribution of households by landholding and income.

THE SOCIOECONOMIC CHARACTERISTICS OF AQUACULTURE PRODUCERS

(see Figure 3 and Table 7.) These results indicate that the share of aquaculture in total household income is greatest for those technologies that require the heaviest capital investment, such as commercial pangas (pond), koi (pond) and pangas (*beel*). Consequently, agriculture makes only a small contribution to the incomes of these producers. Agriculture contributes between approximately one-quarter and one-half of total household incomes for farmers practicing commercial pond, *gher* and rice-fish technologies. The share of non-farm income in household income is greatest for households operating homestead ponds, the technologies which make the smallest financial contribution to household income. The contribution of non-farm earnings to household income is also relatively high for carp+prawn (pond) and shrimp+rice (*gher*) technologies, at 30% and 34% of total income, respectively. Across the whole sample, the share of non-farm income in total income is rather low (less than 25%) compared to a national average for rural areas of around 35% (Ahmed et al. 2013). This suggests that the area of land operated by most commercial fish farmers is sufficient to generate a large enough income to fulfill most household needs. Given the extreme scarcity of land in Bangladesh, this also underlines the finding that commercial aquaculture producers possess larger-than-average landholdings. It also provides an indication of the high returns generated by aquaculture relative to most forms of agriculture.

Households' perceptions of involvement in aquaculture

This section evaluates farmers' perceptions in order to better understand their subjective preferences about aquaculture practices. This is an important exercise because farmers' attitudes affect their production decisions. This section also examines farmers' length of experience with aquaculture; access to information and knowledge; linkages and networking between farmers and other community members; perceptions of benefits of aquaculture technologies; and the impacts of technology on farmers' status, all of which may influence attitudinal or behavioral change among farmers (Adesina and Baidu-Forson 1995).

Fish culture experience

Fish culture in homestead ponds is a common practice for rural people in Bangladesh. The experience level of fish (HS pond) and fish+SIS (HS pond) farmers is 13 years and 14 years respectively, which is higher than producers practicing other, more recently introduced technologies. The shortest length of average experience with any technology was for koi (pond) at 5 years, reflecting its relatively recent development (Table 8). The average length of experience of farmers operating other commercial ponds, *ghers*, *beels* and rice-fish technologies varied from 8 to 11 years.

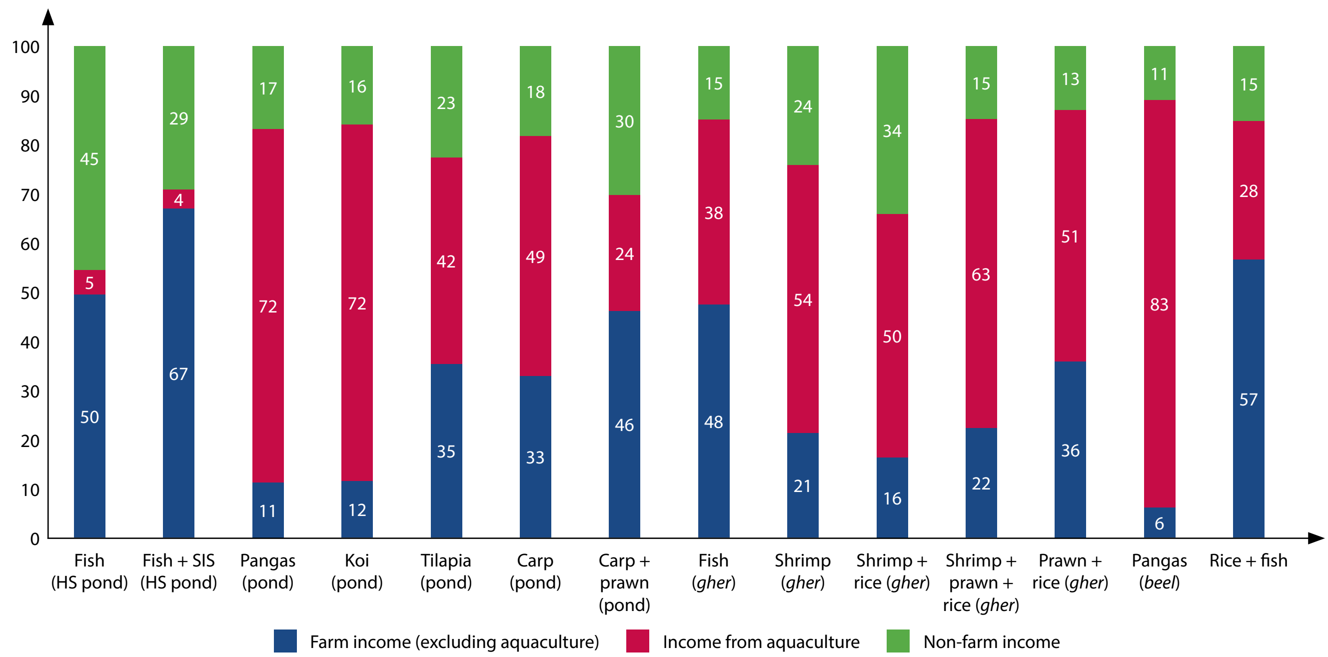


Figure 3. Contribution of different farm and non-farm income sources to total household income (%).

Reasons for involvement in fish culture

Farmers were asked about their reasons for adopting fish culture. The vast majority of homestead pond farmers (fish [HS pond]: 80%; fish+SIS [HS pond]: 81%) said their primary objective was to help meet household subsistence needs through producing fish for home consumption. For farmers practicing commercial technologies, the potential to earn good profits from fish culture was by far the most important reason for practicing fish culture, and was cited by almost all farmers. Other reasons were much less frequently cited than these two primary responses, across all technologies (Table 8).

Access to information and knowledge

Knowledge transfer and access to information play a key role in the dissemination of aquaculture technologies. Friends and neighbors practicing fish farming were the main source of knowledge and information about aquaculture technologies among sample farmers, identified as such by 68%–88% of farmers across all technologies except fish+SIS (HS pond). During interviews, farmers mentioned that the highly profitable nature of fish culture that they observed from their neighbors' farms encouraged them to talk to the neighbors and friends to discover more. About 93% of fish+SIS (HS pond) farmers received training from a WorldFish development project, which introduced the technology to the area. In terms of technology dissemination and lesson learning and sharing, most of the farmers reported that they shared their experiences with their fellow farmers, and identified social gatherings and face-to-face interactions as the most common means of technology dissemination.

Selling tiger shrimp at a depot in Khulna.

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Item	Fish (HS pond)	Fish+SIS (HS pond)	Pangas (pond)	Koi (pond)	Tilapia (pond)	Carp (pond)	Carp+prawn (pond)	Fish (*gher*)	Shrimp (*gher*)	Shrimp+rice (*gher*)	Shrimp+prawn+rice (*gher*)	Prawn+rice (*gher*)	Pangas (*beel*)	Rice-fish
Farm income (excluding aquaculture)	71,508 (50)	68,469 (67)	82,217 (11)	73,475 (12)	135,731 (35)	116,873 (33)	101,106 (46)	152,041 (48)	64,798 (21)	37,881 (16)	90,727 (22)	133,191 (36)	114,038 (6)	107,499 (57)
Income from aquaculture	7,212 (5)	3,910 (4)	526,407 (72)	458,806 (72)	160,623 (42)	173,550 (49)	51,563 (24)	120,386 (38)	164,885 (54)	115,068 (50)	255,395 (63)	190,281 (51)	1,547,374 (83)	53,304 (28)
Non-farm income	65,696 (45)	29,735 (29)	123,350 (17)	100,760 (16)	86,783 (23)	64,796 (18)	66,326 (30)	47,531 (15)	73,181 (24)	79,209 (34)	60,132 (15)	48,110 (13)	202,067 (11)	28,796 (15)
Total household income	144,415 (100)	102,115 (100)	731,975 (100)	633,041 (100)	383,137 (100)	355,218 (100)	218,995 (100)	319,958 (100)	302,863 (100)	232,158 (100)	406,253 (100)	371,582 (100)	1,863,479 (100)	189,599 (100)

Table 7. Average income (BDT) and share of household income (%) by source and technology.

Item	Fish (HS pond)	Fish+SIS (HS pond)	Pangas (pond)	Koi (pond)	Tilapia (pond)	Carp (pond)	Carp+prawn (pond)	Fish (*gher*)	Shrimp (*gher*)	Shrimp+rice (*gher*)	Shrimp+prawn+rice (*gher*)	Prawn+rice (*gher*)	Pangas (*beel*)	Rice-fish
Years of experience in fish culture	13	15	8	5	9	11	13	9	11	14	14	11	9	9
Reason for being involved in aquaculture (%)														
Meeting subsistence needs	80	81	1	-	11	9	1	2	1	-	1	2	-	2
Profitable business	21	29	98	100	100	97	100	100	100	100	100	100	100	96
Family tradition	7	9	-	-	-	1	-	-	-	2	-	6	-	-
Other	3	3	1	-	2	4	-	4	4	4	-	-	3	3
How did you gain knowledge on aquaculture (%)?														
Neighbors or friends	70	15	81	68	78	74	85	75	74	86	90	76	82	88
Family member	20	2	9	9	6	12	4	5	20	5	8	7	-	-
Training program organized by a project	1	93	2	4	2	3	-	-	1	2	-	-	-	1
Other	9	7	11	21	17	14	11	20	9	13	11	20	18	13
Did you share knowledge of your experience with other farmers (%)?														
Yes	65	76	93	97	99	98	100	96	96	91	96	90	100	98
No	35	24	7	3	1	2	-	4	4	9	4	10	-	2
How did you share knowledge of aquaculture (%)?														
Social gathering	52	57	65	75	40	51	62	68	79	72	89	68	84	58
Face-to-face interaction	47	57	36	28	60	52	38	42	25	33	9	34	13	40
Farmer association meeting	1	4	-	1	1	-	-	-	-	-	2	3	3	-
Other	2	5	1	3	1	1	-	-	-	-	11	-	3	2
Access to extension agency (% of total)														
Upazila fisheries office	8	2	20	15	29	30	11	39	30	26	21	38	29	27
Upazila agriculture office	8	9	4	1	19	10	-	23	16	17	30	22	-	19
Upazila livestock office	1	1	1	2	4	2	17	2	13	20	25	11	-	1
Research institutes	1	100	1	2	1	1	-	1	4	9	1	-	3	1
NGOs	24	3	12	7	41	27	58	31	36	44	43	26	8	11
Projects	1	2	6	2	7	2	13	3	1	3	-	3	-	-

Table 8. Household experience and access to knowledge on aquaculture.

As expected, commercial farmers had better access to government extension agencies than homestead pond farmers did. Approximately 11%–39% of commercial farmers with ponds, *ghers* and *beels* had received formal extension support from an *upazila* fisheries officer (an officer of the Department of Fisheries posted at the subdistrict level). Access to *upazila* fisheries officers by noncommercial farmers—fish (HS pond) and fish+SIS (HS pond)—was much lower, at 8% and 2%, respectively. Among aquaculture producers as a whole, the level of contact with NGO staff was greater than with those of the Department of Fisheries, at 24% for fish (HS pond), 8% for pangas (*beel*), 11% for rice-fish, 7%–58% for commercial ponds, and 26%–44% for *ghers*. However, the NGO staff with whom farmers interacted were involved mainly in the provision of microcredit, with very little provision of training. As a result, among the general population of farmers, the proportion who had ever received training organized by a project was very low, at less than 4% for all technologies, with the exception of fish+SIS (HS pond) in homestead ponds, for which 93% of respondents had received training. This result is due to having selected households from a project promoting small indigenous species production in homestead ponds in order to obtain a sample of farmers producing small indigenous species.

Access to formal and informal institutions

Table 9 shows that 4%–10% of homestead pond farmers, 6%–26% of commercial pond farmers, 18%–45% of *gher* farmers and 28% of *beel* farmers participated in formal institutions such as cooperative societies and district or *upazila*-level farmers' associations. None of the farmers practicing rice-fish technologies had access to a formal institution. Results presented in Table 9 also reveal that many farmers are also involved in informal or semiformal institutions such as school committees, mosque or temple committees, market committees, and traders' associations. Except for fish+SIS (HS pond), farmer participation in these informal institutions varied from 3% to 20%. Fish+SIS (HS pond)-based technology is comparatively new in Bangladesh, having been introduced by a WorldFish project. All (100%) of fish farmers practicing this technology were members of an informal fish farmer group developed by the project. The majority of farmers across technologies with links to both formal and informal institutions were general members, and a few were executive members. These results suggest that fish farmers are recognized as important persons within wider society and may have relatively high levels of social capital.

Summary

Framing conditions are the contextual factors that influence how likely it is for aquaculture to develop and the probability of certain impacts occurring (FAO 1996). It is important to identify the socioeconomic characteristics of the farmers to determine their scale of operation and the efficiency with which resources are used. Understanding these system characteristics can help identify the most appropriate intervention measures for the development of the aquaculture sector. In this chapter we considered a number of factors relevant to the framing conditions for aquaculture.

The overwhelming majority (98%–100%) of farmers sampled were men. Limited involvement in and control of aquaculture operations by women is an important concern that needs to be addressed in the future. The average operated landholding of aquaculture producers ranged from 0.71 ha to 7.60 ha, the largest landholdings being those of farmers practicing commercial technologies. The pattern of incomes was similar to that of land size, with the highest accruing to commercial farmers. The contribution of fish to total household incomes was around 5% for homestead pond-based systems, and 24% and 28% respectively for carp+prawn (pond) and rice-fish technologies, but exceeded 50% for most commercial technologies. For pangas (pond), pangas (*beel*) and koi (pond) farmers, the contribution of aquaculture to household income ranged from 72% to 83%. These figures indicate that commercial aquaculture makes a major contribution to livelihoods.

Farmer-to-farmer knowledge transfer was found to be the main pathway for the dissemination of information on aquaculture technologies, and levels of formal extension were low. Among farmers who had received formal extension on aquaculture, it was slightly more common to receive these messages from NGOs than from government staff.

Item	Fish (HS pond)	Fish+SIS (HS pond)	Pangas (pond)	Koi (pond)	Tilapia (pond)	Carp (pond)	Carp+prawn (pond)	Fish (*gher*)	Shrimp (*gher*)	Shrimp+rice (*gher*)	Shrimp+prawn+rice (*gher*)	Prawn+rice (*gher*)	Pangas (*beel*)	Rice-fish
Formal institutional membership (%)														
Yes	4	10	10	6	9	7	26	18	30	45	38	23	28	-
No	96	90	90	94	91	93	74	82	70	55	62	77	73	100
Informal institutional membership (%)														
Yes	8	100	11	5	12	7	10	12	9	10	11	20	3	2
No	92	-	89	95	88	93	90	88	91	90	89	80	97	98
Membership type in formal institution (%)														
Executive	24	14	4	17	14	24	3	8	5	9	8	18	45	-
General member	76	86	96	83	86	76	98	93	95	91	92	82	55	-
Membership type in informal institution (%)														
Executive	23	23	30	60	28	33	13	15	17	23	20	12	100	-
General member	77	77	70	40	72	67	87	85	83	77	80	88	-	100

Table 9. Institutional membership (% of households).

THE SOCIOECONOMIC CHARACTERISTICS OF AQUACULTURE PRODUCERS

CHARACTERISTICS OF WATERBODIES USED FOR AQUACULTURE

This chapter elaborates on the biophysical characteristics of waterbodies utilized for aquaculture and the types of management practices adopted. The first section discusses the biophysical characteristics of waterbodies, and the second elaborates the management practices used. The final section discusses the adoption of different fish culture practices.

The information presented relates to a single waterbody from each farm sampled, which we term the "sample waterbody." Only 10% of households operated two or more waterbodies, in which they usually practiced the same technologies. Where farmers operated multiple waterbodies, one was selected at random as the sample waterbody.

Biophysical characteristics of waterbodies

Size

The productive potential of waterbodies used for aquaculture (ponds, *ghers*, rice plots and *beels*) is closely related to their size (Alam et al. 2004). Homestead pond sizes were smaller on average than commercially managed ponds and *ghers*. The average size of sampled homestead ponds varied from 0.04 ha to 0.06 ha, while average sizes of sampled commercial ponds and *ghers* varied from 0.14 to 0.20 ha and 0.37 to 1.07 ha, respectively. The average size of rice-fish plots was 0.27 ha (Table 10). The average size of *beels* used for pangas culture was much higher, at 3.34 ha. In general, the area of the dikes was about 10% of the surface area of the waterbody. As the name suggests, homestead ponds were located close to the home (15–17 meters [m]), as compared to more distant commercial ponds (90–510 m), *ghers* (320–1550 m), *beels* (440 m) and rice-fish plots (270 m).

Soil quality

Soil quality is important for good fish production, as pond soil plays an important role in regulating the concentration of nutrients in pond water. Good soil types are not highly permeable, thus maintaining the fertility of pond water by preventing rapid loss of nutrients through the pond bottom (Monir et al. 2011). Table 10 shows that the majority of ponds were constructed on sandy loam, clay loam and loam soils (about 80% across technologies), all of which are suitable for pond construction (Alam et al. 2004). Combined, loams and sandy loams accounted for more than 50% of homestead and commercial ponds, whereas clay loam soil was more common in *ghers*, *beels* and rice-fish plots.

Culture period

The majority of the waterbodies used for homestead, commercial pond, *gher* and *beel* farming were perennial (i.e. holding water year round). Table 10 shows that the culture period of these technologies varied from 234 to 336 days. Pangas had the longest grow-out cycle at more than 300 days in both pond and *beel* production systems. *Gher* systems tended to have somewhat shorter growing periods, at around 250 days. The shortest production period among commercial pond technologies was for intensive koi culture (197 days), for which farmers stop production when water quality deteriorates and fish become vulnerable to disease. The shortest production cycle overall was found in rice-fish (162 days), for which 98% of rice plots were used for fish production in rotation with rice production, on an alternate seasonal basis.

Water supply

The average depth of homestead and commercial ponds and *beels* ranged from 1.26 m to 1.76 m. Average water depth in *ghers* was less, ranging from 0.65 m to 1.26 m (Table 10). Rain water was the most important source of water for ponds and *ghers*, followed by river water and groundwater. In many cases, farmers depended on multiple sources for water supply, most commonly a combination of rainfall and groundwater (e.g. 99% of rice-fish depended on both rainfall and groundwater). Rainfall was the main source of water for homestead-based aquaculture technologies (81%–85%), whereas rivers were the main source of water for *gher* farming, especially in shrimp culture technologies. About 98% and 95% of *ghers* used for the production of shrimp and shrimp+rice were irrigated with river water.

Management of waterbodies

Pond or plot holdings and tenure status

Waterbody ownership is presented in Table 11. The majority of homestead ponds, commercial ponds, *ghers* and rice-fish plots were owned and operated by a single individual (single owned). Sixteen percent and 20% of fish (HS pond) and fish+SIS (HS pond), respectively, were owned and operated by more than one individual (joint owned). However, joint ownership was rare for commercially managed waterbodies, ranging from 1% to 5%. The majority of *beels* were leased in by a single operator (84%) and 16% were leased in by more than one operator (joint leased). The single-leased-in arrangement was significant among many commercial pond-based technologies, such as pangas (pond) at 28%, carp (pond) at 18%, tilapia (pond) at 10% and koi (pond) at 7%. Between 31% and 43% of commercial *ghers* were leased in for fish culture. About 13% of terrestrial crop farmers in rural Bangladesh cultivate land under cash-lease arrangements, either as pure tenants or by combining own land and leased land (Ahmed et al. 2013). Accessing land through lease arrangements is more common in commercial aquaculture than in agriculture as a whole.

Use of waterbodies

Homestead ponds have multiple uses besides fish culture. Approximately three-quarters of homestead ponds were utilized for washing and bathing. Water from commercially managed ponds was not generally used for domestic purposes, as water quality is poor due to high levels of feed inputs and high stocking densities, as well as the fact that many ponds are located far from the homestead. Water from prawn and shrimp *ghers* was also not used for domestic purposes, because they are often located far from the homestead, are shallower than ponds (making them unsuitable for bathing), and are mainly located in areas where water is somewhat saline for at least part of the year. Drinking water from waterbodies used for aquaculture was also found to be very rare, being reported for only 1% of homestead ponds. This may indicate that heavy fertilization and supplementary feeding for fish makes water undrinkable, but probably also reflects that most farmers get drinking water from tube-wells (Table 11).

Dike cropping

The use of dikes surrounding waterbodies for the production of vegetables, timber trees and fruits was widespread, and can be considered the second most important overall function related to waterbodies, after fish production. With the exception of those practicing fish+SIS (HS pond), pangas (pond) and carp (pond) technologies, the majority of pond farmers used dikes for productive purposes. Use of *gher* dikes for cropping was much more common for fish (*gher*) at 48%, shrimp+prawn+rice (*gher*) at 57% and prawn+rice (*gher*) at 62% than for shrimp (*gher*) at 7% and shrimp+rice (*gher*) at 1%, most likely because saline water in shrimp *ghers* makes them unsuitable for this purpose, and because shrimp *gher* dikes tend to be very narrow. Table 11 indicates that dikes were used mainly for growing timber trees, followed by vegetables and short-growing fruits (e.g. papaya and banana). Fifty-eight percent of *beel* dikes were used for growing timber trees, but just 2% were used for vegetable production. Rice-fish plot dikes are rarely cropped, due to insufficient space.

Management practices

This section describes farm management practices reported by farmers during the study period. For this analysis, management practices are subdivided into three broad types: (1) pre-stocking; (2) stocking and water management; and (3) feed management. Results are summarized in Tables 12 and 13.

Pre-stocking management aims to prepare ponds to reduce the likelihood of poor survival and unsatisfactory growth in stocked fish seed. Strong, well-constructed dikes serve as boundaries to the pond, hold water within the pond and protect it from flooding. Tables 12 and 13 show that just under half of farmers practicing homestead pond-based aquaculture practiced dike repair and maintenance, whereas the majority of farmers practicing all forms of commercial aquaculture did so. Drying the pond bottom between production cycles was found to be the most practical and effective method of eliminating undesirable species (e.g. predatory fish, which could eat stocked fish seed) from the pond prior to the culture period. It also oxidizes harmful chemical substances, especially sulfides, and facilitates mineralization

Item	Fish (HS pond)	Fish+SIS (HS pond)	Pangas (pond)	Koi (pond)	Tilapia (pond)	Carp (pond)	Carp+prawn (pond)	Fish (*gher*)	Shrimp (*gher*)	Shrimp+rice (*gher*)	Shrimp+prawn+rice (*gher*)	Prawn+rice (*gher*)	Pangas (*beel*)	Rice-fish
Pond surface area (ha)	0.06	0.04	0.23	0.14	0.18	0.27	0.14	1.07	1.86	0.87	0.37	0.37	3.34	0.27
Pond dike area (ha)	0.02	0.01	0.05	0.03	0.05	0.07	0.04	0.14	0.16	0.09	0.09	0.10	0.32	0.04
Distance of pond from homestead (m)	30	40	240	200	510	390	90	1,550	1,170	320	570	490	440	270
Soil type (%)														
Sandy	2	1	1	1	2	1	-	1	-	-	1	1	-	-
Clay	11	1	21	13	20	9	3	17	20	3	8	12	32	-
Loam	8	4	22	10	7	33	-	18	13	13	8	12	-	9
Sandy loam	46	31	40	52	52	21	54	19	16	11	5	25	5	30
Clay loam	31	45	15	24	19	36	42	44	49	60	70	47	63	48
Other	1	19	1	-	-	1	-	1	2	13	7	3	-	13
Growing period for fish (days/year)	278	256	309	197	280	309	306	252	277	234	265	269	336	162
Depth of water body (m)	1.53	1.66	1.49	1.26	1.57	1.59	1.63	1.26	0.98	0.65	0.96	1.11	1.76	0.85
Primary water source (%)														
Rainfall	85	81	5	2	59	55	81	27	2	2	45	46	63	1
Groundwater	5	1	30	44	16	24	15	32	-	1	4	12	3	-
Rainfall and groundwater	8	18	59	54	12	20	3	8	-	-	-	17	34	99
River	1	-	4	-	11	1	-	25	98	95	50	22	-	-
Other	1	-	2	-	2	0.29	1	9	-	2	1	2	-	-

Table 10. Biophysical characteristics of waterbodies used for aquaculture.

Item	Fish (HS pond)	Fish+SIS (HS pond)	Pangas (pond)	Koi (pond)	Tilapia (pond)	Carp (pond)	Carp+prawn (pond)	Fish (*gher*)	Shrimp (*gher*)	Shrimp+rice (*gher*)	Shrimp+prawn+rice (*gher*)	Prawn+rice (*gher*)	Pangas (*beel*)	Rice-fish
Tenure status (%)														
Single owned	83	80	70	92	83	75	97	59	55	54	63	55	-	94
Joint owned	16	20	1	1	5	4	3	2	5	2	-	1	-	-
Single leased	1	-	28	7	10	18	-	31	35	41	36	43	84	5
Joint leased	-	-	1	-	1	3	-	7	5	2	1	0.47	16	2
Single owned + leased in	-	-	0.35	-	-	-	-	-	-	1	-	0.47	-	-
Joint owned + leased in	-	-	-	-	-	-	-	0.45	1	-	-	-	-	-
Use of pond water (%)														
Fish culture	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Washing clothes	77	59	-	-	-	-	-	-	-	-	-	-	-	1
Bathing	81	54	-	-	-	-	-	-	-	-	-	-	-	1
Drinking	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Other	13	1	1	-	3	-	4	-	1	-	-	-	-	-
Use of pond dike (%)														
Unused dikes	38	72	63	35	41	59	20	52	93	99	43	28	42	97
Vegetables	18	9	10	12	24	27	58	24	3	-	53	64	3	2
Timber trees	39	31	16	26	22	5	13	10	3	1	1	3	55	0
Short-growing fruits	6	5	7	24	4	2	2	8	0	-	-	3	-	1
Other	10	7	6	6	6	4	1	8	0	-	1	1	-	-

Table 11. Ownership patterns and use of the sample waterbodies.

CHARACTERISTICS OF WATERBODIES USED FOR AQUACULTURE

Management practice	Fish (HS pond)	Fish+SIS (HS pond)	Pangas (pond)	Koi (pond)	Tilapia (pond)	Carp (pond)	Carp+prawn (pond)
Pre-stocking management							
Dike repair or maintenance	49	42	83	100	91	68	63
Drying pond	38	37	80	99	58	50	60
Control of predatory species	35	37	13	100	4	40	34
Removal of silt or sludge from waterbody	38	32	69	98	51	39	56
Soil management	25	26	78	99	55	44	58
Pre-stocking liming	26	63	94	98	90	86	38
Stocking and water management							
Enhancing natural productivity through organic fertilization	66	82	21	6	59	73	63
Enhancing natural productivity through inorganic fertilization	54	69	44	13	91	95	81
Acclimatization of fry or fingerlings before releasing	48	45	69	100	60	56	60
Acclimatization of shrimp postlarvae before releasing	n/a*	n/a	n/a	n/a	n/a	n/a	n/a
Acclimatization of prawn postlarvae before releasing	n/a	91	n/a	n/a	n/a	n/a	92
Nursing shrimp postlarvae before releasing	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Nursing prawn postlarvae before releasing	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Use of PCR-tested shrimp postlarvae	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Maintenance of water level in the pond	6	1	75	87	27	24	15
Use of oxygen supply substances to add oxygen to the waterbody	-	-	55	52	41	8	1
Control of aquatic weeds and algae	67	70	98	100	93	84	98
Preventive measures to control disease contamination	33	22	99	98	100	89	85
Feed management							
Supplementary feeding – raw feeds	84	100	37	11	74	95	97
Supplementary feeding – commercial pellet	2	1	65	99	57	40	27
Supplementary feeding – homemade pellet	0	0	24	0	0	1	0
Natural food investigation	57	65	15	16	52	75	70
Use of feeding ring or tray	0	0	0	0	2	4	7

* n/a = not applicable.

Table 12. Management practices utilized in pond technologies (% of households applying).

CHARACTERISTICS OF WATERBODIES USED FOR AQUACULTURE

Management practices	Fish (*gher*)	Shrimp (*gher*)	Shrimp+rice (*gher*)	Shrimp+prawn+rice (*gher*)	Prawn+rice (*gher*)	Pangas (*beel*)	Rice-fish
Pre-stocking management							
Dike repair or maintenance	94	90	100	100	100	71	100
Drying pond	90	92	95	100	100	0	98
Control of predatory species	5	2	0	18	29	0	91
Removal of silt or sludge from waterbody	76	29	29	98	99	0	24
Soil management	87	82	87	99	98	0	100
Pre-stocking liming	91	85	83	90	97	100	92
Stocking and water management							
Enhancing natural productivity through organic fertilization	69	57	54	27	39	13	45
Enhancing natural productivity through inorganic fertilization	99	85	84	46	69	34	46
Acclimatization of fry or fingerlings before releasing	77	86	77	99	80	95	92
Acclimatization of shrimp postlarvae before releasing	n/a*	86	85	99	n/a	n/a	n/a
Acclimatization of prawn postlarvae before releasing	91	n/a	n/a	93	92	n/a	n/a
Nursing shrimp postlarvae before releasing	n/a	24	21	89	n/a	n/a	n/a
Nursing prawn postlarvae before releasing	n/a	n/a	n/a	93	91	n/a	n/a
Use of PCR-tested shrimp postlarvae	n/a	3	2	2	n/a	n/a	n/a
Maintenance of water level in the pond	57	98	96	40	34	3	20
Use of oxygen supply substances to add oxygen to the waterbody	17	17	10	43	20	0	0
Control of aquatic weeds and algae	52	77	67	90	77	97	84
Preventive measures to control disease contamination	72	84	77	89	67	100	100
Feed management							
Supplementary feeding – raw ingredients	100	50	39	96	92	53	98
Supplementary feeding – commercial pellet	30	9	13	84	77	95	8
Supplementary feeding – homemade pellet	0	0	0	0	0	3	0
Natural food investigation	58	85	87	69	61	0	0
Use of feeding ring or tray	4	0	0	0	1	0	0

* n/a = not applicable.

Table 13. Management practices utilized in *gher*, *beel* and rice-fish technologies (% of households responding).

CHARACTERISTICS OF WATERBODIES USED FOR AQUACULTURE

of organic matter (CSISA 2011). Tables 12 and 13 show that pond drying was practiced by 37%–38% of homestead farmers. However, these practices were common among most of the farmers practicing commercial technologies. Drying was not practiced at all in *beel* farming because of the perennial nature and large size of these waterbodies, which makes drying very costly. Farmers also used a variety of methods to remove or exclude unwanted fish and other animals, particularly where drying was not possible. Methods included rigorous netting before stocking, use of chemicals and encircling the waterbody with nets.

Removal of sludge and other soil management methods such as plowing and applying lime to the bottom soil are important pre-stocking activities. Sludge deposited on the pond bottom contains organic matter, which can be transformed into harmful gases such as hydrogen sulfide (H_2S), ammonia (NH_3), nitrogen dioxide (NO_2) and methane (CH_4). Removal of bottom sludge ensures better water quality when the pond is refilled and stocked for the next cycle. Tables 12 and 13 show that 32%–38% of homestead farmers removed sludge. Except for carp (pond), shrimp (*gher*), shrimp+rice (*gher*) and rice-fish technologies, the majority of commercial farmers practicing other technologies also removed sludge. Plowing the pond bottom soil improves soil quality by exposing subsoil to the atmosphere, thereby speeding up the oxidation process and the release of nutrients that are locked in the soil. This practice was followed by a quarter of homestead farmers and was common among those practicing commercial technologies, with a few exceptions. The majority of the farmers practicing all technologies, except for fish in homestead ponds, conducted pre-stocking liming as a preventive measure against disease. Again, only around a quarter of farmers with homestead ponds followed this practice.

Organic and inorganic fertilizers are used to enhance the productivity of waterbodies used for aquaculture. Tables 12 and 13 show that the majority of farmers followed this practice, with the exception of those practicing commercial technologies in which the majority of fish or crustacean nutrition is derived from pelleted feeds (e.g. pangas [pond], pangas [*beel*], koi [pond], shrimp+prawn [*gher*] and prawn+rice [*gher*]). Acclimatization of fish seed and shrimp and prawn postlarvae was common for reducing stress on and deaths of stocked seed in commercial technologies in ponds, *ghers*, *beels* and rice-fish. However, less than half of farmers with homestead ponds acclimatized stocked fish. Some farmers nursed shrimp and prawn postlarvae in a separate partitioned area within the waterbody or in a small nursery pond prior to stocking in the *gher*. This technique was commonly practiced in shrimp+prawn+rice and prawn+rice systems. Results showed that polymerase chain reaction (PCR)-tested white spot syndrome virus-negative shrimp postlarvae was used by only 2%–3% of shrimp farmers.

A flow-through water system that allows the entry and exit of water into and out of the pond at the same time is essential in high-density aquaculture systems. Results show that maintaining water levels through water exchange was common in intensive types of aquaculture (e.g. pangas [pond] and koi [pond]). Water exchange was also common in shrimp (*gher*) and shrimp+rice (*gher*) culture, as the system depends on saline water intrusion and utilizes some wild postlarvae that enter the pond along with this water. Use of chemical oxygenation products (e.g. sodium percarbonate and hydrogen peroxide) are sometimes necessary in intensive systems to provide sufficient oxygen for stocked fish. Our study shows that the use of these substances was common in intensive commercial systems such as pangas (pond) at 55%, koi (pond) at 52%, tilapia (pond) at 41%, shrimp+prawn+rice (*gher*) at 43% and prawn+rice (*gher*) at 20%. The use of oxygenating chemicals was minimal for other technologies and nonexistent in homestead, pangas (*beel*) and rice-fish systems.

The majority of farmers across all technologies controlled aquatic weeds and macroalgae to ensure sufficient sunlight penetration and enough nutrients in the water for phytoplankton to bloom, which provides natural food for fish to grow (Tables 12 and 13). Fluctuations in environmental parameters such as dissolved oxygen, acidity, turbidity and temperature may cause stress to fish and predispose them to infectious diseases. Rapid changes in environmental conditions in the pond can be addressed via a range of preventative measures. These include manipulating rates of feeding, fertilization and liming; adding clean water; raking the bottom of the pond; and providing aeration. The majority of commercial farmers in pond, *gher*, *beel* and rice-fish systems used at least some of these measures, but only one-third of farmers producing fish in homestead ponds did so.

Quality feed is an important factor in ensuring good fish growth, while inferior feeds can cause water quality and fish health problems. Supplementary feeding was a commonly reported practice among farmers across all technologies. Most farmers used raw ingredients from agriculture byproducts (e.g. rice bran, wheat bran, mustard oil cake, etc.) rather than pelleted feeds. The main exceptions were intensive commercial pangas (pond) and koi (pond) culture, for which farmers mainly relied on pelleted feed for supplementary feeding. About 65% of farmers used commercial feed and 24% used homemade pelleted feeds, respectively, in pangas culture. Ninety-nine percent of koi (pond) culture used commercially manufactured feeds. In contrast, shrimp (*gher*) and shrimp+rice (*gher*) culture was extensive, and depended mainly on the natural productivity of water in the *gher*. The assessment of natural food abundance was the most common feed management practice across most technologies. Except for pangas (*beel*) and rice-fish, a large proportion of farmers across the technologies (15%–87%) investigated natural food availability in the pond before applying feed or fertilizer. A feeding ring was used by a small number of farmers practicing a variety of technologies.

Summary

Findings show that the average size of homestead ponds was small, at 0.04–0.05 ha. Among commercial farmers, average waterbody size varied from 0.14 ha to 3.34 ha, depending on the technology adopted. Homestead ponds are used for multiple domestic purposes, and dike cropping plays an important role in many aquaculture systems. The use of dikes surrounding waterbodies for the production of vegetables, timber trees and fruits was very widespread across technologies. However, significant underuse of pond dikes suggests that there may be scope for their more efficient use in crop production. The majority of waterbodies used for aquaculture were perennial, with growing seasons lasting approximately 8–10 months. Most waterbodies had loam, clay loam and sandy loam soil types, which are all suitable for fish production. Rainfall and groundwater were the main sources of water for most technologies, except for shrimp (*gher*), which depended largely on river water. The majority of commercially operated waterbodies were single owned or single leased, while 16%–20% of homestead ponds were jointly owned.

Homestead-based technologies, shrimp (*gher*) and rice-fish were mostly extensive in terms of pre-stocking, stocking and feed management practices. A large majority of farmers fertilized ponds to encourage natural food to grow. The most commonly used feeds across technologies were raw agricultural processing byproducts. More intensive technologies—koi (pond), pangas (pond) and pangas (*beel*)—were more dependent on formulated feeds.

Uptake of agricultural technologies is influenced by a variety of factors. This chapter explores the beliefs and attitudes of farmers operating each type of aquaculture technology to understand why farmers adopt particular technologies. Understanding these attitudes can help in the design of appropriate approaches and interventions to ensure sustainability.

Farmers' perceptions of aquaculture technologies

Structured attitude statements were used to obtain quantified perceptions about farmers' understandings of various aspects of aquaculture, including whether they considered aquaculture a viable enterprise, the degree of risk associated with the activity, and its potential benefits. The five-point Likert scale method was used to indicate respondents' agreement or disagreement with each attitude statement. The strength of responses was measured using 1 as "strongly disagree," with 5 as "strongly agree." Scores averaging <3.0 were categorized as indicating farmer disagreement with attitude statements, while an attitude score of >3.0 was taken to represent agreement with the statement, with 3 considered neutral. Farmers' responses to the attitude statements are presented in Table 14.

There was strong agreement across all technologies with the statement "fish culture is enjoyable." During interviews, many farmers mentioned that it is always enjoyable to observe plenty of fish in the pond. Most farmers, except those practicing commercial pangas (pond) and koi (pond) culture, agreed that fish culture techniques are easy to learn. Commercial aquaculture technologies such as pangas and koi culture generate high levels of production and economic returns, but involve intensive management practices, including regular feeding, stocking and harvesting, and water exchange, requiring close monitoring and sound knowledge of fish management practices. This may explain koi and pangas *beel* farmers' responses. A divergent pattern was noted in responses to the statements "fish culture doesn't interfere with my leisure time" and "fish culture is time consuming." Higher agreement with the former and higher disagreement with the latter statement was provided by noncommercial homestead-based pond and rice-fish farmers, as compared to those practicing commercial technologies in ponds, *ghers* and *beels*. This tendency was especially strong among commercial pangas, koi and tilapia farmers. The results show that homestead aquaculture is motivated by a different set of incentives, and involves a different set of behaviors and risks, than entrepreneurial forms of commercial farming (Belton and Azad 2012).

There was strong agreement among commercial farmers that fish culture is capital-intensive and risky. Noncommercial homestead pond and rice-fish farmers tended to take the opposite view, showing a close relationship between the level of investment in fish farming and risk. Shocks such as floods, droughts and disease, which can rapidly result in significant losses, may influence commercial farmers' responses in this regard. However, most respondents across all technologies felt that fish farming provides potentially greater economic returns and other benefits than other agricultural activities (e.g. cash incomes and food for family members year round). The balance of perceived tradeoffs between potential risks and benefits is reflected in responses to "fish culture has made me more vulnerable to shocks," for which farmer responses were less than or close to 3.0, indicating farmers' ambiguity about or slight disagreement with the statement. There was greater agreement (>3.0) about the complementarity of fish culture with other agricultural practices across the technologies (with the exception of shrimp [*gher*] culture). Most farmers also felt that agriculture practices such as dike cropping and rice-fish integration minimized negative shocks. Conflicts and tradeoffs between use of land for agriculture and saline water for shrimp, which make it hard to integrate systems, probably account for less agreement with this statement among shrimp (*gher*) farmers.

Farmers across all the technologies viewed fish culture as a lucrative enterprise (Table 14) and agreed on the benefits of aquaculture. Farmers' responses show that aquaculture can generate higher incomes, improve standards of living, and make contributions to family welfare by, for instance, supporting children's education. A high proportion of farmers across all technologies said fish farming ensures a constant supply of food for family consumption, reducing the number of fish they bought from the market.

Summary

Farmers across all technologies viewed fish farming as an attractive and profitable activity. They viewed it as a source of constant food supply for family consumption, and it made them less reliant on buying fish from the market. Results reveal that although commercial fish farming is perceived as potentially risky, the potential benefits motivated entrepreneurial producers to take risks and invest in the activity.

Photo Credit: Hazrat Ali/WorldFish

Harvesting and weighing pangas in Mymensingh.

Indicators ("Fish farming …")	Strength of agreement	Fish (HS pond)	Fish+SIS (HS pond)	Pangas (pond)	Koi (pond)	Tilapia (pond)	Carp (pond)	Carp+prawn (pond)	Fish (*gher*)	Shrimp (*gher*)	Shrimp+rice (*gher*)	Shrimp+prawn+rice (*gher*)	Prawn+rice (*gher*)	Pangas (*beel*)	Rice-fish
Is enjoyable	1	1	2	1	2	2	0.29	1	0.45	2	2	1	1	5	2
	2	5	1	1	3	2	1	2	2	2	9	1	1	5	2
	3	24	18	8	18	3	10	15	8	10	9	4	15	3	8
	4	44	66	30	33	17	35	39	17	43	39	6	45	8	72
	5	26	12	60	44	76	53	43	72	43	41	87	38	78	17
Is easy to learn	1	3	7	5	13	2	2	4	1	9	8	1	3	3	1
	2	6	2	33	32	24	13	28	10	33	19	10	14	3	4
	3	22	18	36	29	48	52	13	36	21	37	47	45	8	12
	4	48	47	23	18	20	18	32	45	21	24	34	22	8	75
	5	20	27	3	8	5	15	23	9	16	13	7	16	78	9
Doesn't interfere with my leisure time	1	1	4	9	1	7	3	5	4	14	9	2	8	5	2
	2	4	1	21	38	32	11	10	21	10	14	28	13	27	2
	3	26	29	55	55	34	53	37	24	32	20	19	41	41	34
	4	50	31	11	2	21	25	27	26	16	38	39	30	16	36
	5	19	34	4	4	6	8	22	25	29	18	12	9	11	26
Is time consuming	1	8	1	1	3	1	1	3	1	10	2	7	2	5	1
	2	37	50	3	3	5	3	19	12	10	12	16	9	5	33
	3	41	18	21	5	6	34	12	43	25	37	21	33	35	47
	4	12	17	37	19	46	47	45	32	29	34	24	35	24	13
	5	3	14	38	70	41	15	21	11	26	16	31	20	30	6
Requires a lot of investment	1	3	1	2	5	3	4	4	2	2	5	4	1	8	4
	2	47	40	1	4	5	22	9	12	13	23	5	8	8	34
	3	37	45	6	2	16	45	44	29	26	9	24	24	8	44
	4	10	14	36	16	53	25	26	44	49	36	49	30	30	15
	5	3	1	54	72	24	5	17	13	9	28	19	37	46	4
Is a risky activity	1	8	9	0.35	4	1	11	3	1	2	5	1	5	8	4
	2	42	33	7	3	30	24	3	38	4	12	9	14	14	38
	3	37	42	21	9	37	44	38	33	7	11	17	14	27	37
	4	9	13	42	9	24	16	52	25	17	30	51	57	27	18
	5	5	4	29	74	7	5	5	4	70	42	22	9	24	4
Has made me more vulnerable to shocks	1	23	31	5	3	16	33	9	24	8	5	9	2	19	5
	2	37	26	1	5	21	16	19	23	13	7	12	25	8	49
	3	17	12	27	16	26	12	42	26	17	31	22	36	19	32
	4	18	20	35	22	32	29	25	14	15	27	37	8	5	7
	5	5	10	32	54	5	9	6	14	47	29	20	28	49	7
Is complementary to the other agriculture I practice	1	6	3	8	4	18	4	3	20	46	43	5	3	8	2
	2	17	6	4	8	11	12	21	11	34	27	14	14	11	2
	3	40	50	37	57	28	49	35	9	17	19	22	34	35	10
	4	24	40	37	18	20	22	35	18	1	9	51	12	24	23
	5	13	1	13	13	23	12	6	42	2	3	7	37	22	63
Is a profitable activity	1	3	3	1	4	3	0.29	1	1	1	3	1	1	5	2
	2	6	8	1	4	2	0.29	1	1	1	8	1	2	5	4
	3	59	54	14	29	5	7	4	22	7	8	1	3	8	49
	4	30	29	51	38	18	37	8	28	35	50	1	18	16	41
	5	2	6	34	25	73	56	85	48	56	31	96	75	65	4
Has improved my household's standard of living	1	7	2	1	3	3	3	2	0.45	1	5	2	1	5	2
	2	26	19	1	3	5	5	7	4	3	5	11	3	5	12
	3	50	71	14	23	20	32	65	20	15	23	24	24	5	53
	4	12	6	43	51	67	59	23	55	72	44	54	69	11	26
	5	5	2	40	21	5	1	3	20	9	23	8	3	73	7
Provides income that contributes to my children's education	1	22	4	7	6	3	2	3	4	2	1	1	1	3	2
	2	23	18	5	4	3	9	2	3	2	2	2	2	14	6
	3	36	45	32	38	26	35	12	19	15	32	16	18	24	33
	4	10	20	26	32	18	28	15	21	30	37	19	23	14	38
	5	4	12	23	9	41	23	65	43	38	22	60	51	41	20
	0 (n/a)*	6	-	8	10	10	4	3	10	13	6	1	5	5	1
Means that I have to buy less fish from the market	1	1	1	1	4	11	1	1	6	1	1	2	1	8	2
	2	2	13	6	18	11	7	16	14	13	2	3	0	5	3
	3	10	40	10	24	14	11	8	10	7	6	5	10	11	12
	4	41	39	27	29	22	36	17	33	28	32	23	37	41	73
	5	46	6	55	26	42	45	58	37	50	59	66	51	35	10
Produces enough fish to meet my family's needs	1	0.26	2	1	2	11	0.29	2	2	1	1	1	1	5	2
	2	5	12	4	18	13	7	3	17	13	2	2	1	8	2
	3	16	8	13	21	14	15	6	20	18	20	15	17	43	20
	4	45	36	34	29	21	44	28	32	29	42	43	38	16	48
	5	34	42	48	31	42	34	62	29	39	34	38	43	27	30

* n/a = not applicable.

Table 14. Fish farmer attitudes toward aquaculture (strength of agreement: 1 = strongly disagree, 5 = strongly agree).

FARMERS' ATTITUDES AND PRACTICES

AQUACULTURE ENTERPRISE BUDGETS AND PERFORMANCE

This chapter details the production performance of the technologies surveyed. The first section deals with enterprise budgets and cost structures of the technologies, including a breakdown of fixed and direct operating costs for fish production that takes into account the three major costs (seed, feed and labor). The second part of the chapter describes the performance of different aquaculture technologies in terms of productivity, margins and benefit-cost ratios.

Aquaculture cost structures by technology

Higher levels of investment were found in all types of commercial technologies compared with homestead pond or rice-fish technologies (Tables 15 and 16). The highest levels of investment (including variable and fixed costs) per hectare were found in commercial koi (pond) at BDT 2,894,189/ha/yr, followed by pangas (pond) at BDT 1,836,158/ha/yr. Investment in tilapia (pond) and carp (pond) stood at BDT 517,899/ha/yr and BDT 287,560/ha/yr, respectively. Costs of investment in prawn and fish-dominated *ghers* ranged from BDT 207,264/ha/yr to BDT 241,299/ha/yr. Per unit area investment costs stood at around BDT 100,000/ha/yr for shrimp (*gher*) and rice-fish systems. Investment in homestead ponds was lower per unit area than in any other system, at BDT 76,610/ha/yr for fish (HS pond) and BDT 80,129/ha/yr for fish+SIS (HS pond) technologies.

Tables 15 and 16 categorize cost items by operating and fixed costs. The operating costs for fish culture are fish seed, fertilizers, feed, labor, and other costs such as marketing, irrigation and water exchange. Tables 15 and 16 show that the contribution of operating costs to total costs among the technologies varied from 76% to 98%. Fish seed, feed and labor were identified as the three major operating costs for fish production. Fish seed was the major cost in homestead ponds, contributing 46% and 50% of total costs for fish (HS pond) and fish+SIS (HS pond) technologies, respectively. The shares of feed and labor costs in these technologies were 15% and 7%, respectively.

Conversely, among commercial technologies in ponds, feed was the major cost. In terms of contribution to overall costs, koi (pond) was the most feed-intensive commercial pond-based technology (feed: 80%; seed: 12%; labor: 3%) followed by pangas in ponds (feed: 75%; seed: 14%; labor: 4%), tilapia in ponds (feed: 52%; seed: 18%; labor: 12%) and carp in ponds (feed: 31%; seed: 25%; labor: 16%). With the exception of fish (*gher*) culture, fish seed was the major cost in *gher* and rice-fish systems. This is because natural feed more significantly influences fish growth in *gher* and rice-fish systems than in intensive commercial pond-based systems. Seed accounted for 31%–42% of costs in shrimp, prawn and rice-fish technologies. Labor was the major cost in fish culture in *ghers*, accounting for 27% of total costs.

The contribution of fixed costs (e.g. pond depreciation, repairs, equipment, rental costs and interest) to total costs was around 15% for homestead ponds. The share of fixed costs varied from 3% to 15% among commercial technologies in ponds and 10% to 24% among commercial technologies in *ghers*.

Seed costs

Seed of multiple species were stocked together in polyculture in all of the aquaculture systems surveyed (Table 17). Carp and tilapia were the most commonly stocked species across all technologies, although in most cases they were not the major harvested species.

Table 17 shows that almost 100% of farmers stocked carp species in their homestead ponds. These were dominated by Indian major carp, followed by exotic carps and Indian minor carp. The main sources of fingerlings for homestead pond farmers were mobile fish traders (87%–91%), followed by hatcheries (28%–95%) and nurseries (4%–30%). (See Table 18 and Annex 2.) Tables 19 and 20 show that the stocking rate of carp was much higher than other fish species in homestead-based technologies. Stocking costs for homestead ponds averaged BDT 40,816/ha for fish (HS pond) and BDT 46,368/ha for fish+SIS (HS pond) technologies, of which carp species accounted for about 91% and 68% of seed costs, respectively. A small proportion of farmers also stocked prawn, pangas, koi, shing and tilapia in their homestead systems. All farmers practicing fish+SIS (HS pond) stocked small indigenous species (mainly *mola*, *dhela*, *darkina* and prawn). These small indigenous species were also deliberately stocked in homestead ponds by 5% of fish (HS pond) farmers.

Table 17 shows that among pond-based commercial technologies defined by the main target species stocked (i.e. pangas in pond, tilapia in pond, etc.), 100% of farmers stocked the main target species. Carp were commonly stocked in commercial pond systems, with the exception of koi (pond) systems, for which only 10%–12% of farmers stocked carp. The main source of fingerlings for commercial pond farmers was hatcheries (55%–65%), followed by nurseries (36%–87%) and mobile fish traders (8%–75%). (See Table 18 and Annex 2. The stocking rate of target species in their respective commercial pond systems was much higher than that of other stocked species (Table 19). Annual stocking costs in commercial pond systems were substantial, ranging from a maximum of BDT 338,073/ha for koi (pond) to BDT 63,922/ha for carp+prawn (pond). Table 20 shows that the main target species stocked accounted for more than 60% of total seed costs across all technologies.

Tables 17 and 19 show that the stocking rates of shrimp and prawn in *gher*-based farming systems were much higher than those of other species, except fish (*gher*). Shrimp and prawn seed comprised more than 75% of seed costs in shrimp and prawn *gher* technologies (Table 21). Carp stocking costs in shrimp and prawn *ghers* was 4%–24% of total stocking costs. Fish (*gher*) technology was dominated by carp, followed by prawn and tilapia. There was also a tendency among the farmers to stock some indigenous species, especially in shrimp and prawn *ghers*, in which the wild indigenous species most commonly stocked were *paisa* (mullet), *vetki* (Asian seabass) and *tengra* (Mystus catfish). *Gher* farmers depended mainly on hatcheries, nurseries and mobile traders for access to fish seed, but obtained shrimp and prawn postlarvae primarily from postlarvae traders and seed commission agents (Table 18 and Annex 2).


Photo Credit: Yousuf Tushar/WorldFish

Small trader buying shrimp from a farmer in Bagerhat.

Cost item	Fish (HS pond)		Fish+SIS (HS pond)		Pangas (pond)		Koi (pond)		Tilapia (pond)		Carp (pond)		Carp+prawn (pond)	
	Cost (BDT)	% total costs	Cost (BDT)	% total costs	Cost (BDT)	% total costs	Cost (BDT)	% total costs	Cost (BDT)	% total costs	Cost (BDT)	% total costs	Cost (BDT)	% total costs
Total cost (BDT/HH)*	4,978		3,464		367,291		372,275		105,930		90,976		21,667	
Total cost (BDT/ha)	92,727		94,822		1,836,158		2,894,189		517,899		287,560		178,286	
Variable costs (BDT/ha)	76,610	83	80,129	85	1,764,833	96	2,826,381	98	489,169	93	257,927	89	153,780	85
Fish seed	40,816	46	46,368	50	227,042	14	338,073	12	80,019	18	66,372	25	63,922	37
Organic fertilizer	2,157	3	2,557	3	1,060	0.13	6	0	2,348	1	4,942	3	359	0.25
Inorganic fertilizer	3,263	3	2,997	3	3,195	0.31	281	0.02	7,455	3	23,448	7	6,720	4
Chemicals	2,142	3	2,491	3	11,963	1	29,119	1	8,664	2	5,863	2	2,909	2
Feed	15,595	15	10,339	11	1,432,351	75	2,324,899	80	330,127	53	105,859	31	49,366	27
Labor	6,179	7	9,528	10	62,150	4	82,914	3	41,452	12	38,709	16	15,981	9
Other (water supply, repairs, marketing, etc.)	6,458	6	5,848	6	27,073	2	51,088	2	19,103	4	12,734	4	14,524	7
Fixed costs (BDT/ha)	16,116	17	14,693	15	71,324	4	67,809	2	28,731	7	29,633	11	24,507	15
Depreciation	15,154	16	13,914	14	35,551	2	43,217	2	18,537	5	14,352	6	23,655	15
Rental	467	0.21	0	0	18,067	1	4,699	0.15	5,156	1	12,639	4	0	0
Other (land tax, interest on loan, etc.)	495	1	779	1	17,706	1	19,893	1	5,038	1	2,642	1	852	0.43

* HH stand for household.

Table 15. Fish production costs and budget shares by technology (homestead and commercial ponds).

Cost item	Fish (*gher*)		Shrimp (*gher*)		Shrimp+rice (*gher*)		Shrimp+prawn+rice (*gher*)		Prawn+rice (*gher*)		Pangas (*beel*)		Rice-fish	
	Cost (BDT)	% total costs	Cost (BDT)	% total costs	Cost (BDT)	% total costs	Cost (BDT)	% total costs	Cost (BDT)	% total costs	Cost (BDT)	% total costs	Cost (BDT)	% total costs
Total cost (BDT/HH)	143,431		146,576		83,526		85,336		71,357		2,424,108		27,330	
Total cost (BDT/ha)	207,264		98,798		103,300		241,299		209,933		1,039,508		107,323	
Variable costs (BDT/ha)	179,850	87	75,436	76	81,301	79	214,636	89	188,454	90	946,061	89	96,506	90
Fish seed	51,961	25	39,976	41	42,238	42	84,202	35	66,375	31	137,120	14	44,663	42
Organic fertilizer	1,252	1	434	1	685	1	1,054	0.32	549	0.44	1,191	0.13	3,522	4
Inorganic fertilizer	14,312	8	1,955	2	3,262	4	4,328	2	8,805	4	1,189	0	2,585	2
Chemicals	3,977	2	1,806	2	1,844	2	5,676	2	2,808	1	9,300	1	1,690	2
Feed	37,625	18	2,927	3	1,678	2	59,506	24	60,583	29	733,919	68	18,708	16
Labor	55,506	26	26,217	26	29,238	26	44,799	19	33,458	16	56,785	6	13,277	13
Other (water supply, repairs, marketing, etc.)	15,217	7	2,121	2	2,356	3	15,072	7	15,877	8	6,558	1	12,062	11
Fixed costs (BDT/ha)	27,414	13	23,362	24	21,999	21	26,662	11	21,479	10	93,447	11	10,817	10
Depreciation	11,909	6	6,005	7	5,256	6	5,526	3	6,276	3	16,119	2	7,855	8
Rental	12,102	6	15,441	15	14,776	13	12,272	5	13,890	7	62,871	8	2,483	1
Other (land tax, interest on loan, etc.)	3,403	2	1,916	2	1,967	2	8,865	3	1,313	1	14,457	2	479	0.41

Table 16. Fish production costs and budget shares by technology (*ghers*, *beels* and rice-fish).

AQUACULTURE ENTERPRISE BUDGETS AND PERFORMANCE

Fish species name	Fish (HS pond)	Fish+SIS (HS pond)	Pangas (pond)	Koi (pond)	Tilapia (pond)	Carp (pond)	Carp+prawn (pond)	Fish (*gher*)	Shrimp (*gher*)	Shrimp+rice (*gher*)	Shrimp+prawn+rice (*gher*)	Prawn+rice (*gher*)	Pangas (*beel*)	Rice-fish
Indian major carp	99	99	96	12	80	100	94	100	37	12	100	100	100	100
Exotic carps	96	99	78	10	75	100	97	99	44	19	71	92	100	99
Indian minor carp	42	75	13	-	4	50	3	33	3	1	3	9	89	69
Small indigenous species	4	100	-	-	4	2	-	-	-	-	-	-	-	-
Shing	2	3	2	47	9	14	1	4	1	-	-	-	-	4
Pangas	4	-	100	-	4	1	4	6	1	-	2	-	100	1
Tilapia	41	9	52	12	100	24	16	69	38	74	4	3	76	8
Koi	2	-		100	9	2	1	10	-	-	-	0.47	-	12
Other fish	5	3	1	-	1	5	1	6	35	59		0.47	3	2
Chingri or prawn	1	95	-	-	2	1	100	23			100	100	-	-
Tiger shrimp	-	-	-	-	-	-	-	-	100	100	100	-	-	-
Other shrimp	-	-	-	-	-	-	-	-	8	60	-	-	-	

Table 17. Fish species stocking composition by technology (% of households stocking).

Fish species name	Fish (HS pond)	Fish+SIS (HS pond)	Pangas (pond)	Koi (pond)	Tilapia (pond)	Carp (pond)	Carp+prawn (pond)	Fish (*gher*)	Shrimp (*gher*)	Shrimp+rice (*gher*)	Shrimp+prawn+rice (*gher*)	Prawn+rice (*gher*)	Pangas (*beel*)	Rice-fish
Hatchery	28	95	55	65	57	67	61	33	36	37	97	85	57	16
Nursery	30	4	87	56	53	52	36	74	19	2	24	42	73	34
Mobile fish seed trader (*patil wallah*)	87	91	26	8	53	63	75	72	73	88	81	57	8	78
Postlarvae *faria*	-	-	-	-	-	1	31	0.45	8	79	22	9	-	-
Seed commission agent	-	-	1	-	4	-	3	-	59	18	52	12	-	-
Neighboring farmers	10	33	-	-	6	-	1	-	-	-	4	-	-	-
Open source	3	67	-	-	2	2	4	1	7	5	-	0.47	-	-

Table 18. Source of fish seed stocked by technology (% of households obtaining by source).

Fish species name	Fish (HS pond)	Fish+SIS (HS pond)	Pangas (pond)	Koi (pond)	Tilapia (pond)	Carp (pond)	Carp+prawn (pond)	Fish (*gher*)	Shrimp (*gher*)	Shrimp+rice (*gher*)	Shrimp+prawn+rice (*gher*)	Prawn+rice (*gher*)	Pangas (*beel*)	Rice-fish
Total stocking rate (fish only)	345	318	1,699	464	425	544	138	348	42	25	102	112	488	413
Indian major carp	183	112	192	36	90	237	56	165	20	8	85	72	116	156
Exotic carps	124	148	101	39	68	280	74	139	14	4	16	39	104	199
Indian minor carp	13	39	5	-	1	15	1	11	1	0.08	0.27	1	33	52
Small indigenous species	1	16	-	-	0.31	0.08	-	-	-	-	-	-	-	-
Pangas	2	-	1,383	-	2	0.36	2	3	0.11	-	0.08	-	211	1
Shing	0.25	0.23	0.30	56	4	5	0.12	1	0.04	-	-	-	-	1
Tilapia	21	2	17	25	256	5	5	29	5	10	1	0.43	25	3
Koi	0.11	-	-	307	4	0.04	0.01	0.10	-	-	-	0.001	-	0.15
Other fish	1	0.29	1	-	0.02	0.45	0.20	1	2	3	-	0.002	0.11	0.36
Total stocking rate (shrimp only)	-	-	-	-	-	-	-	-	70,027	95,121	65,524	-	-	-
Prawn	48	2,193	-	-	197	51	14,136	1,546	-	-	20,912	21,119	-	-
Tiger shrimp	-	-	-	-	-	-	-	-	68,382	77,071	44,612	-	-	-
Other shrimp	-	-	-	-	-	-	-	-	1644	18,050	-	-	-	-

Table 19. Stocking rates per hectare, by technology
(fish = kg of fingerlings/ha; shrimp and prawn = number of postlarvae/ha).

AQUACULTURE ENTERPRISE BUDGETS AND PERFORMANCE

Fish species name	Fish (HS pond)		Fish+SIS (HS pond)		Pangas (pond)		Koi (pond)		Tilapia (pond)		Carp (pond)		Carp+prawn (pond)	
	Cost	% total costs	Cost	% total costs	Cost	% total costs	Cost	% total costs	Cost	% total costs	Cost	% total costs	Cost	% total costs
Total stocking cost (BDT/HH)	2,135	-	1,665	-	47,412	-	42,861	-	15,238	-	20,394	-	7,742	-
Total stocking cost (BDT/ha)	40,816	100	46,368	100	227,042	100	338,073	100	80,019	100	66,372	100	63,922	100
Indian major carp	21,675	53	12,687	27	23,610	10	5,409	2	13,772	17	32,638	49	8,300	13
Exotic carps	13,279	33	14,825	32	11,248	5	5,071	2	7,959	10	27,650	42	8,985	14
Indian minor carp	1,860	5	4,196	9	716	0.32	-	-	242	0.30	2,522	4	97	0.15
Small indigenous species	90	0.22	3,816	8	-	-	-	-	46	0.06	11	0.02	-	-
Shing	146	0.36	116	0.25	199	0.09	63,942	19	3,557	4	1,897	3	37	0.06
Pangas	275	1	-	-	186,890	82	-	-	337	0.42	99	0.15	270	0.42
Tilapia	3,063	8	252	1	4,289	2	6,842	2	50,243	63	1,129	2	1,275	2
Koi	96	0.24	-	-	-	-	256,809	76	2,983	4	33	0.05	6	0.01
Other	155	0.38	61	0.13	91	0.04	-	-	10	0.01	265	0.40	99	0.15
Prawn	175	0.43	10,415	22	-	-	-	-	868	1	128	0.19	44,853	70
Tiger shrimp	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other shrimp	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 20. Stocking costs for homestead and commercial pond technologies by species (BDT/ha and % of total stocking costs).

Fish species name	Fish (*gher*)		Shrimp (*gher*)		Shrimp+rice (*gher*)		Shrimp+prawn+rice (*gher*)		Prawn+rice (*gher*)		Pangas (*beel*)		Rice-fish	
	Cost	% total costs	Cost	% total costs	Cost	% total costs	Cost	% total costs	Cost	% total costs	Cost	% total costs	Cost	% total costs
Total stocking cost (BDT/HH)	34,676	-	41,259	-	33,345	-	30,472	-	21,593	-	288,712	-	12,017	-
Total stocking cost (BDT/ha)	51,961	100	39,976	100	42,238	100	84,202	100	66,375	100	137,120	100	44,663	100
Indian major carp	19,779	38	3,454	9	792	2	10,913	13	10,472	16	35,565	26	17,754	40
Exotic carps	15,743	30	1,975	5	647	2	2,682	3	5,579	8	27,378	20	19,905	45
Indian minor carp	1,605	3	115	0.29	23	0.06	36	0.04	107	0.16	14,421	11	6,060	14
Small indigenous species	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shing	247	0.47	52	0.13	-	-	-	-	-	-	-	-	278	1
Pangas	300	1	11	0.03	-	-	14	0.02	-	-	51,172	37	103	0.23
Tilapia	8,365	16	628	2	858	2	72	0.09	56	0.08	8,561	6	404	1
Koi	91	0.17	-	-	-	-	-	-	1	0.001	-	-	98	0.22
Other	115	0.22	730	2	1485	4	-	-	1	0.002	22	0.02	61	0.14
Prawn	5,717	11	-	-	-	-	42,294	50	50,159	76	-	-	-	-
Tiger shrimp	-	-	32,860	82	35,941	85	28,190	33	-	-	-	-	-	-
Other shrimp	-	-	151	0.38	2,492	6	-	-	-	-	-	-	-	-

Table 21. Stocking costs for *gher*, *beel* and rice-fish technologies by species (BDT/ha and % of total stocking costs).

AQUACULTURE ENTERPRISE BUDGETS AND PERFORMANCE

The *beel*-based pangas production system was dominated by pangas and carp. All *beel* farmers stocked both (Table 17), which they collected mainly from hatcheries and nurseries (Table 18 and Annex 2). The stocking rate for pangas in *beel* was higher than that of carp (Table 19). However, carp fingerlings accounted for a higher proportion of the fingerling costs (57%) than pangas (34%) did (Table 21), because *beel* farmers generally stocked large carp fingerlings with a high unit value. Tables 17 and 19 show that carp were dominant in rice-fish systems, accounting for about 98% of total fingerling costs (Table 21).

Feed costs

Across technologies, 16 main feed items were used in fish production (Table 22). Three additional items (egg, powdered milk and molasses) were also used as feeds in minimal quantities. Feed use rates and feeding costs were higher in commercial aquaculture technologies than homestead pond and rice-fish technologies (Tables 23 and 24).

The most widely used feed items in homestead-based fish ponds were rice bran (62%–91%), mustard oil cake (27%–46%) and rice products such as boiled rice (36%–40%). (See Tables 22, 23 and 24.) These feeds accounted for about 72%–87% of total feed costs in this system. Commercial aquaculture pond technologies are feed intensive, and large numbers of farmers used pelleted fish feeds. Pangas (pond), koi (pond) and tilapia (pond) culture were the most feed-intensive technologies (Tables 22, 23 and 24). The use of commercial pelleted (sinking and floating) and homemade (pelleted and mixed) feed was common among farmers of pangas (pond), koi (pond) and tilapia (pond) technologies. The contributions of commercial pelleted (sinking), commercial pelleted (floating), homemade pelleted and homemade (mash) feeds to total feed costs in commercial pangas culture in ponds were 46%, 12%, 26% and 15%, respectively. Farmers of koi and tilapia were more dependent on commercial pelleted feed, which comprised about 99% and 85% of total feed costs, respectively. Results show that 57% and 22% of pangas (pond), 80% and 31% of koi (pond), and 26% and 43% of tilapia (pond) farmers were using commercial (sinking) and commercial (floating) feed, respectively. The share of raw feed ingredients (e.g. rice bran, wheat bran) in total feed costs was very low for these technologies.

Most fish and shrimp farms in coastal south and southwest Bangladesh follow extensive culture practices, relying mainly on food produced naturally in the ponds with moderate or minimal use of additional feeds. For commercial *gher* technologies, the most common feed types were mustard oil cake (89%), rice bran (45%), wheat bran (31%), commercial pelleted feed—floating and sinking combined—(30%), and homemade mash (39%). These feed items accounted for around 77% of total feed costs, but were applied at much lower rates than in commercial pond-based technologies.

Shrimp (*gher*) and shrimp+rice (*gher*) culture depended mainly on the food produced naturally in the farming system (i.e. stocked shrimp and other aquatic animals received little, if any, nutrition from supplemental feeds). Feed use in these systems was very low compared to other technologies. Table 22 shows that total feed costs in shrimp (*gher*) and shrimp+rice (*gher*) technologies were just BDT 3028/ha and BDT 1475/ha, respectively, which is much lower than the feeding costs of all other technologies. On the other hand, shrimp+prawn+rice (*gher*) and prawn+rice (*gher*) technologies were both feed dependent. Shrimp+prawn+rice (*gher*) and prawn+rice (*gher*) farmers used commercial pelleted (sinking) feed at a higher percentage (84% and 77%, respectively) than other *gher*-based systems, accounting for over a third of the total feed costs for these technologies. Pelleted feeds were used mainly for prawn production in these systems. Other important feed items used in *gher*-based prawn farming technologies were wheat bran, snail meat, pulses and boiled rice.

In the case of commercial pangas (*beel*) technology, commercial pelleted sinking feed was the most important feed item. This feed was used by about 92% of the farmers at the rate of 23,838 kg/ha, accounting for 90% of feed costs. Use of feed was very limited in rice-fish systems, as fish growth depends on food produced naturally in the system and fertilizer residues from the rice component of the system.

Labor costs

Labor was the third most important cost in aquaculture systems. Labor requirements and costs for each of the technologies are presented in Table 26. Labor requirements are presented as full-time equivalents (FTEs) to provide a comparative indicator of the potential of the technologies to create employment. FTE is a ratio of the total number of paid hours worked during a period (part time, full time and contracted) to full-time working hours. It represents the number of full-time employees that would be required to perform work over a fish production cycle. Full-time working hours are considered to be 40 hours per week. Here, both family and hired labor are included in the FTE calculation. Labor used is categorized as family and hired, and disaggregated for men and women (Table 27). The results in Table 27 are grouped by labor use for different activities (e.g. pond and plot preparation, feeding, weed removal, harvesting and marketing, etc.).

Table 26 shows that the labor requirements for most commercial aquaculture technologies in ponds, *ghers* and *beels* (excluding labor use in crop production) were higher than those in homestead pond-based aquaculture technologies and rice-fish. Annual labor use in fish (HS pond), fish+SIS (HS pond) and rice-fish stood at 208 person-days/ha, 202 person-days/ha and 113 person-days/ha, respectively, reflecting low levels of input use and limited husbandry. As the average size of these resources was very small, this amounted to just 13 person-days, 9 person-days and 30 person-days per household, respectively. Among commercial aquaculture technologies, the highest annual labor requirement was found for commercial koi farming (643 person-days/ha), followed by pangas (pond) at 514 person-days/ha and shrimp+prawn+rice (*gher*), tilapia (pond), carp+prawn (pond), prawn+rice (*gher*), carp (pond), and fish (*gher*), all around 300 person-days/ha. Annual labor requirements for shrimp+rice (*gher*), pangas (*beel*) and shrimp (*gher*) fell between approximately 220 and 250 person-days/ha. Labor costs followed a somewhat similar pattern to labor demand, ranging from a maximum of BDT 82,914/ha/yr for koi (pond) farming to a minimum of BDT 6179/ha/yr for homestead ponds. These results show that some forms of aquaculture can create significant on-farm employment, with koi (pond) culture generating a maximum of 2.47 FTEs per production year for 1 hectare of pond area.

Feeding, followed by harvesting and marketing, collection of inputs, pond preparation, and application of nonfeed inputs were the major work activities in the homestead pond and rice-fish technologies. Together these accounted for 95% of total labor use in fish production in those systems. Feeding, guarding, harvesting and marketing, and pond or plot preparation were the four activities with the highest labor requirements among all commercial technologies except for shrimp (*gher*) and shrimp+rice (*gher*). Very little labor is used for feeding in shrimp (*gher*) and shrimp+rice (*gher*) culture, as these systems depend mainly on naturally occurring food.

Table 27 shows that family was the main source of labor in aquaculture. Except for pangas (*beel*), the share of family labor was greater than that of hired labor across all the aquaculture technologies. Hired labor provided 71% of labor requirements in pangas (*beel*). The share of family labor was 89%–92% in homestead-based ponds, 68%–87% in commercial ponds, 51%–72% in commercial *ghers* and 69% in rice-fish systems. Homestead pond farmers were partially reliant on hired labor for pond preparation and fish harvesting (Table 27). On the other hand, farmers practicing commercial technologies in ponds and *ghers* depended on hired labor mainly for feeding, harvesting and marketing, guarding, pond preparation, and removal of unwanted weeds.

Participation of female labor in aquaculture was much lower than that of men, who accounted for a disproportionately large share of total labor (Table 26). Women household members provided 22% and 25% of total labor in the fish (HS pond) and fish+SIS (HS pond) technologies, respectively. Among commercial ponds, 11%, 5% and 24% of total labor was provided by women family members in the tilapia (pond), carp (pond) and carp+prawn (pond) technologies, respectively. The contribution of female family labor was very small (about 2%) in pangas (pond) and koi (pond) culture. Feeding, collecting inputs, and harvesting and marketing were the main activities women were involved with in homestead and commercial pond technologies. Use of female hired labor in aquaculture ponds was virtually nonexistent.

Feed item	Fish (HS pond)	Fish+SIS (HS pond)	Pangas (pond)	Koi (pond)	Tilapia (pond)	Carp (pond)	Carp+prawn (pond)	Fish (*gher*)	Shrimp (*gher*)	Shrimp+rice (*gher*)	Shrimp+prawn+rice (*gher*)	Prawn+rice (*gher*)	Pangas (*beel*)	Rice-fish
Rice bran	62	91	7	1	42	73	40	50	15	45	9	17	5	34
Rice products	36	40	7	8	11	34	15	2	23	20	33	17	3	42
Wheat products	8	4	2	1	9	13	63	31	5	6	69	44	-	13
Mustard oil cake	46	27	12	2	31	81	28	89	18	14	4	30	35	45
Fish meal	-	-	1	-	1	0.29	21	10	3	-	-	11	-	-
Soybean meal	0.26	-	-	-	-	-	-	-	-	-	13	5	-	-
Snail meat	-	-	-	-	33	-	42	15	-	-	48	51	-	-
Commercial pelleted feed (nursery)	-	-	0.35	-	1	-	-	-	-	-	1	4	-	-
Commercial pelleted feed (sinking)	1	-	57	80	26	38	32	25	9	13	84	77	92	1
Commercial pelleted feed (floating)	1	1	22	31	43	4	1	5	-	-	-	-	5	8
Homemade feed (pellet)	-	-	25	-	-	1	-	-	-	-	-	0.47	27	-
Homemade feed (mash)	2	98	16	-	17	4	10	6	1	5	3	3	14	26
Kitchen waste	5	23	-	-	-	-	-	-	1	2	-	-	-	-
Pulses	-	-	-	-	-	-	-	0.45	1	-	16	41	-	-
Azolla or duckweed	2	-	3	-	14	1	18	2	-	-	-	-	3	-
Other	0.26	-	1	-	2	-	6	-	5	12	1	3	-	1

Table 22. Feed use by technology (% of households using).

Feed item	Fish (HS pond)	Fish+SIS (HS pond)	Pangas (pond)	Koi (pond)	Tilapia (pond)	Carp (pond)	Carp+prawn (pond)	Fish (*gher*)	Shrimp (*gher*)	Shrimp+rice (*gher*)	Shrimp+prawn+rice (*gher*)	Prawn+rice (*gher*)	Pangas (*beel*)	Rice-fish
Rice bran	614	626	237	8	853	1,613	239	401	38	33	45	67	54	224
Rice products	139	86	244	129	177	572	84	28	26	19	170	97	21	295
Wheat products	42	12	31	875	147	144	443	137	7	4	697	302	-	80
Mustard oil cake	251	65	190	2	548	1,331	96	767	31	6	26	104	349	116
Fish meal	-	-	6	-	1	2	300	43	8	-	-	64	-	-
Soybean meal	1	-	-	-	-	-	-	-	-	-	26	47	-	-
Snail meat	-	-	-	-	1,662	-	1,580	205	-	-	595	1,580	-	-
Commercial pelleted feed (nursery)	-	-	26	-	0.31	-	-	-	-	-	2	5	-	-
Commercial pelleted feed (sinking)	7	-	24,399	50,622	4,221	1,231	341	100	11	10	711	818	23,838	3
Commercial pelleted feed (floating)	2	2	4,353	15,395	3,787	102	0.32	61	-	-	-	-	760	52
Homemade feed (pellet)	-	-	17,305	-	-	31	-	-	-	-	-	7	560	-
Homemade feed (mash)	32	116	10,139	-	519	75	60	151	3	3	36	31	778	250
Kitchen waste	7	42	-	-	-	-	-	-	0.25	0.11	-	-	-	-
Pulses	-	-	-	-	-	-	-	1	1	-	176	264	-	-
Azolla or duckweed	20	-	161	-	812	17	737	32	-	-	-	-	4	-
Other	0.27	-	4	-	134	-	13	-	2	3	0.01	8	-	3

Table 23. Feed application rate by technology (kg/ha).

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Cost item	Fish (HS pond)		Fish+SIS (HS pond)		Pangas (pond)		Koi (pond)		Tilapia (pond)		Carp (pond)		Carp+prawn (pond)	
	Cost	% total costs	Cost	% total costs	Cost	% total costs	Cost	% total costs	Cost	% total costs	Cost	% total costs	Cost	% total costs
Total feed cost (BDT/HH)	882	-	401	-	286,155	-	298,840	-	70,864	-	35,057	-	6,408	-
Total feed cost (BDT/ha)	15,595	100	10,339	100	1,432,351	100	2,324,899	100	330,127	100	105,859	100	49,366	100
Rice bran	4,720	30	4,508	44	2,162	0.15	252	0.01	5,611	2	14,416	14	1,647	3
Rice products	2,297	15	1,244	12	3,490	0.24	920	0.04	1,553	0.47	9,174	9	1,366	3
Wheat products	974	6	250	2	625	0.04	24,509	1	2,567	1	3,343	3	7,968	16
Mustard oil cake	6,540	42	1,641	16	4,897	0.34	56	0.002	15,449	5	35,889	34	2,750	6
Fish meal	-	-	-	-	218	0.02	-	-	47	0.01	71	0.07	10,319	21
Soybean meal	35	0.22	-	-	-	-	-	-	-	-	-	-	-	-
Snail meat	-	-	-	-	-	-	-	-	12,002	4	-	-	11,011	22
Commercial pelleted feed (nursery)	-	-	-	-	916	0.06	-	-	11	0.003	-	-	-	-
Commercial pelleted feed (sinking)	205	1	-	-	655,591	46	1,698,391	73	128,461	39	36,855	35	10,521	21
Commercial pelleted feed (floating)	62	0.40	75	1	166,642	12	600,771	26	151,684	46	4,078	4	16	0.03
Homemade feed (pellet)	-	-	-	-	378,323	26	-	-	-	-	685	1	-	-
Homemade feed (mash)	652	4	2,378	23	219,215	15	-	-	10,229	3	1,314	1	1,428	3
Kitchen waste	52	0.34	244	2	-	-	-	-	-	-	-	-	-	-
Pulses	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Azolla or duckweed	40	0.26	-	-	180	0.01	-	-	2,267	1	33	0.03	2,211	4
Other	18	0.11	-	-	90	0.01	-	-	246	0.07	-	-	128	0.26

Table 24. Cost of feed items for homestead and commercial pond technologies (BDT/ha and % of total feed cost).

Cost item	Fish (*gher*)		Shrimp (*gher*)		Shrimp+rice (*gher*)		Shrimp+prawn+rice (*gher*)		Prawn+rice (*gher*)		Pangas (*beel*)		Rice-fish	
	Cost	% total costs	Cost	% total costs	Cost	% total costs	Cost	% total costs	Cost	% total costs	Cost	% total costs	Cost	% total costs
Total feed cost (BDT/HH)	20,339	-	2,445	-	1,206	-	20,839	-	20,911	-	1,707,811	-	5,132	-
Total feed cost (BDT/ha)	37,625	100	2,927	100	1,678	100	59,506	100	60,583	100	733,919	100	18,708	100
Rice bran	3,319	9	503	17	405	24	684	1	796	1	436	0.06	2,522	13
Rice products	495	1	563	19	540	32	3,311	6	1,780	3	329	0.04	3,953	21
Wheat products	2,694	7	172	6	88	5	15,765	26	6,192	10	-	-	1,566	8
Mustard oil cake	20,051	53	851	29	151	9	707	1	2,671	4	9,940	1	3,011	16
Fish meal	1,515	4	312	11	-	-	-	-	2,326	4	-	-	-	-
Soybean meal	-	-	-	-	-	-	890	1	1,330	2	-	-	-	-
Snail meat	1,446	4	-	-	-	-	10,104	17	13,967	23	-	-	-	-
Commercial pelleted feed (nursery)	-	-	-	-	-	-	81	0.14	190	0.31	-	-	-	-
Commercial pelleted feed (sinking)	3,015	8	300	10	286	17	22,615	38	23,612	39	660,563	90	69	0.37
Commercial pelleted feed (floating)	2,400	6	-	-	-	-	-	-	-	-	30,390	4	2,094	11
Homemade feed (pellet)	-	-	-	-	-	-	-	-	137	0.23	12,860	2	-	-
Homemade feed (mash)	2,622	7	53	2	80	5	711	1	753	1	19,390	3	5,317	28
Kitchen waste	-	-	2	0.08	1	0.07	-	-	-	-	-	-	-	-
Pulses	37	0.10	19	1	-	-	4,638	8	6,636	11	-	-	-	-
Azolla or duckweed	32	0.08	-	-	-	-	-	-	-	-	12	0.002	-	-
Other	-	-	151	5	127	8	1	0.002	192	0.32	-	-	177	1

Table 25. Cost of feed items for *gher*, *beel* and rice-fish technologies (BDT/ha and % of total feed cost).

Labor type	Fish (HS pond)	Fish+SIS (HS pond)	Pangas (pond)	Koi (pond)	Tilapia (pond)	Carp (pond)	Carp+prawn (pond)	Fish (*gher*)	Shrimp (*gher*)	Shrimp+rice (*gher*)	Shrimp+prawn+rice (*gher*)	Prawn+rice (*gher*)	Pangas (*beel*)	Rice-fish
Labor use (person-days/ha)	208	202	514	643	303	282	303	276	217	242	311	287	220	113
Labor cost (BDT/ha)	6,179	9,528	62,150	82,914	41,452	38,709	15,981	55,506	26,217	29,238	44,799	33,458	56,785	13,277
Employment, FTE/pond	0.05	0.03	0.40	0.39	0.25	0.34	0.16	0.75	0.84	0.64	0.49	0.46	1.95	0.12
Employment, FTE/ha	0.80	0.78	1.98	2.47	1.17	1.08	1.17	1.06	0.83	0.93	1.20	1.11	0.85	0.43
Wage rate – Men (BDT/day)	333	331	404	432	402	397	343	345	313	305	348	377	363	361
Wage rate – Women (BDT/day)	281		344		352	344	294	295	256	250	296	327	313	291
Difference in wage rate of men compared to women (%)	16	-	15	-	12	13	14	15	18	18	15	13	14	19

Table 26. Labor use by aquaculture technology.

Labor types	Labor use by activity (person-days/ha)									Total labor use (person-days/ ha)	% of total labor use
	Pond preparation	Collection of inputs	Input use	Feeding	Pond monitoring	Harvesting and marketing	Weed removal	Guarding	Other		
Fish (HS pond)											
Male family	15	20	20	43	4	39	-	7	-	146	70
Female family	3	7	3	26	2	3	-	0.23	-	45	22
Male hired	5	1	0.06	1	0.14	8	-	-	-	16	7
Female hired	0.16	0.19	-	-	-	0.02	-	-	-	0.37	0.18
Total labor use (person-days/ha)	**23**	**29**	**23**	**70**	**6**	**51**	**-**	**7**	**-**	**208**	**-**
% of total labor use	**11**	**14**	**11**	**34**	**3**	**24**	**-**	**3**	**-**	**-**	**100**
Fish+SIS (HS pond)											
Male family	14	20	20	47	0.25	27		0.13	0.00	129	64
Female family	7	8	0.76	27	0.44	8				50	25
Male hired	7	0.46	2.57	0.47	0.15	13				23	12
Female hired										-	-
Total labor use (person-days/ha)	**27**	**29**	**23**	**74**	**0.74**	**48**		**0.13**		**202**	**-**
% of total labor use	**13**	**14**	**12**	**37**	**1**	**23**	**-**	**0.06**	**-**	**-**	**100**
Pangas (pond)											
Male family	13	13	18	206	8	25	2	72	0.07	356	69
Female family	0.01	0.60	0.02	2	-	0.02	-	0.45	-	3	1
Male hired	15	3	5	50	2	51	2	26	0.04	153	30
Female hired	0.17	-	-	1	-	-	-	-	-	1	0.28
Total labor use (person-days/ha)	**28**	**16**	**23**	**259**	**11**	**76**	**4**	**98**	**0.11**	**514**	**-**
% of total labor use	**5**	**3**	**4**	**50**	**2**	**15**	**1**	**19**	**0.02**	**-**	**100**
Koi (pond)											
Male family	18	11	24	210	8	24	-	147	5	448	70
Female family	1	-	-	13	-	-	-	-	-	14	2
Male hired	20	3	9	50	4	53	-	40	2	181	28
Female hired	-	-	-	-	-	-	-	-	-	-	-
Total labor use (person-days/ha)	**39**	**14**	**33**	**273**	**12**	**78**	**-**	**187**	**8**	**643**	**-**
% of total labor use	**6**	**2**	**5**	**42**	**2**	**12**	**-**	**29**	**1**	**-**	**100**
Tilapia (pond)											
Male family	12	17	19	74	6	32	-	17	-	176	58
Female family	0.38	2	0.67	26	0.23	2	-	0.77	-	32	11
Male hired	21	3	5	19	2	35	-	9	-	94	31
Female hired	0.56	0.10	-	1	-	-	-	-	-	2	1
Total labor use (person-days/ha)	**34**	**21**	**25**	**120**	**8**	**69**	**-**	**26**	**-**	**303**	**-**
% of total labor use	**11**	**7**	**8**	**40**	**3**	**23**	**-**	**9**	**-**	**-**	**100**

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Labor types	Labor use by activity (person-days/ha)									Total labor use (person-days/ha)	% of total labor use
	Pond preparation	Collection of inputs	Input use	Feeding	Pond monitoring	Harvesting and marketing	Weed removal	Guarding	Other		
Carp (pond)											
Male family	15	16	18	78	5	25	-	19	-	177	63
Female family	0.22	2	0.89	11	0.50	0.97	-	0.50	-	15	5
Male hired	16	2	2	19	4	43	-	5	-	89	32
Female hired	0.11	-	-	0.06	-	0.03	-	-	-	0.19	0.07
Total labor use (person-days/ha)	**31**	**20**	**20**	**108**	**10**	**69**	**-**	**24**	**-**	**282**	**-**
% of total labor use	**11**	**7**	**7**	**38**	**4**	**25**	**-**	**9**	**-**	**-**	**100**
Carp+prawn (pond)											
Male family	22	13	15	69	0.12	26	3	44	-	192	63
Female family	4	7	0.74	46	-	1	4	11	-	73	24
Male hired	14	1	0.46	2	0.09	18	0.19	1	-	37	12
Female hired	0.50	-	-	-	-	-	-	-	-	0.50	0.16
Total labor use (person-days/ha)	**40**	**20**	**16**	**117**	**0.21**	**46**	**7**	**56**	**-**	**303**	**-**
% of total labor use	**13**	**7**	**5**	**39**	**0.07**	**15**	**2**	**19**		**-**	**100**
Fish (*gher*)											
Male family	17	14	14	41	4	28	0.37	15	0.01	133	48
Female family	0.54	1	0.31	6	0.04	0.69	0.22	0.15	-	9	3
Male hired	39	4	5	42	2	27	1	5	0.14	125	45
Female hired	3	0.10	0.23	5	-	0.32	0.39	-	-	9	3
Total labor use (person-days/ha)	**59**	**20**	**19**	**94**	**6**	**56**	**2**	**21**	**0.15**	**276**	**-**
% of total labor use	**21**	**7**	**7**	**34**	**2**	**20**	**1**	**7**	**0.05**	**-**	**100**
Shrimp (*gher*)											
Male family	8	10	9	8	3	39	2	46	-	125	58
Female family	1	3	0.08	0.97	0.16	2	2	1	-	10	5
Male hired	20	2	2	2	0.91	11	0.83	12	-	51	24
Female hired	12	0.23	0.02	-	-	0.02	18	-	-	30	14
Total labor use (person-days/ha)	**42**	**14**	**11**	**11**	**4**	**52**	**23**	**60**	**-**	**217**	**-**
% of total labor use	**19**	**6**	**5**	**5**	**2**	**24**	**11**	**27**	**-**	**-**	**100**
Shrimp+rice (*gher*)											
Male family	13	11	10	1	2	33	2	69	-	141	58
Female family	3	0.40	0.63	0.07	0.08	1	0.44	0.69	-	7	3
Male hired	30	2	2	0.68	0.53	6	0.99	11	-	53	22
Female hired	17	-	-	1.27	-	0.02	22	0.22	-	41	17
Total labor use (person-days/ha)	**63**	**13**	**12**	**3**	**3**	**41**	**26**	**81**	**-**	**242**	**-**
% of total labor use	**26**	**5**	**5**	**1**	**1**	**17**	**11**	**33**	**-**	**-**	**100**
Shrimp+prawn+rice (*gher*)											
Male family	12	5	5	51	5	26	4	63	-	172	55
Female family	3	1	0.48	16	0.02	0.64	0.64	1	-	23	7
Male hired	32	0.36	0.86	15	2	27	2	13	-	91	29
Female hired	4	0.07	1	20	-	-	-	-	-	26	8
Total labor use (person-days/ha)	**51**	**7**	**8**	**102**	**7**	**54**	**7**	**77**	**-**	**311**	**-**
% of total labor use	**16**	**2**	**3**	**33**	**2**	**17**	**2**	**25**	**-**	**-**	**100**

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Labor types	Labor use by activity (person-days/ha)									Total labor use (person-days/ha)	% of total labor use
	Pond preparation	Collection of inputs	Input use	Feeding	Pond monitoring	Harvesting and marketing	Weed removal	Guarding	Other		
Prawn+rice (*gher*)											
Male family	16	12	15	50	5	25	1	51	0.06	176	61
Female family	4	2	0.58	21	0.24	0.99	2	0.43	-	32	11
Male hired	24	1	0.95	11	0.75	22	0.91	2	-	62	22
Female hired	9	0.22	-	6	-	0.54	1	-	-	17	6
Total labor use (person-days/ha)	**54**	**16**	**16**	**87**	**6**	**49**	**5**	**54**	**0.06**	**287**	**-**
% of total labor use	**19**	**6**	**6**	**30**	**2**	**17**	**2**	**19**	**0.02**	**-**	**100**
Pangas (*beel*)											
Male family	2	2	3	28	1	6	1	20	-	63	29
Female family	-	-	-	-	-	-	-	-	-	-	-
Male hired	5	2	4	64	2	26	3	51	-	157	71
Female hired	0.01	-	-	-	-	-	-	-	-	0.01	0.004
Total labor use (person-days/ha)	**7**	**5**	**7**	**92**	**3**	**32**	**4**	**71**	**-**	**220**	**-**
% of total labor use	**3**	**2**	**3**	**42**	**1**	**15**	**2**	**32**		**-**	**100**
Rice-fish											
Male family	5	11	7	21	2	10	-	7	-	64	57
Female family	1	6	0.17	4	-	0.13	-	2	-	13	12
Male hired	11	0.35	0.28	6	0.24	16	-	0.50	-	35	31
Female hired	0.26	-	-	0.76	-	-	-	-	-	1	1
Total labor use (person-days/ha)	**18**	**17**	**8**	**32**	**2**	**26**	**-**	**10**	**-**	**113**	**-**
% of total labor use	**16**	**15**	**7**	**28**	**2**	**23**		**9**		**-**	**100**

Table 27. Labor use by activity and technology.

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Among *gher*-based technologies, the contribution of women's work to total labor was in a similar range to that in pond-based technologies, but hired female labor accounted for a greater share of women's labor than female family labor in all but prawn+rice (pond). The contributions of female labor in the fish (*gher*), shrimp (*gher*), shrimp+rice (*gher*), shrimp+prawn+rice (*gher*) and prawn+rice (*gher*) technologies were 6% (family: 3%, hired: 3%); 19% (family: 5%, hired 14%); 20% (family: 3%, hired 17%); 15% (family: 7%, hired 8%); and 17% (family: 11%, hired 6%), respectively. There was no participation of female labor in pangas (*beel*) technology. The contribution of family and hired female labor in rice-fish technology was 12% and 1%, respectively.

The disparity between male and female labor participation in aquaculture was raised with fish producers during group discussions. Explanations given for this gap included the distance of the waterbody from the homes, social norms and religious restrictions, and a lack of skills. Results presented in Table 26 show that differences also exist in the wage rates earned by men and women. Estimates across all the technologies show that women earned 12%–19% less than men for comparable work. During discussions, many male farmers reported that they set differential wages for male and female workers with practically no resistance. In individual discussion with women, the reasons cited for accepting lower wages were a lack of higher-paying alternatives and the high supply of female labor relative to demand.

Productivity and returns

Tables 28 and 29 present the productivity (yield) in kg/ha and gross return in BDT/ha for the aquaculture technologies. Results indicate that commercial technologies were more productive and generated higher gross returns than homestead and rice-fish technologies. Tables 28 and 31 show that productivity and returns from fish (HS pond) and fish+SIS (HS pond) were 1759 kg/ha and 1687 kg/ha, and 150,841 BDT/ha and 175,569 BDT/ha, respectively. Tables 28 and 30 also show that productivity and returns per household were 95 kg and 59 kg, and BDT 8114 and BDT 6098, respectively, for the above homestead technologies. In the fish (HS pond) technology, carp contributed 87% and 86% of fish biomass and returns, respectively.

In the fish+SIS (HS pond) technology, the contributions of carp to total fish biomass and returns were 83% and 75%, respectively, with 13% of the total production coming from small indigenous species, as compared to only 2% in the fish (HS pond) system. The contribution of small indigenous species to monetary return in the fish+SIS (HS pond) technology was 15%, as compared to 3% in the fish (HS pond) system. These results indicate that stocking small indigenous species in the homestead-based system increases small indigenous species production, with little tradeoff with carp production.

Among pond-based commercial aquaculture technologies, koi (pond) farming was the most productive and generated the highest returns (33,036 kg/ha and BDT 3,504,941/ha), followed by the commercial technologies in ponds such as pangas (pond) at 32,688 kg/ha and BDT 2,421,458/ha, tilapia (pond) at 8856 kg/ha and BDT 783,843/ha, carp (pond) at 4754 kg/ha and BDT 567,282/ha, and carp+prawn (pond) at 2429 kg/ha and BDT 439,925/ha. Tables 28 and 30 show that for each of the technologies, the main target species contributed more than 60% of total production and returns.

Tables 29 and 31 show that fish (*gher* farming was the most productive *gher*-based technology in terms of volume (3275 kg/ha), followed by prawn+rice (*gher*) at 1736 kg/ha, prawn+shrimp+rice (*gher*) at 1577 kg/ha, shrimp+rice (*gher*) at 857 kg/ha and shrimp (*gher*) at 860 kg/ha. However, in terms of value, prawn+shrimp+rice (*gher*) farming generated the highest gross returns (BDT 509,191/ha), followed by prawn+rice (*gher*) at BDT 465,234/ha, fish (*gher*) at BDT 332,171/ha, shrimp (*gher*) at BDT 205,302/ha and shrimp+rice (*gher*) at BDT 181,445/ha. Carp were the dominant fish in terms of harvested biomass in fish (*gher*), shrimp+prawn+rice (*gher*) and prawn+rice (*gher*) technologies. The major contribution in shrimp (*gher*) and shrimp+rice (*gher*) technologies came from shrimp and tilapia. The target species (shrimp) contributed 71% and 63% of the returns in the shrimp (*gher*) and shrimp+rice (*gher*) technologies, respectively. The contribution of shrimp and prawn to total returns in the shrimp+prawn+rice (*gher*) and prawn+rice (*gher*) technologies was 77% and 67%, respectively. The pangas (*beel*) system was dominated by pangas and carp, and was a highly productive technology with a yield of 22,046 kg/ha, generating gross returns of BDT 1,522,458/ha. Pangas and carp contributed more than 90% of total fish biomass and returns. The rice-fish production system was dominated by carp species. Total fish production and gross returns in rice-fish stood at 2221 kg/ha and BDT 188,781/ha, respectively. The share of carp in biomass and gross returns in rice-fish was about 96%.

Annexes 3 and 4 present differences in productivity and fish prices by fish species and location. Annex 3 shows that differences in productivity existed across hubs. In the fish (HS pond) technology, productivity varied from a minimum of 1478 kg/ha in Dinajpur hub to a maximum of 2129 kg/ha in Barisal hub. Among commercial technologies in ponds, fish productivity ranged from 22,195 kg/ha in Jessore hub to 41,575 kg/ha in Mymensingh hub for pangas (pond), from 4514 kg/ha in Faridpur hub to 19,326 kg/ha in Mymensingh hub for tilapia (pond), and from 3592 kg/ha in Dinajpur hub to 6278 kg/ha outside the hubs for carp (pond). Among commercial technologies in *ghers*, fish productivity was lowest at 3061 kg/ha in Jessore hub and highest at 3612 kg/ha in Barisal hub for fish (*gher*), lowest at 382 kg/ha in Cox's Bazar district (outside the hubs) and highest at 999 kg/ha in Khulna hub for shrimp (*gher*), and lowest at 1109 kg/ha in Khulna hub and highest at 2414 kg/ha in Faridpur hub for prawn+rice (*gher*) technologies. Annex 4 shows that farm gate prices were higher in districts outside the main hubs for most species.

Tables 32 and 33 show how harvested fish were disposed. The proportion of fish sold was more than 75% of total harvest in commercial ponds, rice-fish plots, *ghers* and *beels*. The opposite was observed for homestead pond-based technologies, for which 55%–70% of total production was consumed by the household, and 27%–41% of harvested fish were sold to the market. The distribution of fish among neighbors and relatives, particularly during festivals, is a cultural tradition of the Bengali community (Jahan et al. 2010). Evidence of gifting fish to neighbors and relatives is also observed in Table 32.

Production performance of surveyed technologies

The gross margin, net margin and benefit-cost ratios were calculated to evaluate the production performance of the aquaculture technologies studied (Tables 34 and 35). Gross margin was determined by subtracting operating costs from gross return. Net margin was calculated by subtracting operating and fixed costs from gross return. The benefit-cost ratio is the ratio of gross margin to operating costs. Results in the previous chapter show that many households adopted integrated management practices by using the waterbody dike for growing vegetables and/or the rice plot or *gher* for rice production, either alternatively or concurrently with fish. The financial benefit added to the system by vegetable cropping on dikes or rice production in *ghers* is also estimated in Tables 34 and 35.

From Tables 34 and 35 it is evident that regardless of the technology deployed, all farm types were able to generate profits on average (positive gross margin). This indicates that farms were effectively managing operating expenses relative to the value of output. The highest gross margin from fish came from koi (pond) at BDT 678,357/ha. This was closely followed by pangas (pond) and pangas (*beel*). The gross margin for carp (pond), shrimp+prawn+rice (*gher*), tilapia (pond), carp+prawn (pond) and prawn+rice (*gher*) all stood at close to BDT 300,000/ha, while the gross margin for fish (*gher*), shrimp (*gher*), shrimp+rice (*gher*), rice-fish and fish+SIS (HS pond) technologies ranged from approximately BDT 150,000 to BDT 100,000/ha. The lowest gross margin was derived from fish (HS pond) at BDT 73,819/ha. Tables 34 and 35 show that farmers across technologies received positive net margins from aquaculture production, on average. Ranking technologies in terms of net margin exhibits a similar pattern to gross margin.

The benefit-cost ratio is calculated by dividing the benefits (gross margin) associated with each technology by the operating costs (variable costs). If the ratio is less than zero, then the costs exceed the benefits. However, if the ratio is greater than zero, then benefits exceed costs. From highest to lowest, benefit-cost ratios ranged from 2.00 for shrimp

Production	Fish (HS pond)		Fish+SIS (HS pond)		Pangas (pond)		Koi (pond)		Tilapia (pond)		Carp (pond)		Carp+prawn (pond)	
	Production	% total production	Production	% total production	Production	% total production	Production	% total production	Production	% total production	Production	% total production	Production	% total production
Total fish production (kg/HH)	95	-	59	-	6,373	-	4,285	-	1,920	-	1,289	-	299	-
Total fish production (kg/ha)	1,759	100	1,687	100	32,688	100	33,036	100	8,856	100	4,754	100	2,429	100
Indian major carp	758	43	559	33	1,571	5	152	0.46	1,035	12	2,008	42	769	32
Exotic carps	708	40	681	40	1,162	4	95	0.29	1,028	12	2,352	49	1,170	48
Indian minor carp	72	4	177	10	43	0.13	-	-	13	0.15	198	4	8	0.32
Small indigenous species	42	2	227	13	2	0.01	-	-	13	0.14	27	1	0.36	0.01
Shing	6	0.35	3	0.18	5	0.01	964	3	118	1	36	1	2	0.08
Pangas	13	1	-	-	29,324	90	-	-	35	0.40	3	0.06	30	1
Tilapia	127	7	3	0.19	567	2	1,253	4	6,279	71	111	2	77	3
Koi	3	0.19	-	-	-	-	30,572	93	314	4	2	0.036	1	0.03
Other	30	2	13	1	13	0.04	-	-	17	0.19	17	0.361	77	3
Prawn	1	0.06	24	1	-	-	-	-	5	0.06	0.26	0.005	296	12
Tiger shrimp	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other shrimp	-	-	-	-	-	-	-	-	-	-	0.11	0.002	-	-

Table 28. Fish yields from homestead and commercial pond technologies (kg/ha and % contribution of fish species to total production).

Production	Fish (*gher*)		Shrimp (*gher*)		Shrimp+rice (*gher*)		Shrimp+prawn+rice (*gher*)		Prawn+rice (*gher*)		Pangas (*beel*)		Rice-fish	
	Production	% total production	Production	% total production	Production	% total production	Production	% total production	Production	% total production	Production	% total production	Production	% total production
Total fish production (kg/HH)	2,181	-	813	-	605	-	549	-	579	-	49,990	-	553	-
Total fish production (kg/ha)	3,275	100	860	100	857	100	1,577	100	1,736	100	22,046	100	2,221	100
Indian major carp	1,192	36	115	13	29	3	623	40	709	41	3,216	15	774	35
Exotic carps	1,129	34	66	8	19	2	184	12	485	28	3,018	14	1,073	48
Indian minor carp	93	3	12	1	0.23	0.03	2	0.13	12	1	595	3	289	13
Small indigenous species	22	1	3	0.39	0.43	0.05	26	2	19	1	-	-	38	2
Shing	5	0.16	2	0.28	-	-	0.08	0.005	-	-	-	-	3	0.13
Pangas	24	1	1	0.07	-	-	1	0.06	-	-	13,673	62	-	-
Tilapia	728	22	222	26	291	34	31	2	9	0.49	1,533	7	22	1
Koi	4	0.13	3	0.34	-	-	5	0.29	1	0.05	-	-	5	0.20
Other	41	1	134	16	134	16	96	6	48	3	10	0.05	18	1
Prawn	36	1	-	-	-	-	357	23	453	26	-	-	-	-
Tiger shrimp	-	-	274	32	271	32	251	16	-	-	-	-	-	-
Other shrimp	2	0.05	27	3	113	13	2	0.14	-	-	-	-	-	-

Table 29. Fish yields from *gher*, *beel* and rice-fish technologies (kg/ha and % contribution of fish species to total production).

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Gross return	Fish (HS pond)		Fish+SIS (HS pond)		Pangas (pond)		Koi (pond)		Tilapia (pond)		Carp (pond)		Carp+prawn (pond)	
	Return	% total return	Return	% total return	Return	% total return	Return	% total return	Return	% total return	Return	% total return	Return	% total return
Gross fish return (BDT/HH)	8,114	-	6,098	-	481,605	-	457,032	-	169,078	-	171,558	-	56,298	-
Gross fish return (BDT/ha)	150,841	100	175,569	100	2,421,458	100	3,504,941	100	783,843	100	567,282	100	439,925	100
Indian major carp	69,129	46	57,503	33	147,996	6	13,666	0.39	100,223	13	296,562	52	89,937	20
Exotic carps	52,746	35	55,950	32	89,090	4	7,288	0.21	80,742	10	222,845	39	99,851	23
Indian minor carp	6,979	5	18,226	10	4,010	0.17	-	-	1,211	0.15	19,977	4	684	0.16
Small indigenous species	4,137	3	26,933	15	108	0.004	-	-	1,605	0.20	3,030	1	26	0.01
Shing	1,791	1	330	0.19	1,256	0.05	259,946	7	36,639	5	12,056	2	471	0.11
Pangas	1,045	1	-	-	2,134,278	88	-	-	2,427	0.31	240	0.04	2,818	1
Tilapia	8,873	6	357	0.20	43,644	2	103,072	3	521,706	67	9,218	2	7,391	2
Koi	427	0.28	-	-	-	-	3,120,969	89	34,773	4	540	0.10	138	0.03
Other	5,469	4	2,728	2	1,076	0.04	-	-	2,370	0.30	2,638	0.47	7,959	2
Prawn	245	0.16	13,544	8	-	-	-	-	2,147	0.27	153	0.03	230,650	52
Tiger shrimp	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other shrimp	-	-	-	-	-	-	-	-	-	-	22	0.004	-	-

Table 30. Gross return from fish production in homestead and commercial pond technologies (BDT/ha and % contribution of fish species to total returns).

Gross return	Fish (*gher*)		Shrimp (*gher*)		Shrimp+rice (*gher*)		Shrimp+prawn+rice (*gher*)		Prawn+rice (*gher*)		Pangas (*beel*)		Rice-fish	
	Return	% total return	Return	% total return	Return	% total return	Return	% total return	Return	% total return	Return	% total return	Return	% total return
Gross fish return (BDT/HH)	202,035	-	231,834	-	150,605	-	192,408	-	155,957	-	3,517,435	-	48,339	-
Gross fish return (BDT/ha)	332,171	100	205,302	100	181,445	100	509,191	100	465,234	100	1,522,458	100	188,781	100
Indian major carp	123,180	37	13,051	6	3,079	2	86,097	17	96,500	21	286,447	19	66,766	35
Exotic carps	95,571	29	5,710	3	1,463	1	19,204	4	47,062	10	214,904	14	88,334	47
Indian minor carp	7,584	2	2,128	1	64	0.04	171	0.03	1,206	0.26	50,891	3	25,548	14
Small indigenous species	2,408	1	199	0.10	42	0.02	1,682	0.33	1,606	0.35	-	-	2,316	1
Shing	1,356	0.41	899	0.44	-	-	26	0.01	-	-	-	-	1,280	1
Pangas	1,868	1	54	0.03	-	-	76	0.01	-	-	856,835	56	-	-
Tilapia	66,212	20	10,899	5	16,677	9	2,633	1	629	0.14	112,561	7	1,868	1
Koi	445	0.13	300	0.15	-	-	567	0.11	121	0.03	-	-	496	0.26
Other fish	4,822	1	21,593	11	25,540	14	9,527	2	5,273	1	821	0.05	2,175	1
Prawn	28,434	9	-	-	-	-	226,989	45	312,837	67	-	-	-	-
Tiger shrimp	-	-	145,041	71	114,822	63	161,991	32	-	-	-	-	-	-
Other shrimp	289	0.09	5,428	3	19,758	11	228	0.04	-	-	-	-	-	-

Table 31. Gross return from fish production in *gher*, *beel* and rice-fish technologies (BDT/ha and % contribution by fish species).

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Production	Fish (HS pond)		Fish+SIS (HS pond)		Pangas (pond)		Koi (pond)		Tilapia (pond)		Carp (pond)		Carp+prawn (pond)	
	Quantity	% total	Quantity	% total	Quantity	% total	Quantity	% total	Quantity	% total	Quantity	% total	Quantity	% total
Sold	39	41	16	27	6,327	99	4,237	99	1,880	98	1,247	97	254	85
Consumed	52	55	41	70	23	0	19	0	27	1	34	3	42	14
Given away	4	4	2	3	23	0	30	1	13	1	8	1	3	1
Total production	95	100	59	100	6,373	100	4,285	100	1,920	100	1,289	100	299	100

Table 32. End use of harvested fish from homestead and commercial ponds (kg and %).

Production	Fish (*gher*)		Shrimp (*gher*)		Shrimp+rice (*gher*)		Shrimp+prawn+rice (*gher*)		Prawn+rice (*gher*)		Pangas (*beel*)		Rice-fish	
	Quantity	% total	Quantity	% total	Quantity	% total	Quantity	% total	Quantity	% total	Quantity	% total	Quantity	% total
Sold	2,116	97	706	87	504	83	489	89	516	89	49,831	100	514	93
Consumed	56	3	91	11	82	14	51	9	55	9	90	0	33	6
Given away	9	0	15	2	18	3	8	2	8	1	62	0	7	1
Total production	2,181	100	813	100	605	100	549	100	579	100	49,983	100	553	100

Table 33. End use of harvested fish from *gher*, *beel* and rice-fish technologies (kg and %).

Item	Fish (HS pond)	Fish+SIS (HS pond)	Pangas (pond)	Koi (pond)	Tilapia (pond)	Carp (pond)	Carp+prawn (pond)
Fish gross margin (BDT/ha)	74,057	95,440	656,624	678,561	294,674	309,355	286,145
Fish net margin (BDT/ha)	57,941	80,747	585,300	610,752	265,943	279,722	261,639
Fish benefit-cost ratio	1.50	1.33	0.40	0.27	1.03	1.65	2.01
Fish gross margin (BDT/HH)	3,986	3,121	128,137	92,987	68,312	89,871	36,986
Fish net margin (BDT/HH)	3,128	2,634	114,314	84,757	63,148	80,582	34,631
Fish + dike crops gross margin (BDT/HH)	5,338	3,256	130,260	93,860	76,278	101,537	44,109
Fish + dike crops net margin (BDT/HH)	4,474	2,769	116,232	85,474	71,054	91,854	41,739
Increase in gross margin due to dike cropping (% increase over fish gross margin)	34	4	2	1	12	13	19
Increase in net margin due to dike cropping (% increase over fish net margin)	43	5	2	1	13	14	21

Table 34. Summary of aquaculture system performance (pond technologies).

Item	Fish (*gher*)	Shrimp (*gher*)	Shrimp+rice (*gher*)	Shrimp+prawn+rice (*gher*)	Prawn+rice (*gher*)	Pangas (*beel*)	Rice-fish
Gross margin of fish (BDT/ha)	152,320	129,866	100,144	294,555	276,780	576,114	92,275
Net margin of fish (BDT/ha)	124,906	106,505	78,145	267,892	255,301	482,666	81,458
Fish benefit-cost ratio	0.95	2.00	1.76	1.48	1.55	0.85	1.11
Fish gross margin (BDT/HH)	87,085	137,871	84,091	115,336	92,255	1,357,974	23,851
Fish net margin (BDT/HH)	58,604	85,258	67,079	107,072	84,601	1,092,741	21,009
Fish + dike crops gross margin (BDT/HH)	90,250	137,939	84,106	124,123	105,921	1,364,788	23,892
Fish + dike crops net margin (BDT/HH)	61,022	85,315	67,073	115,280	97,627	1,093,871	21,026
Fish + dike crops + rice gross margin (BDT/HH)	110,410	137,939	103,004	137,829	134,307	1,364,788	50,457
Fish + dike crops + rice net margin (BDT/HH)	78,464	85,315	82,514	127,078	124,150	1,093,871	47,209
Increase in gross margin due to dike cropping (% increase over fish gross margin)	4	0.05	0.02	8	15	0.50	0.17
Increase in gross margin due to rice farming (% increase over fish + dike gross margin)	22	-	23	11	27	-	111
Increase in net margin due to dike farming (% increase over fish net margin)	4	0.07	0.00	8	15	0.10	0.08
Increase in net margin due to rice farming (% increase over fish + dike net margin)	29	-	23	10	27	-	125

Table 35. Summary of aquaculture system performance (*gher*, *beel* and rice-fish technologies).

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(*gher*) to 0.27 for koi (pond). A comparison of technologies indicates that benefit-cost ratios for technologies that are mostly or partially dependent on natural productivity for fish growth were higher than those that depend on feed and labor-intensive technologies. However, it should be noted that despite a lower benefit-cost ratio, technologies utilizing greater feed and labor inputs tended to have higher gross margins per unit area than those with fewer inputs.

A special aspect of aquaculture technologies in Bangladesh is the integration of fish farming with agriculture. It is said that integrated farming approaches reduce spending on feeds and organic fertilizers, and can thereby increase a farm's overall profit margin (Jahan et al. 2011). This study shows that except for some intensive commercial technologies (koi [pond], pangas [pond] and pangas [*beel*]) and brackish-water technologies (shrimp [*gher*] and shrimp+rice [*gher*]), the integration of dikes and rice plots with aquaculture did increase the profit margin of the farming system.

Summary

The objectives of this chapter were to assess the technical and economic performance of aquaculture technologies in Bangladesh. Results show that all the technologies surveyed were polyculture, but dominated by one or two major fish species or species groups (e.g. carp, pangas, prawn, shrimp, tilapia, koi, etc.). The study found that carp were the most commonly cultured species across all technologies. Small indigenous species were deliberately stocked in the fish+SIS (HS pond) system, but a small number of small indigenous species were also observed in most other technologies during harvest. These were not usually stocked, and mainly entered ponds or *ghers* from open water bodies.

Results show that commercial aquaculture technologies in ponds, *ghers* and *beels* are capital intensive and demand more investment than homestead pond technologies. Feed, fish seed and labor were identified as the three main expenses, which together accounted for 75%–80% of the total costs for fish production. Feed accounted for the largest share of costs in feed-intensive commercial technologies in ponds and *beels*. Seed accounted for the major share of costs in homestead ponds, *ghers* and rice-fish systems. Commercial pond-based technologies had high levels of inputs and high levels of production. Their economic returns were also high compared to homestead pond-based aquaculture technologies.

Access to formal and informal sources of credit and marketing networks is vital for facilitating aquaculture development. The availability and characteristics of credit and markets are also important factors in influencing farmers' decisions about aquaculture investments. The first section of this chapter characterizes the nature and type of credit available to aquaculture producers in Bangladesh. The second section discusses harvesting and marketing practices and postharvest handling.

Types of aquaculture credit

Tables 36 and 37 show that a higher share of commercial farmers (pond, *gher* and *beel*) accessed credit for aquaculture than those practicing homestead pond and rice-fish technologies. Among commercial fish farmers, 92% of pangas (*beel*) farmers and 80% of koi (pond) farmers reported accessing credit in order to fund their operations, as compared to 21% of tilapia (pond) and 16% of carp (pond) farmers. Conversely, only 1% of fish (HS pond) households and 4% of rice-fish households accessed credit for fish culture. As indicated in Tables 36 and 37, farmers received loans in three forms: in cash, in kind, and both in cash and in kind. Farmers were asked about loan requirements during interviews and group discussions. Most respondents mentioned that their purpose was to cover expenses related to the purchase of inputs (seed, feed, fertilizers, chemicals and labor). Some commercial farmers, especially koi (pond), pangas (pond) and shrimp (*gher*) farmers, also mentioned that they used loans to rent land or purchase machinery and equipment.

Sources of cash loans and repayment schedules

Table 38 presents data on the characteristics of cash loans. Farmers received cash loans from both formal and informal sources. Of the formal financial institutions, public and private banks, the Bangladesh Rural Development Board (BRDB), and NGOs were the most common sources of loans for fish culture. The informal lending sector included relatives or neighbors and informal moneylenders (*mahajon* or *dadander*). Hishamunda and Manning (2002) have emphasized the importance of informal credit sources for rural farmers with very limited access to formal finance sources. Loans from these informal sources do not always require collateral (Thillairajah 1994).

Table 38 reveals that commercial pond farmers across all technologies accessed cash loans from banks, NGOs, and relatives or neighbors. Among commercial pond farmers who took loans, a high proportion accessed them from banks (33%–64%), followed by NGOs (23%–33%) and relatives or neighbors (18%–33%). Five percent of koi (pond) farm operators had access to BRDB loans, and 5% and 10% of koi (pond) and carp (pond) farmers, respectively, took loans from informal moneylenders. The majority of *gher* and rice-fish farmers took loans from NGOs (56%–68%), followed by banks (26%–40%), relatives or neighbors (5%–15%), informal moneylenders (3%–15%), wholesalers (*arotder*; 1%–10%), and BRDB (2%–5%). The remoteness of *gher*-farming households, large-scale NGO activities in these areas, and frequent communication between NGO staff and *gher* and rice-fish farming households may be reasons for the higher incidence of NGO loans in the *gher*-farming areas, as compared to commercial pond aquaculture. Only 17% of pangas (*beel*) farmers took cash loans, and all of these obtained them from banks.

Among borrowers of cash loans, the largest average loans were taken by pangas (*beel*) farmers (BDT 795,833) followed by carp (pond) farmers at BDT 128,306. The average value of cash loans varied from BDT 92,027 to BDT 18,297 across all other technologies. On average, across all technologies, farmers received larger loans from banks (BDT 111,420) than moneylenders (BDT 58,222), relatives or neighbors (BDT 48,634), wholesalers (BDT 40,667), NGOs (BDT 30,064), or BRDB (BDT 15,571). The usual mode of repayment was in cash, although a few farmers of shrimp (*gher*), shrimp+rice (*gher*) and prawn+rice (*gher*) also repaid the principal borrowed both in cash and in kind (harvested shrimp or prawn). Thus, the majority of informal credit supplied for aquaculture was not output-tied.

Indicators No. of HH		Fish (HS pond)		Fish+SIS (HS pond)		Pangas (pond)		Koi (pond)		Tilapia (pond)		Carp (pond)		Carp+prawn (pond)	
		No. of HH	% total HH	No. of HH	% total HH	No. of HH	% total HH	No. of HH	% total HH	No. of HH	% total HH	No. of HH	% total HH	No. of HH	% total HH
Credit received?	Yes	2	1	-	-	177	63	78	80	31	21	55	16	3	2
	No	379	99	137	100	106	37	19	20	117	79	293	84	153	98
Type of loan	In cash	1	0.3	-	-	33	12	5	5	11	7	20	6	3	2
	In kind	1	0.3	-	-	103	36	58	60	14	9	24	7	-	-
	In cash and in kind	-	-	-	-	41	14	15	15	6	4	11	3	-	-

Table 36. Details of credit received for aquaculture within the last 12 months (homestead and commercial pond).

Indicators No. of HH		Fish (*gher*)		Shrimp (*gher*)		Shrimp+rice (*gher*)		Shrimp+prawn+rice (*gher*)		Prawn+rice (*gher*)		Pangas (*beel*)		Rice-fish	
		No. of HH	% total HH	No. of HH	% total HH	No. of HH	% total HH	No. of HH	% total HH	No. of HH	% total HH	No. of HH	% total HH	No. of HH	% total HH
Access to credit	Yes	60	27	117	44	94	73	79	59	56	26	34	92	5	4
	No	161	73	151	56	34	27	55	41	156	74	3	8	123	96
Type of loan	In cash	48	22	35	13	14	11	56	42	30	14	1	3	5	4
	In kind	6	3	58	22	50	39	6	4	19	9	28	76	-	-
	In cash and in kind	6	3	24	9	30	23	17	13	7	3	5	14	-	-

Table 37. Details of credit received for aquaculture within the last 12 months (*gher*, *beel* and rice-fish).

Item	Fish (HS pond)	Fish+SIS (HS pond)	Pangas (pond)	Koi (pond)	Tilapia (pond)	Carp (pond)	Carp+ prawn (pond)	Fish (*gher*)	Shrimp (*gher*)	Shrimp+rice (*gher*)	Shrimp+prawn+rice (*gher*)	Prawn+ rice (*gher*)	Pangas (*beel*)	Rice-fish
Number of farmers taking cash loans	1	-	74	20	17	31	3	54	59	44	73	37	6	5
Percentage of farmers taking cash loans	0.3	-	26	20	11	9	2	25	22	34	55	17	17	4
Source of cash loan (%)														
Large trader (e.g. *arotder*, *paiker*, *bepari*, etc.)	-	-	-	-	-	-	-	-	10	5	1	-	-	-
Bank (government or private)	-	-	64	55	59	55	33	26	25	25	49	32	100	40
Government financial organization (BRDB)	-	-	-	5	-	-	-	-	2	-	5	3	-	-
Traditional moneylender (*mahajon* or *dadander*)	-	-	-	5	-	10	-	15	12	7	5	3	-	-
NGO	-	-	23	30	29	32	33	56	59	68	49	57	-	60
Relative, neighbor or family member	100	-	18	15	18	3	33	15	7	9	1	5	-	-
Average size of cash loan (BDT)	20,000	-	92,027	74,700	69,588	128,306	41,667	57,481	42,068	27,648	56,425	18,297	795,833	33,800
Average size of cash loan from sources (BDT)														
Large trader (e.g. *arotder*, *paiker*, *bepari*, etc.)	-	-	-	-	-	-	-	-	55,833	13,000	5,000	-	-	-
Bank (government or private)	-	-	117,957	86,455	95,400	190,147	50,000	51,714	60,533	37,727	66,444	21,500	795,833	37,500
Government financial organization (BRDB)	-	-	-	18,000	-	-	-	-	19,000	-	14,250	15,000	-	-
Traditional moneylender (*mahajon* or *dadander*)	-	-	-	75,000	-	60,000	-	99,375	22,857	25,000	68,000	15,000	-	-
NGO	-	-	36,765	33,333	37,000	50,500	15,000	29,767	29,000	20,950	37,167	15,905	-	31,333
Relative, neighbor or family member	20,000		49,308	83,333	14,667	60,000	60,000	86,500	11,250	18,000	55,000	27,500		
Mode of repayment of cash loan (%)														
Cash	100	-	100	100	100	100	100	100	86	98	100	97	100	100
Cash and in kind	-	-	-	-	-	-	-	-	14	2	-	3	-	-
Annual rate of interest on cash loan (%)														
Large trader (e.g. *arotder*, *paiker*, *bepari*, etc.)	-	-	-	-	-	-	-	-	25	21	29	-	-	-
Bank (government or private)	-	-	12	12	13	10	10	11	13	11	13	14	13	13
Government financial organization (BRDB)	-	-	-	12	-	-	-	-	11	-	13	10	-	-
Traditional moneylender (*mahajon* or *dadander*)	-	-	-	36	-	12	-	35	25	16	48	16	-	-
NGO	-	-	15	18	20	16	15	17	16	17	18	19	-	21
Relative, neighbor or family member	13	-	18	26	24	12	8	19	27	15	17	4	-	-
Margin due to in-kind repayment (%)														
Received <2.5% less than market value of fish	-	-	-	-	-	-	-	-	5	2	-	-	-	-
Received 2.51%–5.00% less than market value of fish	-	-	-	-	-	-	-	-	-	-	-	3	-	-
Received 5.01%–7.00% less than market value of fish	-	-	-	-	-	-	-	-	8	-	-	-	-	-

Table 38. Sources and terms of cash loans by technology.

Table 38 shows that interest rates charged on loans varied widely among sources. Compared to other sources, interest rates paid on loans from banks and BRDB were much lower and less variable than those from other sources, ranging from 10% to 14% per year. The interest rates paid to moneylenders, wholesalers, relatives or neighbors, and NGOs were higher and more variable, ranging from 12% to 48%, 21% to 29%, 4% to 27% and 15% to 21% per year, respectively. Shrimp and prawn farmers who were obliged to repay cash loans by selling their produce to the credit provider received slightly lower than prevailing market prices for their products.

Sources of in-kind loans and repayment schedules

In-kind loans are an important source of financing for aquaculture farms in Bangladesh. Input suppliers (e.g. seed and feed sellers) are often willing to supply inputs in kind as a form of credit during the production cycle if farmers do not have cash on hand. Table 39 shows that about 16% of farmers had taken an in-kind loan during the survey year. Loans in kind were taken most frequently by commercial farmers. No farmers practicing fish+SIS (HS pond), carp+prawn (pond) or rice-fish technologies had obtained inputs through in-kind loans. The highest percentage of farmers taking loans in kind were pangas (*beel*) at 90%, followed by koi (pond) at 75%, pangas (pond) at 50%, shrimp+rice (*gher*) at 62% and shrimp (*gher*) at 32%. Among other commercial technologies in ponds and *ghers*, the percentage varied between 6% and 17%.

Table 39 shows that fish seed suppliers (nurseries, hatcheries, seed commission agents, mobile seed traders, postlarvae traders and feed dealers) were the source of most in-kind loans. Items advanced as in-kind credit included pelleted fish feeds, fingerlings or postlarvae, fertilizer, chemicals, and feed ingredients (e.g. rice bran, mustard oil cake, etc.). Pelleted feed was the most widely borrowed of these, followed by seed. Farmers usually repaid these loans at a slightly higher price than the prevailing market rate. The majority of in-kind loan recipients paid 2.5%–5% above the market price upon repayment, with this figure mainly varying according to the loan repayment period. Some farmers reported not paying any extra money for in-kind loans that they had taken.

Constraints on credit for aquaculture

Capital, the monetary value of all factors of production used in a business, is necessary to create, maintain and expand a business; increase efficiency; and meet operating costs (Hishamunda and Manning 2002). Because of a lack of self-funds, most of the farmers in Bangladesh depend on external sources of credit, especially when starting commercial operations. Farmers generally prefer to borrow money from formal financial institutions such as banks, as the interest rates of bank loans are less costly than those on loans taken from informal providers.

However, as Table 40 shows, borrowers often have difficulty taking loans from formal financial institutions. Many farmers pointed out that meeting banks' lending requirements, especially collateral, was very difficult for them because of their poor resource base. Lengthy administrative processes and difficulties in preparing and presenting loan applications also limited farmers' access to bank loans. The distance from bank branches to the farm was identified as a major problem among farmers practicing all types of technology. Respondents mentioned that in comparison to banks, NGO loans were easy to access because of their wider presence in rural areas and easier application requirements. However, they mentioned that the high interest rates paid on NGO loans demotivate farmers from applying for them. For many microfinance loans from NGOs, the repayment schedule starts immediately after the loan has been taken, and there is no gestation period for the fish to reach marketable size. These two issues were identified as problems by farmers.

Harvesting

All commercial farmers of *gher* and *beel*, koi (pond), and pangas (pond) reported that their main reason for engaging in fish culture was for business; i.e. producing fish for sale (Table 41). More than 90% of other commercial pond farmers responded that they produced fish primarily for sale, with the remainder producing for both consumption and sale. On the other hand, 44% and 64% of operators of homestead pond technologies (fish [HS pond] and fish+SIS [HS pond]) responded that they practiced fish culture only for subsistence fish consumption and family nutrition, with the remainder of producers for both these technologies reporting that they produced fish for both sale and consumption. About 74% of farmers practicing rice-fish responded that their motivation for practicing aquaculture was selling fish, and the remaining 26% said their motivation was both consuming and selling fish. This indicates that homestead and commercial farmers possess significantly different motivations for and attitudes toward fish production.

Among homestead technologies, including rice-fish, the four main factors influencing the decision to harvest were household consumption and nutrition needs, fish reaching desired market size, coping with financial shocks, and visits by guests. On the other hand, among all commercial technologies, the main factors reported as influencing the decision to harvest were fish attaining the desired market size, high market price, coping with financial shocks, and generating capital to support another enterprise (e.g. rice cultivation). Other reasons reported by farmers were falling water levels, harvesting before winter to avoid disease problems, and harvesting to reduce stocking densities. These results show that market-based factors drove harvesting decisions among commercial farmers, whereas household consumption needs were the main factor influencing homestead farmers. These results also indicate that both commercial and noncommercial types of aquaculture can play an important insurance function in mitigating the impacts of economic shocks.

Table 41 shows that decisions concerning the quantity of fish to be harvested for sale were usually made by the male household head, ranging from 72% to 95% across all technologies. A substantial proportion of respondents (6%–28%) reported that male household heads often discussed the decision to harvest fish for sale with other household members. In some cases, male household heads and their wives made the decision to harvest fish jointly. Decisions were sometimes also made following discussion with business partners. Although many women participated in the harvest of fish for the family's daily or weekly consumption needs, results indicate that decisions regarding harvest of fish, even in small quantities for family consumption, were mainly under the control of male household members (Table 41). However, joint decision making between male household heads and wives or other household members about harvesting fish for home consumption was common across all technologies.

Marketing and postharvest management

A variety of marketing intermediaries, including wholesalers (*arotdar*, *paiker* or *bepari*), local fish traders (*faria*), fish harvesting teams, and depot owners, were identified in the areas studied (see Annex 5 for descriptions). Table 42 shows that the majority of farmers across all technologies sold fish directly to a wholesaler. *Faria*, who collect fish from producers in small quantities and sell to wholesalers or retailers, also played a significant role in marketing products across all technologies. The role of *faria* was most important for commercial technologies such as pangas (pond), koi (pond), shrimp (*gher*) and pangas (*beel*), where the amount of fish harvested was sometimes not sufficiently large to justify the time and cost to the farmer of delivering to a wholesale market. Depot owners acted as important intermediaries for shrimp and prawn marketing by buying these products from producers in order to supply them to processing factories. The main role of fish harvesting teams is to harvest fish for farmers, but they often also act as traders, buying harvested fish from farmers. The role of harvesting teams in trading fish was particularly important for homestead pond-based technologies (fish [HS pond] at 29%, fish+SIS [HS pond] at 67% and commercial carp farmers at 14%). A small number of fish farmers across most technologies also sold fish directly to consumers.

Table 42 shows that decisions regarding choice of marketing channel depended mainly on distance to market and quantity of fish harvested. Farmers across technologies reported that producers located a long distance from the nearest market incurred high costs if attempting to market fish themselves, which influenced them to sell fish through local intermediaries such as *faria* or harvesting teams. The amount of fish harvested was also a major factor in determining the marketing channel chosen. Farmers often travelled to the market in person to sell fish to an *arot* or depot if the quantity harvested was large.

Indicators	Fish (HS pond)	Fish+SIS (HS pond)	Pangas (pond)	Koi (pond)	Tilapia (pond)	Carp (pond)	Carp+ prawn (pond)	Fish (*gher*)	Shrimp (*gher*)	Shrimp+rice (*gher*)	Shrimp+prawn+rice (*gher*)	Prawn+ rice (*gher*)	Pangas (*beel*)	Rice-fish
Number of farmers taking in-kind loans	1	-	144	73	20	35	-	12	82	80	23	26	33	-
Percentage of farmers taking in-kind loans	0.3	-	50	75	13	10	-	6	31	62	17	12	90	-
Source of in-kind loans (%)														
Hatchery	-	-	-	4	-	-	-	-	-	-	4	23	-	-
Nursery	100	-	3	1	-	6	-	-	18	15	-	12	-	-
Feed dealer	-	-	97	95	100	97	-	92	1	3	96	62	100	-
Seed commission agent	-	-	9	-	-	17	-	8	72	54	4	8	-	-
Chemical seller	-	-	1	-	-	-	-	8	-	4	-	-	-	-
Mobile fish seed trader (*patil wallah*)	-	-	-	-	-	-	-	-	9	8	-	-	-	-
Mobile shrimp seed trader (postlarvae *faria*)	-	-	-	-	-	-	-	-	-	19	4	4	-	-
Form of in-kind loans (%)														
Seed	100	-	1	4	-	9	-	25	99	95	13	35	-	-
Pelleted feed	-	-	93	95	100	77	-	58	1	5	96	73	100	-
Chemicals	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Fertilizer	-	-	-	-	-	17	-	25	-	-	-	-	-	-
Feed ingredients	-	-	7	-	-	14	-	-	-	-	-	-	-	-
Repayment arrangement for in-kind loans (%)														
Paid <2.5% more than market price	-	-	67	19	20	69	-	50	17	5	17	8	12	-
Paid 2.5%–5.0% more than market price	-	-	31	45	55	23	-	25	12	5	48	4	76	-
Paid 5.01%–10.0% more than market price	-	-	6	11	15	3	-	17	26	19	39	19	12	-
Paid >10.00% more than market price	-	-	5	-	10	3	-	25	54	70	-	4	-	-
No extra money paid	100	-	19	22	-	3	-	-	17	9	9	54	-	-

Table 39. Sources and terms of in-kind loans.

Indicators	Fish (HS pond)	Fish+SIS (HS pond)	Pangas (pond)	Koi (pond)	Tilapia (pond)	Carp (pond)	Carp+ prawn (pond)	Fish (*gher*)	Shrimp (*gher*)	Shrimp+rice (*gher*)	Shrimp+prawn+rice (*gher*)	Prawn+ rice (*gher*)	Pangas (*beel*)	Rice-fish
Applying for a bank loan is difficult because of collateral	43	20	27	36	37	28	35	18	28	22	40	18	51	27
Lengthy administrative process in applying for bank loans	12	-	6	11	9	10	13	18	22	20	60	20	22	13
Banks are far from the locality	19	2	3	3	9	1	17	8	13	8	27	3	-	4
NGOs charge high interest rates	23	4	10	7	20	14	13	33	21	23	51	22	3	15
Weekly payment schedule of NGOs is difficult to meet	13	1	6	6	13	3	18	24	16	34	31	22	5	8
No gestation period for repayment of loan	3	19	1	6	3	1	-	-	-	-	9	2	-	2
No idea about credit institutions	3	-	12	13	2	1	1	-	7	9	2	0	8	2
Other	8	1	8	7	7	4	7	4	6	4	7	6	8	1

Table 40. Farmer perceptions about constraints on taking loans from formal financial institutions (% of households responding).

Item	Fish (HS pond)	Fish+SIS (HS pond)	Pangas (pond)	Koi (pond)	Tilapia (pond)	Carp (pond)	Carp+ prawn (pond)	Fish (*gher*)	Shrimp (*gher*)	Shrimp+rice (*gher*)	Shrimp+prawn+rice (*gher*)	Prawn+ rice (*gher*)	Pangas (*beel*)	Rice-fish
Why fish culture is most important for you (%)														
Meeting own consumption and nutrition needs	44	64	-	-	-	-	-	-	-	-	-	-	-	-
Sale	-	-	100	100	93	95	91	93	100	100	100	100	100	74
Own consumption and sales equally important	56	36	-	-	7	5	9	7	-	-	-	-	-	26
Why the decision to harvest fish was made (%)														
Physiological behavior of stocked fish or shrimp	-	-	-	-	-	-	-	0	76	76	16	1	-	-
Fish attained marketable size	45	55	56	82	77	66	99	61	86	98	54	80	92	63
Household consumption needs	67	97	-	-	14	7	26	2	1	1	-	-	-	32
High market price	4	2	50	45	26	33	11	35	11	2	34	45	41	8
To purchase inputs for rice cultivation	0	-	-	-	-	-	-	19	-	-	20	8	-	12
To cope with a financial shock	14	8	25	18	20	27	27	22	3	-	22	33	11	26
Harvest before winter to avoid disease problems	1	-	2	6	5	1	1	3	1	-	5	2	-	4
Harvest when water levels drop	16	1	11	-	1	5	1	10	7	-	2	2	5	4
To reduce the density of stocked fish	2	1	4	-	-	11	10	1	4	9	11	9	-	1
When guests come to home	12	26	-	-	-	1	1	-	-	-	-	-	-	-
Other	4	-	1	-	1	1	1	8	0	-	6	6	-	1
Who makes the decision to harvest fish for sale (%)														
Male household head	74	82	72	86	80	81	69	85	87	80	72	77	95	80
Male household head and wife	8	6	5	-	16	5	12	1	1	3	-	1	-	8
Male household head and other household members	15	6	22	10	3	14	15	8	7	12	28	20	-	12
Self and business partner	3	4	-	-	2	1	2	5	3	1	-	-	5	-
Other	1	2	2	4	1	1	3	0	1	4	-	1	-	1
Who makes decision to harvest fish for consumption (%)														
Male household head	30	53	41	38	23	44	25	41	55	52	28	34	84	22
Male household head and wife	36	26	26	40	9	26	19	19	18	9	2	34	5	16
Male household head and other household members	30	15	25	9	58	29	49	30	22	27	69	26	-	62
Self and business partner	4	9	0	4	4	1	2	9	2	2	-	2	5	-
Other	5	1	6	6	4	1	5	1	3	9	1	4	-	-

Table 41. Reasons for farmers' decisions regarding fish harvesting, marketing and consumption (% of households responding).

Item	Fish (HS pond)	Fish+SIS (HS pond)	Pangas (pond)	Koi (pond)	Tilapia (pond)	Carp (pond)	Carp+ prawn (pond)	Fish (*gher*)	Shrimp (*gher*)	Shrimp+rice (*gher*)	Shrimp+prawn+rice (*gher*)	Prawn+ rice (*gher*)	Pangas (*beel*)	Rice-fish
Who the fish was sold to (%)														
Large trader (e.g. *arotdar, paiker* or *bepari*)	49	30	90	93	80	67	93	88	61	58	72	74	97	99
Small trader (e.g. *faria*)	10	4	28	25	23	25	2	11	34	39	23	17	43	2
Depot	-	-	-	-	1	0	11	6	8	20	37	25	-	-
Fish harvesting team	29	67	3	-	3	14	1	4	0	-	1	4	-	5
Direct marketing to consumers	11	7	-	4	1	0	-	1	-	-	-	-	3	-
Other	7	7	2	5	4	5	-	9	1	1	1	3	-	2
Why you chose to sell fish to this buyer (%)														
Harvest volume	13	35	43	16	18	37	23	29	16	13	13	8	30	45
Higher price offered by the buyer	19	12	8	8	6	34	26	43	48	43	75	61	24	13
Instant cash payment by the buyer	15	4	43	73	63	29	37	26	21	16	21	29	70	38
Good relationship with the buyer	5	1	4	3	1	6	1	0	7	16	2	15	5	1
Price offered by the buyer based on product grading	0	-	6	1	7	7	19	11	11	8	2	0	8	4
Market is far away—higher marketing costs	15	3	19	19	22	12	23	27	24	24	25	27	27	10
Other	4	2	4	6	3	5	-	4	6	9	4	1	-	-
What steps were taken to preserve the quality of harvested fish (%)														
Keep alive in *hapa* or seine net in pond	-	1	3	3	1	11	-	5	7	5	8	8	5	4
Keep alive in drum or cistern	2	1	99	100	18	16	8	14	10	8	7	5	97	16
Keep in cox sheet with ice	1	2	5	-	3	1	4	1	9	16	16	6	3	-
Keep in a basket or dish after cleaning with pond water	41	45	13	19	28	32	34	33	46	30	14	25	12	28
Keep in shaded place on the open ground after cleaning with pond water	16	10	9	24	16	11	12	12	4	9	13	20	27	14
Keep in plastic or jute sheet after cleaning with pond water	51	46	23	16	41	43	60	42	41	43	50	46	18	39

Table 42. Farmers' fish marketing behavior (% of households responding).

CREDIT AND MARKETING ACTIVITIES

On the other hand, if the amount was small, farmers generally preferred to sell to *faria* or harvesting teams. Receipt of instant cash payment, competitive pricing offered by marketing intermediaries, concerns about intermediaries fixing prices by size grading, and good relationships with existing buyers were mentioned as concerns affecting choice of market channel.

The fisheries sector in Bangladesh suffers from serious postharvest losses due to inadequate knowledge and poor handling practices among actors along the value chain from harvest to retail (Alam 2010). As fish is perishable, it requires proper and efficient handling in order to ensure that optimum prices and quality are attained. Hassan et al. (2012), in their study on shrimp and prawn farmers in Bangladesh, show that the duration between harvesting and marketing was between 1 and 4 hours in all areas studied. This indicates the importance of the role of producers in postharvest handling, as quality deteriorates immediately after harvesting. Table 42 reports practices followed by fish farmers after harvesting to maintain quality. A significant share of farmers placed harvested fish on plastic or jute sheets or on open ground after cleaning them with pond or *gher* water. This practice was common across all homestead and commercial technologies. There is considerable scope for contamination of fish at this stage, which may reduce the quality as well as the price of fish. Few farmers practicing commercial technologies stored fish with ice in foam boxes. In most cases when this happened, the buyers supplied the foam box. This practice was almost nonexistent among homestead producers. Keeping fish alive until the time of sale was also practiced by some farmers across technologies, and was most common with the air-breathing species pangas and koi, which can survive in poorly oxygenated water for long periods. Finfish harvested from *ghers* were also sometimes traded live.

Summary

Access to credit is an important factor linked to the productivity and commercialization of aquaculture. Credit can be obtained from formal financial institutions (e.g. banks) and from noninstitutional sources (e.g. local moneylenders, wholesalers, etc.). Across all technologies, 30% of farmers interviewed accessed some form of formal or informal credit. Rahman and Ali (1986) report that fish farmers' access to institutional credit was very low. Shang (1990) and Alam and Thompson (2001) in their respective studies found that only 20% and 16% of pond farmers were able to obtain credit from any sources. Results of our study show the positive changes in the credit scenario. A significant share of commercial farmers accessed credit in cash or in kind (mainly feed or seed), but access was very limited for homestead pond farmers. This may be because homestead producers were unable to access credit, but it may also suggest that these types of farmers do not require credit in order to operate their farms because investment costs are low. "Interlocked" or "output tied" credit arrangements in which farmers are obligated to sell harvested product to a supplier of cash or in-kind credit were rare, suggesting the presence of a reasonable degree of access to credit for those who require it and competitive marketing channels.

Among formal institutions, the credit programs of NGOs appeared to be easily accessible to farmers, but expensive due to high rates of interest. Although these interest rates reflect the transaction costs of administering large numbers of small unsecured loans, they tended to discourage farmers from using these credit facilities. Farmers also indicated that the repayment schedules of microfinance loans do not match the fish production cycle. Lengthy administrative formalities and collateral requirements were identified as major obstacles to accessing bank loans with lower rates of interest. In comparison to previous studies, these results show that Bangladesh has achieved positive changes in terms of access to credit among fish farmers.

With the exception of homestead-based fish farming technologies, where meeting household consumption and nutrition needs is the main purpose of the farming, fish farmers across all technologies cultured fish primarily for sale. This reflects the entrepreneurial attitude of fish farmers in Bangladesh. For commercial farmers, high prices and demand were the main factors motivating the decision to harvest fish. Among households operating homestead ponds, fish harvesting decisions were driven primarily by household consumption needs. Within the fish farming household, decisions about harvesting fish for sale were mainly dominated by (usually male) household heads. On the other hand, although decisions about harvesting fish for home consumption were also dominated by men, it was common for husbands and wives to make these decisions together.

Making fish available to consumers at the right time and in the right place requires an effective marketing system. Fish farmers who used the services of a harvesting team to harvest fish did not usually sell fish directly to consumers. It is evident that the majority of fish farmers now deal directly with *arotdars* at higher secondary wholesale markets. Farmers located a long distance from a wholesale market were more likely to sell fish through smaller traders who collect fish from the farm. Good relationships with buyers, receipt of instant cash payment from traders, and higher prices than those offered in local wholesale markets were other factors that may influence a farmer's decisions regarding choice of marketing channel.

Photo Credit: Din M Shibly/WorldFish

Harvesting fish and prawn from a *gher*.

Aquaculture has been one of Bangladesh's fastest-growing food production sectors over the past two decades, with significant public and private investments, scientific and technical development, and output growth. As a result of this growth, aquaculture now accounts for 55% of the country's total fish production (DOF 2015). Aquaculture has also been promoted for several decades as a mechanism for rural development and poverty alleviation (Edwards 1999; Dey et al. 2005; World Bank 2006). However, the sector faces a number of challenges in maintaining current rates of growth and production. Aquaculture is heavily dependent on the availability and quality of natural resources, most critically water, and is vulnerable to the impacts of natural disasters. Infectious diseases pose significant threats. The aquaculture sector also needs to address valid concerns about its negative environmental and social impacts on individuals and the communities to which they belong. This chapter explores these issues from the perspective of fish farmers and the communities in which they reside.

Shocks

Aquaculture producers face similar risks to those involved in agriculture. However, given the complexity of aquaculture in terms of species selection, environmental conditions, production technologies, and levels of investment, the hazards and risks are probably higher than those experienced in terrestrial farming. Tables 43 and 44 present the types of shocks experienced by farmers during the study year and over the last 5 years, respectively. Tables 45 and 46 present estimates of the losses incurred by farmers due to those shocks.

Climatic shocks

Bangladesh is vulnerable to a variety of natural disasters, which disrupt the lives of large numbers of people every year. Fish farmers are severely affected by natural disasters, which include floods, cyclones and droughts. Results from the study year and from the last 5 years show that the farmers were most frequently affected by flooding, followed by cyclones and drought. Table 43 shows that except for pangas (*beel*) and rice-fish technologies, about 1%–4% of homestead pond farmers, 1%–7% of commercial pond farmers and 1%–8% of *gher* farmers experienced flooding during 2011–12. The occurrence of other natural disasters such as cyclones and droughts was minimal during the study year (1%–3%), and limited to only a few technologies: cyclones in tilapia (pond) and prawn+rice (*gher*); and drought in carp+prawn (pond), fish (*gher*), shrimp (*gher*), shrimp+prawn+rice (*gher*) and pangas (*beel*).

Looking back over a 5-year time period, Table 44 shows that 1%–12% of homestead pond farmers, 3%–43% of commercial pond farmers, 9%–29% of *gher* farmers and 5% of pangas (*beel*) farmers were affected by flood. Farmers practicing fish (HS pond), tilapia (pond), carp+prawn (pond), fish (*gher*), shrimp (*gher*) and prawn (*gher*) technologies were also seriously affected by cyclones during these periods. Affected farms were located in coastal districts, which are particularly vulnerable to cyclone damage. The impacts of drought during this period were found to be limited, with 1%–4% of carp+prawn (pond), fish (*gher*), pangas (*beel*), rice-fish, and shrimp and prawn farmers affected.

According to respondents, these calamities resulted in the loss of stocked fish and structural damage to pond dikes and other infrastructure. It is difficult to accurately calculate the value of losses caused by these calamities based on the results of this survey. However, some commercial farmers reported significant losses as a result of natural disasters. The highest monetary loss per affected farm was reported by koi (pond) farmers at BDT 52,000, followed by BDT 33,209 for prawn+rice (*gher*) producers and BDT 31,000 for pangas (*beel*) farmers. Average loss for other commercial technologies was reported at below BDT 20,000. The average monetary loss for fish (HS pond) was BDT 3779.

Disease

Diseases of fish and shellfish are among the most serious threats to the commercial success of aquaculture. Farmers reported being vulnerable to high levels of stock mortality as a result of disease, constituting an important shock. A list of diseases that farmers commonly mentioned during interviews is provided in Annex 6. In many instances, farmers were not able to state the common name of the disease that affected their stock. Diseases listed in the table were identified based on the symptoms reported by farmers during the survey. The frequency of disease occurrence was greatest for shrimp, prawn, pangas and koi technologies (Tables 43 and 44). Between 29% and 38% of farms producing shrimp or prawn experienced disease problems in the year preceding the study, as did 11% of pangas (pond) and 21% of koi (pond) farmers. This reflects the high susceptibility of crustaceans (particularly shrimp) to disease, as well as the increasing likelihood of disease outbreaks at high production intensities, as in the case of koi and pangas.

The share of shrimp and prawn farms affected by disease was between 50% and 64% over the 5 years preceding the survey. During this period about 35% of pangas (pond) and pangas (*beel*) farmers and 45% of koi (pond) farmers were impacted by disease outbreaks. The percent of affected farms varied from 16% to 22% across all other technologies. Results show that disease-affected pangas (*beel*) farmers had the largest losses, at around BDT 47,333 per farmer, with average losses varying from BDT 6282 to BDT 30,850 across all other technologies in the study year.

Other shocks

The study revealed that a small share of farmers (1%–4%) practicing a variety of technologies suffered monetary losses due to poisonings or poaching. According to respondents, family or personal conflicts with neighbors or community members and professional jealousy were the main reasons for these events. Heavy mortalities due to stocking fish at very high densities or excessive use of feeds and fertilizers leading to water quality deterioration were also reported in this study as a source of shock. Limited technical capacity among farmers was identified as the main reason for this kind of event.

Shocks may also occur due to market instability. Farmers' production decisions are not always based on accurate market information. This sometimes results in the market being flooded with fish, resulting in a drop in price and unforeseen loss of profits. Tables 43 and 44 show that this type of shock was most common for highly productive technologies such as pangas, koi and tilapia. In the case of shrimp and prawn, which is mainly export oriented, low prices sometimes resulted from poor-quality product due to limited care during postharvest handling, or from downward price movements in global markets.

Environmental impacts of aquaculture

Aquaculture depends on a variety of natural resources, including water, land, seed and feed, and can affect the environment by modifying natural habitats, biodiversity, soil, water and landscapes. Some forms of aquaculture, such as integrated fish farming, can positively affect the agro-environment by minimizing input use for fish or crop production or cycling nutrients, while others result in a range of negative impacts. The survey revealed a range of impacts, both positive and negative (Tables 47 and 48).

Positive environmental aspects of aquaculture

One of the positive environmental impacts of aquaculture identified across technologies was the increased availability of indigenous fish species from pond and *gher* farming systems (Table 47). Introduction of aquaculture technologies for the production of small indigenous species and positive extension messages about their nutritional benefits may be a factor contributing to increasing production of these species from aquaculture. This was certainly the case for the project-supported fish+SIS (HS pond) technology, where small indigenous species were introduced in traditional carp polyculture systems with project support.

Increased crop productivity and reduced use of fertilizers and pesticides were identified by the fish (*gher*), shrimp+rice (*gher*), prawn+rice (*gher*) and rice-fish farmers as positive outcomes of integrating fish production with rice cultivation (either concurrently or on a rotational basis). A number of studies, including Frei and Becker (2005), Mustow (2002), Halwart and Gupta (2004), and Lu and Li (2006), also support this conclusion. These studies show that fish in rice-fish farming systems excrete nitrogen and

Type of shock	Fish (HS pond)	Fish+SIS (HS pond)	Pangas (pond)	Koi (pond)	Tilapia (pond)	Carp (pond)	Carp+ prawn (pond)	Fish (*gher*)	Shrimp (*gher*)	Shrimp+rice (*gher*)	Shrimp+prawn+rice (*gher*)	Prawn+ rice (*gher*)	Pangas (*beel*)	Rice-fish
Cyclone	-	-	-	-	1	-	-	-	-	-	-	1	-	-
Drought	-	-	-	-	-	-	1	1	1	-	1	-	3	-
Flooding	4	1	1	4	7	2	3	8	4	2	1	4	-	-
Disease	6	4	11	21	5	8	7	4	34	38	35	29	8	4
Poisoning	-	-	-	-	-	-	1	-	-	1	-	1	-	-
Poaching	-	2	2	-	-	-	4	-	-	2	2	2	-	-
Sudden market price fall	-	-	4	2	-	-	-	1	-	-	-	1	3	-
Huge mortality of fish (e.g. due to poor water quality or lack of technical knowhow)	1	-	1	2	-	1	-	-	1	-	-	-	-	-

Table 43. Shocks to aquaculture occurring within the last 12 months (% of households responding).

Type of shock	Fish (HS pond)	Fish+SIS (HS pond)	Pangas (pond)	Koi (pond)	Tilapia (pond)	Carp (pond)	Carp+ prawn (pond)	Fish (*gher*)	Shrimp (*gher*)	Shrimp+rice (*gher*)	Shrimp+prawn+rice (*gher*)	Prawn+ rice (*gher*)	Pangas (*beel*)	Rice-fish
Cyclone	5	-	-	-	21	-	32	29	14	9	9	2	-	-
Drought	-	-	-	-	-	-	1	1	1	-	1	1	3	4
Flooding	12	1	3	4	43	8	38	29	21	9	11	29	5	-
Disease	18	19	35	45	16	20	22	16	52	64	62	50	35	20
Poisoning	-	-	1	-	2	1	3	0	1	2	3	4	-	-
Poaching	-	2	2	-	4	-	11	-	-	2	4	8	3	-
Sudden market price fall	-	-	17	10	3	1	-	2	5	5	9	11	22	-
Huge mortality of fish (e.g. due to poor water quality or lack of technical knowhow)	3	7	4	15	2	2	-	0	2	4	2	1	8	10

Table 44. Shocks to aquaculture occurring within the preceding 5 years (% of households responding).

Type of shock	Fish (HS pond)		Fish+SIS (HS pond)		Pangas (pond)		Koi (pond)		Tilapia (pond)		Carp (pond)		Carp+prawn (pond)	
	Production (kg)	Value (BDT)	Production (kg)	Value (BDT)	Production (kg)	Value (BDT)	Production (kg)	Value (BDT)	Production (kg)	Value (BDT)	Production (kg)	Value (BDT)	Production (kg)	Value (BDT)
Cyclone	-	-	-	-	-	-	-	-	60	6,000	-	-	-	-
Drought	-	-	-	-	-	-	-	-	-	-	-	-	20	6,500
Flooding	42	3,779	5	400	350	24,000	388	52,500	154	11,300	110	10,333	47	5,850
Disease	57	4,550	16	1,740	269	23,950	291	30,850	189	19,000	119	13,122	41	6,282
Deteriorating water quality	34	3,000	-	-	230	17,500	60	7,000	-	-	90	8,000	-	-
Poisoning	-	-	-	-	-	-	-	-	-	-	-	-	25	4,500
Poaching	-	-	12	1,200	81	5,920	-	-	-	-	-	-	47	9,850
High fish mortality	-	-	-	-	204	16,800	115	11,000	-	-	-	-	-	-

Table 45. Financial losses occurring due to shocks within the last 12 months (homestead and commercial pond technologies, average loss in BDT).

Type of shock	Fish (*gher*)		Shrimp (*gher*)		Shrimp+rice (*gher*)		Shrimp+prawn+rice (*gher*)		Prawn+rice (*gher*)		Pangas (*beel*)		Rice-fish	
	Production (kg)	Value (BDT)	Production (kg)	Value (BDT)	Production (kg)	Value (BDT)	Production (kg)	Value (BDT)	Production (kg)	Value (BDT)	Production (kg)	Value (BDT)	Production (kg)	Value (BDT)
Cyclone	-	-	-	-	-	-	-	-	100	42,500	-	-	-	-
Drought	150	14,500	35	10,500			60	20,000			400	31,000		
Flooding	73	7,806	99	20,640	68	19,500	63	22,500	77	30,886				
Disease	204	24,167	73	26,713	46	17,031	22	12,002	42	23,210	600	47,333	36	4,100
Deteriorating water quality	-	-	45	19,000	-	-	-	-	-	-	-	-	-	-
Poisoning	-	-	-	-	50	14,000	-	-	40	17,500	-	-	-	-
Poaching	-	-	-	-	20	10,167	24	12,667	28	16,000	-	-	-	-
High fish mortality	125	10,000	-	-	-	-	-	-	23	14,235	300	22,000	-	-

Table 46. Financial losses occurring due to shocks within the last 12 months (*gher*, *beel* and rice-fish technologies, average loss in BDT).

Positive impact	Fish (HS pond)	Fish+ SIS (HS pond)	Pangas (pond)	Koi (pond)	Tilapia (pond)	Carp (pond)	Carp+ prawn (pond)	Fish (*gher*)	Shrimp (*gher*)	Shrimp+rice (*gher*)	Shrimp+ prawn+rice (*gher*)	Prawn+rice (*gher*)	Pangas (*beel*)	Rice-fish
Rice production increased due to improved soil fertility	-	-	-	-	-	-	-	73	-	13	48	87	-	55
Pesticide use reduced due to integration of fish with rice	-	-	-	-	-	-	-	5	-	9	1	1	-	12
Availability of local indigenous fish species increased	7	51	17	20	14	11	15	12	9	20	40	18	14	16
Discharge of water to neighboring plots increased crop production	-	-	2	7	1	3	1	1	-	-	-	-	14	1
Dike cropping minimized input use and improved productivity of vegetables	13	9	16	20	14	18	22	15	1	1	10	28	19	2
Fertilizer use reduced due to integration of fish with rice	-	-	-	-	-	-	-	10	-	16	20	21	-	25
No response	71	42	16	25	11	1	-	-	-	-	-	-	19	-

Table 47. Farmer perceptions of the positive environmental impacts of aquaculture (% of households reporting).

Negative impact	Fish (HS pond)	Fish+ SIS (HS pond)	Pangas (pond)	Koi (pond)	Tilapia (pond)	Carp (pond)	Carp+ prawn (pond)	Fish (*gher*)	Shrimp (*gher*)	Shrimp+rice (*gher*)	Shrimp+ prawn+rice (*gher*)	Prawn+rice (*gher*)	Pangas (*beel*)	Rice-fish
Reduced production of rice due to increased salinity	-	-	-	-	-	-	-	-	38	26	28	-	-	-
Declining livestock numbers due to scarcity of grazing land	-	-	-	3	-	3	-	1	32	63	1	6	-	-
Decline of fruit or timber trees and vegetation due to increased salinity	-	-	-	-	-	-	-	-	43	72	7	1	-	-
Loss of aquatic animals (snails, worms, etc.)	-	-	12	-	7	4	15	21	9	14	-	2	11	-
Runoff and leaching of pond water to cropland, reducing crop yield	-	-	8	10	5	2	-	8	-	-	1	2	-	2
Waterlogging in neighboring plots due to water exchange	-	-	8	15	2	1	-	1	11	16	7	3	-	-

Table 48. Farmer perceptions of the negative environmental impacts of aquaculture (% of households reporting).

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phosphorus, which improve soil fertility and release nutrients from rice field sediments through their movements. According to farmers surveyed, smaller quantities of fertilizers were required in integrated rice-fish farming than in rice monoculture per unit production of rice. Fish wastes and uneaten supplementary feed increased the organic fertilization of rice fields. Moreover, fish may also play a significant role in these integrated systems by eating aquatic weeds and algae that act as hosts for pests and compete with rice for nutrients.

Production of vegetables and short-growing fruits on dikes with minimal use of fertilizers was another positive environmental aspect of aquaculture mentioned by 10%–28% of farmers across all technologies, with the exception of shrimp (*gher*), shrimp+rice (*gher*) and rice-fish, where salinity and/or small dikes prevented integrated terrestrial crop production. Use of nutrient-rich pond mud and pond water on dikes for crop production can have positive impacts on soil fertility and productivity, which is also documented in the literature (Karim 2006; Jahan et al. 2011; Haque et al. 2016).

There were diverse views about the effects of effluent discharge from commercial aquaculture. Some farmers stated that discharge of aquaculture effluents onto nearby agricultural land had positive impacts, on the basis that it could supplement inorganic fertilizers and improve crop yields, while others were of the opposite opinion. A detailed study on the cycling of nutrients contained in aquaculture effluents is thus needed to ensure the minimization of risks from, and maximization of benefits of, waste from commercial ponds.

Negative environmental aspects of aquaculture

Many of the major environmental impacts of aquaculture are associated with high-input, high-output intensive systems. The negative environmental effects of commercial aquaculture include discharge of suspended solids, nutrient and organic enrichment of receiving waters, and buildup of anoxic sediments that negatively affect crop production. However, the extent and nature of these impacts vary with intensity of production, farm infrastructure and site location. Results show that intensive koi (pond), pangas (pond) and tilapia (pond) farmers were the main group that raised concerns regarding the impacts of waste discharge on crop production and nearby waterbodies, at 10%, 8% and 5%, respectively. Shrimp and prawn culture in Bangladesh are relatively low intensity. Only a few farmers practicing shrimp+prawn+rice (*gher*) raised concerns about effluent discharge from their *ghers* (Table 48).

Shrimp farming in Bangladesh has been the subject of frequent debate over its negative environmental impacts. In this study, shrimp farmers reported some concerns about the negative impacts of shrimp farming (26%–38%), based on their observation of the environment surrounding their farms. The major area of concern was increasing salinity levels. This was reported to reduce rice yields and to cause a decline in trees and vegetation. Lower numbers of poultry and livestock due to reduced grazing land in shrimp-producing localities were also reported. These farmer observations are supported by numerous other studies. Karim (2006) observed that vegetation had quickly disappeared because of high salinity and inundation in shrimp farming areas, and Rahman et al. (2002) reports the depletion of livestock as a consequence of salinity increases. According to shrimp farmers, siltation of rivers and canals and unplanned construction of the embankments were among the main reasons for salinity increases in shrimp-producing areas.

Waterlogging was identified as another negative environmental impact by commercial shrimp, pangas and koi farmers. Unplanned construction of ponds or *ghers* by converting rice fields was mentioned as a major cause of waterlogging, as it leaves little space for drainage or the exchange of water between ponds and rivers.

Conflicts

Conflicts take place in aquaculture when the action of an individual farmer or group of farmers creates adverse effects for another individual or group. A complete understanding of the conflict, its nature and its type can help develop a conflict resolution process. Some conflicts can be avoided entirely or kept from escalating if what is happening and why it is happening is fully understood (Jahan et al. 2014). This study therefore attempted to investigate what conflicts existed in the aquaculture sector and identify possible mitigation mechanisms.

Table 49 shows that the majority of farmers reported no conflicts. The conflicts that did occur were mainly reported in regard to intensive pond-based technologies such as koi (pond) at 11%, pangas (pond) at 12% and carp (pond) at 5% and in shrimp farming areas (9%–18%). Conflicts in aquaculture occurred among several different actors: between fish farmers, between fish farmers and neighboring crop farmers, and between fish farmers and community members. Many of the conflicts identified by respondents were associated with the negative environmental impacts discussed in the preceding subsection.

Leakage of water between one pond and another was identified as a cause of conflict between the fish farmers where the ponds or *ghers* were located in close vicinity. This was observed among the following farms: koi (pond) at 3%, fish (*gher*) at 1%, shrimp (*gher*) at 4% and shrimp+rice (*gher*) at 6%. Deteriorated water quality and disease outbreaks were the main concerns in this type of conflict. Sharing a common pond dike was another cause of conflicts between fish farmers (1%–6%) for some technologies, such as pangas (pond) and koi (pond). When any repairs or modifications were performed on the common dike, the question of who would bear the costs was a major cause of conflict.

Conflict was also reported to happen between wealthy shrimp farmers and smaller operators when the former wanted to forcibly encroach upon the *ghers* of the smaller farmers. The potentially high profitability of shrimp and commercial farming encourages farmers to expand their farming areas, but this expansion is not always possible due to land scarcity. As a result, powerful large farm operators sometimes attempt to forcibly occupy the land of others and thus create conflicts. Another type of conflict between shrimp farmers and landowners may occur when the latter artificially hike the lease value of land rented for aquaculture. Small shrimp farmers complained that artificial price hikes were intended to force them out of shrimp farming.

Across technologies, farmers identified multiple ownership of ponds or *ghers* as an issue that sometimes resulted in conflict among owners. This was especially pronounced in the case of homestead ponds. Decisions regarding investment, production, and how to share costs and benefits among owners were the main sources of conflict among owners in this case.

Conflict between shrimp and paddy farmers frequently occurs when saline water from shrimp ponds seeps into neighboring paddy fields, adversely affecting the production of rice. For intensive forms of fish farming, including pangas (pond), koi (pond) and carp (pond), a commonly reported cause of conflict was the discharge of water onto neighboring cropland. According to crop farmers, this pond water is high in nutrients and adversely impacts paddy production by increasing the vegetative growth of plants and affecting grain yields negatively. This type of conflict (identified as a serious negative environmental concern in the previous section) was also reported in the case of shrimp and prawn farming in *ghers*.

Conflicts between fish farmers and crop farmers can start when the fish farmers claim that some of their fish died because water from croplands, which has poisonous pesticides and herbicides, entered their ponds during irrigation or the rainy season. Conflicts over the boundaries between ponds and neighboring cropland were also reported as occurring when parties attempted to illegally claim rights to land.

Waterlogging was another major cause of conflict between fish farmers and members of the wider community. Water exchange is a common practice among commercial fish farmers that can cause waterlogging in the surrounding area and, similar to seepage of pond water, can seriously affect the productivity of crop and rice production in nearby fields. Unplanned construction of ponds or *ghers*, as well as siltation of irrigation canals, were the main causes of waterlogging identified by farmers and community members. This problem is aggravated during the rainy season, when large areas can be submerged and impassable for long periods.

Conflict	Fish (HS pond)	Fish+SIS (HS pond)	Pangas (pond)	Koi (pond)	Tilapia (pond)	Carp (pond)	Carp+ prawn (pond)	Fish (*gher*)	Shrimp (*gher*)	Shrimp+rice (*gher*)	Shrimp+prawn+rice (*gher*)	Prawn+rice (*gher*)	Pangas (*beel*)	Rice-fish
No conflicts	94	92	75	71	95	89	97	83	56	47	57	77	84	98
Water leaked to neighboring pond	-	-	-	3	-	-	-	1	4	6	-	-	-	-
Disputes over paying the repair costs for common dikes between two waterbodies	-	-	1	6	-	1	-	2	1	-	1	2	-	-
Larger farm operators attempting to encroach on the property of others	-	-	-	-	-	-	-	-	4	5	3	2	-	-
High lease value claimed by landowner	-	-	4	3	3	2	-	5	18	13	13	2	16	2
Multiownership problems	6	7	1	-	1	2	2	1	1	2	1	2	-	-
Shrimp farmers blamed for saline intrusion	-	-	-	-	-	-	-	-	1	-	1	-	-	-
Water management issues—pond or *gher* water discharged into nearby croplands	-	-	12	11	1	5	-	1	4	12	17	9	-	1
Residual effects of crop farming—pesticides entering ponds with rain water	-	-	1	-	-	1	-	1	1	-	-	-	-	-
Conflicts due to improper demarcation of land or waterbodies	-	-	-	1	-	-	-	3	-	1	-	1	-	-
Waterlogging due to unplanned construction of aquaculture farms	-	-	4	4	-	-	-	1	10	13	6	3	-	-
Poaching	-	1	1	-	-	-	1	-	1	1	1	1	-	-
Other	-	-	2	-	-	1	-	1	-	1	-	-	-	-

Table 49. Conflicts occurring within the last 12 months (% of households reporting).

Resolution process	Fish (HS pond)	Fish+SIS (HS pond)	Pangas (pond)	Koi (pond)	Tilapia (pond)	Carp (pond)	Carp+ prawn (pond)	Fish (*gher*)	Shrimp (*gher*)	Shrimp+rice (*gher*)	Shrimp+prawn+rice (*gher*)	Prawn+rice (*gher*)	Pangas (*beel*)	Rice-fish
Direct dialogue or meetings between conflicting parties	4	5	16	16	4	8	2	10	19	27	11	11	3	2
Consensus reached through community discussions (e.g. *saleesh*, meetings, etc.)	0.26	-	5	11	1	3	-	5	13	19	23	8	14	-
Solved by court of law	-	-	-	-	-	-	-	1	-	1	-	2	-	-
Unresolved	2	3	5	1	-	1	1	1	12	6	9	1	-	-

Table 50. Conflict mitigation processes (% of households reporting).

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In shrimp farming areas, existing drainage systems often become clogged because of unplanned or improper construction of ponds. Damage caused to flood embankments, which sometimes is done purposively by shrimp farmers to facilitate entry of saline water into *ghers*, was also identified as a cause of waterlogging. This often created conflicts with other community members, who were forced to walk long distances due to the disruption of access, and with those unable to produce rice and other crops because of the salinization of croplands. A final source of conflict occurred when farmers identified an individual suspected of poaching fish. These situations can quickly turn into serious or violent conflicts, and often involve large numbers of community members in the resolution process.

The study found that many conflicts were resolved through informal or formal discussions. Direct dialogue or discussion between the conflicting parties was observed as an effective means of resolving conflicts in some cases. Reaching consensus through community discussion was identified as an effective way of dealing with large-scale conflicts such as waterlogging problems. In such cases, complainants usually first brought cases to the head of the village or *Union Parishad* (the lowest level of local government) who, along with a panel of elders, would summon the conflicting parties, hear their arguments and concerns, and come to a decision on the issue (a process known as *saleesh*). Study participants noted that other conflicts, including disputes over poaching and conflicts between crop farmers and fish farmers, were also generally settled by *saleesh*. According to respondents, one of the main advantages of settling the disputes locally was that powerful local individuals involved in deciding the outcome of the *saleesh* could monitor and better implement their decisions. However, local settlement of disputes was also reported to result in unfavorable outcomes when one of the conflicting parties had good relations with powerful local individuals. Some conflicts, particularly those involving demarcation of land, were brought before formal courts. Conflict issues such as waterlogging and poaching remained unresolved in many instances.

Constraints to aquaculture development

Aquaculture is a rapidly growing industry in Bangladesh. However, its progress is not without constraints. In the present study, farmers were asked about their perceptions of constraints to aquaculture from the perspective of productivity growth and areal expansion.

Constraints to fish production

Table 51 shows that high capital requirements were noted by both homestead and commercial farmers as a key constraint to achieving higher levels of fish production. Good production requires regular use of feed, fertilizer and other inputs, which means that farmers require better access to finance than is presently available to them. Many poorer farmers may therefore struggle to increase production unless adequate credit facilities become available to them.

Half of shrimp farmers, 31% of koi (pond) farmers, 22% of pangas (pond) farmers and 8%–17% of all other farmers reported disease to be the main obstacle to good levels of production. Shrimp farmers reported that diseases such as white spot disease were serious and usually ended in high levels of mortality. However, in the case of finfish, the main effects of disease usually reduced fish growth. High stocking densities, poor water quality and stocking of diseased seed are the main causes of disease outbreaks (Hossain et al. 2008; Karim et al. 2012).

Lack of access to good-quality seed was reported by 9%–17% of homestead pond farmers, 14%–25% of commercial pond farmers and 13%–29% of commercial *gher* farmers as a constraint that resulted in suboptimal levels of production. Many farmers across technologies mentioned fish seed as a very important input, but reported a lack of timely availability as a problem, saying that although fish seed was available during the peak production season, they often struggled to obtain good-quality seed during the slack season (August–September) for fingerling production. A lack of good hatcheries and nurseries in the locality was identified as the main cause of scarcity of good-quality fish seed. The limited availability and high price of good-quality feed was also recognized as a constraint by some producers.

Continuous increases in the price of feed ingredients and formulated feeds, as compared to fish prices that were often static or declining in real terms, also represented a problem for commercial farmers.

Other reasons reported by farmers as to why they had not been able to fully benefit from aquaculture included a lack of knowledge about fish farming practices, shortages of manpower, conflicts over multiple ownership of ponds, frequent natural disasters, and unsuitable ponds. Fluctuating market prices were also regarded as a problem, especially by pangas and koi farmers (26% and 23%, respectively), for whom obtaining prices at which they were unable to realize acceptable profits demotivated them from making investments in increasing fish production.

Constraints to the expansion of aquaculture enterprises

Expanding the area under fish culture is an obvious means of increasing fish production. Even if the technology and productivity remain constant, expanding the area can provide additional production and income. This can be done either through leasing in land or through constructing new ponds on one's own land. However, the lack of financial capacity was a major limitation to this type of horizontal expansion (Table 52). Farmers mentioned that many of the most suitable areas were already in use for fish production, and expansion into new areas was not always feasible. The high lease value of ponds and *ghers*, or land on which to construct them, was mentioned as a major constraint to farmers wishing to expand the area of their operations.

Problems of collective decision making on cost sharing and distribution of benefits often limited the potential for the expansion or intensification of production in ponds with multiple owners. Problems associated with distribution of benefits and assignment of responsibility and accountability for management of multiowner ponds sometimes led to their underutilization and even abandonment. Some farmers also mentioned poaching and poisoning events in the locality as a factor that demotivated them from attempting to expand the area under production.

Summary

Aquaculture has long been considered an important means of ensuring adequate food supplies in a context of growing demand, while acting as a vehicle for rural development. However, many concerns have been raised over the activity's environmental and social sustainability and the conflicts engendered. The interplay of these positive and negative factors will ultimately determine how effective aquaculture is as a mechanism for inclusive rural development. A thorough understanding of these issues is required in order to develop effective strategies for minimizing negative aspects of aquaculture while maximizing benefits. This study attempted to investigate farmer perceptions of these issues.

Diseases and natural disasters were identified by respondents as the greatest threats to successful aquaculture production. Farmers were vulnerable to severe losses caused by these shocks. The impacts of aquaculture on the surrounding environment were mainly related to the destruction of surrounding agro-ecosystems by salinity intrusion associated with shrimp farming, as well as the environmental impacts of effluent discharge from intensive fish production systems into receiving ecosystems. Serious concerns have been raised about the social and environmental impacts of shrimp farms for a number of years. This study confirms that the shrimp industry is often guilty of abuses such as land grabbing, salinity intrusion into nearby cropland, and causing waterlogging.

Item	Fish (HS pond)	Fish+SIS (HS pond)	Pangas (pond)	Koi (pond)	Tilapia (pond)	Carp (pond)	Carp+ prawn (pond)	Fish (*gher*)	Shrimp (*gher*)	Shrimp+rice (*gher*)	Shrimp+prawn+rice (*gher*)	Prawn+rice (*gher*)	Pangas (*beel*)	Rice-fish
High investment costs	15	18	72	52	66	57	44	62	20	16	30	53	84	18
Poor-quality fish seed	9	17	14	15	25	20	21	13	19	16	29	25	3	8
Lack of timely availability of quality seed	15	7	12	33	12	16	14	10	17	19	22	16	46	9
Poor access to market information	13	18	18	21	9	11	29	14	19	17	21	18	16	23
Limited availability of quality feed	3	-	10	12	16	2	1	4	1	2	12	4	-	2
Lack of labor for farming operations	4	3	6	-	9	10	2	3	7	4	2	2	-	9
Fish disease	8	14	22	31	10	11	17	11	49	56	52	40	22	13
Lack of postharvest handling facilities (e.g. ice)	-	-	1	-	-	-	-	1	3	1	-	-	-	-
Frequent occurrence of natural disasters	10	1	2	-	36	7	34	33	19	10	13	23	5	-
Unstable market (e.g. sudden price drop or low demand)	2	-	36	23	2	2	1	3	2	-	1	2	19	-
Lack of technical knowhow	27	11	5	20	20	9	18	25	10	13	16	27	3	9
Pond characteristics or local infrastructure unsuitable for good production	9	20	1	10	1	5	-	-	9	17	22	3	-	-
High price of good-quality feed	10	12	20	20	7	19	5	14	3	-	28	20	-	39
Multiple ownership	14	15	-	-	-	5	1	4	6	4	-	0.47	8	1
Other	1	-	0.35	-	-	1	-	-	1	-	1	-	-	-
No response	7	9	1	-	-	2	-	-	1	2	1	-	-	-

Table 51. Farmer perceptions of constraints to aquaculture that inhibit production increases (% of households responding).

Item	Fish (HS pond)	Fish+SIS (HS pond)	Pangas (pond)	Koi (pond)	Tilapia (pond)	Carp (pond)	Carp+ prawn (pond)	Fish (*gher*)	Shrimp (*gher*)	Shrimp+rice (*gher*)	Shrimp+prawn+rice (*gher*)	Prawn+rice (*gher*)	Pangas (*beel*)	Rice-fish
Lack of financial capacity	13	26	17	44	43	37	44	40	48	50	37	53	57	27
Quality of own land not suitable for fish culture	11	26	3	2	18	13	4	12	12	16	22	7	19	48
Increased lease value (high competition among the entrepreneurs)	1	-	5	11	5	5	-	27	23	34	19	40	-	3
Multiple ownership	16	20	2	1	1	5	1	5	7	2	1	2	3	2
Poisoning problem	0.26	-	1	-	3	1	5	-	-	-	6	1	-	-
Poaching problem	1	5	1	-	3	2	9	2	3	-	7	3	-	1
No constraint (too busy with other business or did many times)	0.26	-	-	1	-	1	-	1	1	6	1	-	-	-
No response	60	42	73	41	26	35	37	18	9	6	23	20	14	14

Table 52. Farmer perceptions of constraints that prevent expansion of the area under production (% of households responding).

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SUMMARY AND CONCLUSIONS

This study evaluates the performance of a wide range of aquaculture systems in Bangladesh. It is by far the largest of its kind attempted to date. The purpose of this study was to identify and analyze the most important production systems, rather than to provide a nationally representative overview of the entire aquaculture sector of Bangladesh. As such, the study yields a huge amount of new information on production technologies that have never been thoroughly researched before. The study reveals an extremely diverse array of specialized, dynamic and rapidly evolving production technologies, adapted to a variety of market niches and local environmental conditions. This is a testament to the innovativeness of farmers and other value chain actors who have been the principal drivers of this development in Bangladesh.

Data was collected from six geographical hubs (clusters of districts with similar agro-ecology). The hubs considered for this study were Khulna, Jessore, Faridpur, Barisal, Mymensingh and Dinajpur. Data was collected from 12 districts in these hubs. Four additional districts (Natore, Bogra, Narsingdi and Cox's Bazar) were also surveyed due to the importance of aquaculture there. A purposive sampling strategy was adopted to select the farmers, as aquaculture development in Bangladesh occurs in a highly geographically clustered manner, which makes it very difficult to sample representatively over a broad area. A total of 14 distinct aquaculture technologies were identified, covering a broad range of species, intensity and commercial orientation.

The performance of farming technologies was examined in terms of production practices, productivity and returns. The specific objectives of the study were as follows:

- to identify socioeconomic characteristics of fish farmers practicing a variety of technologies
- to delineate differences in production practices and productivity across technologies
- to estimate production costs, revenues and profits generated from fish culture
- to identify rationales and incentives in farmer decision making pertaining to aquaculture
- to identify risk factors, environmental impacts, conflicts and constraints related to aquaculture development.

This survey was conducted from November 2011 to June 2012. Technological performance in terms of detailed input and output information, fish management practices, credit and marketing, and social and environmental issues were captured by the survey questionnaire, which had both open and closed format questions. The study generated insights that enable better understanding of aquaculture development in Bangladesh. The most important of these are summarized below, with reference to the study objectives.

Summary of key findings

Socioeconomic characteristics of fish farmers

- The majority (99%) of all farmers sampled were male. Limited participation and involvement of women in aquaculture is thus an important concern that needs to be addressed in the future.
- Homestead pond farmers had 13–15 years' experience on average, which is greater than that of commercial fish farmers, who had 5–13 years. This shows that commercial fish farming is comparatively new in Bangladesh.
- The average area of land operated by farmers ranged from 0.71 ha to 7.60 ha across technologies, with the highest areas being among farmers practicing commercial technologies. Annual incomes were closely correlated with aquaculture landholding size, with the highest returns achieved by commercial farmers.
- The relative contributions of commercial and homestead pond aquaculture to total household incomes varied widely, with homestead aquaculture contributing just 4%–5% of total household income, whereas all but one commercial technology contributed more than 50% of household income. The highest contributions to household income came from pangas (*beel*) at 83% and koi (pond) and pangas (pond), both at 72%.

- Farmers acquired new knowledge and technologies from a variety of sources, but not all farmers had equal access to information, with commercial farmers faring best. Social gatherings and farmer-to-farmer communications were found to be a common and often effective means of technology dissemination.
- Although commercial fish farming can be risky, the scale of potential benefits motivated farmers to invest in aquaculture, meaning that commercial aquaculture producers can be seen as entrepreneurial risk takers.
- Among the waterbodies utilized for aquaculture, homestead ponds were the smallest, at an average of 0.04–0.05 ha. The average area of waterbodies used for commercial aquaculture ranged across technologies from 0.14 ha to 3.34 ha.
- The majority of the waterbodies across technologies were single owned or single leased. Sixteen percent to 20% of homestead ponds were owned and operated by more than one individual (joint owned). However, joint ownership was rare for commercially managed waterbodies, ranging from 1% to 5%.
- Most waterbodies utilized for aquaculture were perennial, with growing seasons lasting approximately 8–10 months. The soil type of most waterbodies was loam, clay loam or sandy loam, all of which are suitable for fish production. Rainfall and groundwater were the major sources of water used for most technologies, except shrimp, which depended mainly on salt water from coastal rivers.

Differences in production practices across aquaculture technologies

- Fourteen technologies with distinct characteristics were identified. The management practices of homestead-based pond technologies were predominantly extensive in nature. Intensive or semi-intensive management practices were followed in pangas (pond), pangas (*beel*) and koi (pond) systems, and semi-intensive management practices were followed in tilapia (pond), carp (pond) and carp+prawn (pond) systems. Management practices in *gher*-based technologies and rice-fish were extensive (shrimp and shrimp+rice) or semi-intensive (fish- and prawn-based technologies).
- All technologies were polyculture, comprising a mix of species, but were usually dominated by one or two major species, most commonly carp, pangas, prawn, shrimp, tilapia or koi. Carp was the most common cultured species group across all technologies. Small local indigenous species were present to a small extent across all technologies, indicating potential for further expansion of their production.
- With the exception of homestead-based pond technologies, all technologies were market oriented. In commercial technologies, 80%–90% of total production was sold. In homestead pond technologies, about 55%–70% of total harvested biomass was used for home consumption.
- Supplementary feeding (e.g. with rice bran, wheat bran, mustard oil cake, etc.) was commonly reported among farmers across technologies, with the exception of those producing commercial pangas (pond), koi (pond), shrimp (*gher*) or shrimp+rice (*gher*). About 90% of the commercial pangas (pond) and koi (pond) culture used pelleted feed. In contrast, shrimp (*gher*) and shrimp+rice (*gher*) culture depended mainly on the naturally occurring food in the *gher* with very little additional supplementary feed use.
- Disease posed a serious threat to aquaculture farms. With the exception of producers operating homestead-based pond technologies, the majority of farmers took preventive measures against diseases. However, these measures were limited mainly to liming during pond preparation or immediately before winter.
- The use of dikes surrounding waterbodies for the production of vegetables, timber trees and fruits was widespread across technologies, with the exception of shrimp, shrimp+rice and rice-fish, most likely because the saline water used in shrimp culture and the narrowness of the *gher* and rice plot dikes are not suited to vegetable cropping.

Production performance

- The cost structures of aquaculture technologies presented in this study reveal that commercial aquaculture technologies are capital intensive compared to homestead pond-based technologies. Feed, fish seed and labor were identified as the three main cost items, accounting for about 75%–80% of the total cost of fish production across systems.

- The survey shows that some forms of aquaculture can create significant on-farm employment, with koi culture generating a maximum of 2.47 person-years (FTE) of employment per hectare of pond and rice-fish production generating a minimum of 0.43 person-years/ha.
- The study revealed relatively low levels of participation by rural women in aquaculture activities, as both family and hired labor. The causes identified for low participation included the distance of waterbodies from the homestead, social norms and religious restrictions, and lack of skills and knowledge. Differences also existed in the wage rates earned by men and women. Women earned 12%–19% less than their male counterparts for comparable work across all technologies.
- Regardless of technology, on average all types of farms generated profits (positive gross margins). The highest gross margin from fish came from koi (pond) culture (BDT 678,357/ha). The lowest gross margin was in fish (HS pond) at BDT 73,819/ha. Farmers received positive net margins on average from all technologies.
- Benefit-cost ratios ranged from 0.27 for koi (pond) to 2.00 for shrimp (*gher*). Benefit-cost ratios for technologies mostly or partially dependent on natural productivity for fish growth were higher than those from feed- and labor-intensive technologies, but the latter tended to yield higher absolute returns.
- With the exception of a small number of intensive commercial technologies and brackish-water shrimp production, the integration of dikes and/or rice plots with aquaculture increased the profit margins of the farming systems.

Factors affecting farmer decision making and investments in aquaculture

- Access to credit is closely linked to the productivity and commercialization of aquaculture. Around 30% of farmers accessed credit for aquaculture investments, from a mix of formal and informal sources. Among borrowers, only 22% took credit from a bank. Long distances, administrative bureaucracy and collateral requirements were identified as major obstacles to bank loans. The credit programs of NGOs appeared to be easily accessible but expensive due to high interest rates, and had difficult repayment schedules.
- The informal lending sector played a significant role in serving the credit needs of borrowers with limited access to formal finance. Loans from these sources were usually not secured, but interest rates were reportedly high.
- Market conditions were the main factor influencing farmer decisions regarding their aquaculture operations. High market demand (expressed as high prices) was the major reason given for harvesting fish among commercial operators.
- Decisions regarding harvesting fish for sale were dominated by male household heads, but decisions regarding harvesting for home consumption, while also dominated by men, were often made jointly by husbands and wives.
- The study identified a variety of marketing intermediaries, including wholesalers, collectors, depot owners and harvesting teams, who purchased fish from the producers and supplied to wholesale and retail markets. Most farmers sold directly to wholesalers. Output-tied or interlocked credit arrangements were very rare, with the partial exception of shrimp production.
- Slow transportation, bad roads and other infrastructure facilities, as well as lack of preservation facilities (e.g. limited icing facilities) close to the farm, were the main constraints to direct marketing of fish by farmers.
- A large proportion of farmers (16%–60% across technologies) placed harvested fish on plastic or jute sheets or on open ground after cleaning them with pond or *gher* water. The practice was common across all homestead and commercial technologies. There is ample scope for contamination of fish at this stage, which may reduce the final quality and price of fish.

Social, environmental and other factors affecting aquaculture expansion

- Many farmers had experienced shocks, mainly in the form of diseases and natural

calamities (e.g. floods and droughts). These crises were common among both homestead and commercial farmers, but caused greatest financial damage and losses to commercial farmers with larger investments. Nevertheless, average losses were usually relatively minor compared to average returns.
- A variety of conflicts between fish farmers, crop farmers and members of neighboring communities were identified. These were mainly driven by discharge of water in the areas surrounding farms. This resulted in waterlogging, excessive nutrient loading, saline intrusion in croplands and reduced agricultural crop yields, which together also represent major negative environmental impacts. The most severe conflicts and environmental impacts were associated with shrimp farming, followed by intensive pond-based technologies, most notably pangas and koi.
- Aquaculture in Bangladesh is a rapidly growing industry, and the impressive upward trend in production is likely to continue in the future. However, this progress is accompanied by a number of constraints that may hamper future growth. The most important of these include the limited financial capacity of smaller farmers, environmental degradation and related conflicts, fish diseases, limited availability of good-quality fish seed and feed, and rising input prices.

Policy implications

Aquaculture is the fastest-growing food-producing sector in Bangladesh and has demonstrated continuous increases in production over recent decades. Evidence presented in this study shows clearly that aquaculture, in particular in its commercial forms, has great potential to create income and employment opportunities and improve food security. However, much of the potential to improve food security and rural livelihoods remains to be harnessed. Addressing a number of critical social, economic and policy constraints could contribute a great deal to achieving these goals.

This study demonstrates that, with the partial exception of homestead pond systems, direct participation in aquaculture by resource-poor households was limited. Further institutional innovations are required to improve the production and profits of aquaculture in small ponds and other waterbodies located close to homesteads (to which the resource-poor have some access). Public services should be more effectively targeted to ensure that poorer households are better reached by extension services.

The study also shows that small indigenous fish species rich in vitamin A, calcium, iron, zinc and other micronutrients can be successfully introduced to traditional polyculture systems without hampering the production of other fish species. Mass dissemination of these technologies, as well as hatchery production of the seed required to support them, is needed to improve the welfare of the resource-poor.

Although many of the inputs required for aquaculture production (feed, seed, fertilizer and labor) are widely available, participants identified the timely availability of good-quality inputs, most importantly seed and feed, as a constraint. The government should continue its efforts to improve input quality (e.g. through support for genetic improvements in seed quality), but also pay attention to developing the efficiency of distribution channels (e.g. through further investments in transport infrastructure) so that seed and feed are available when farmers need them.

Capacity development for market intermediaries, as well as the development of links between resource-poor rural producers and input suppliers, will also be important for ensuring that producers can access quality inputs in time and are able to sell their produce at higher prices. The study shows that most homestead pond producers and many commercial farmers were unaware of the importance of ensuring adequate postharvest handling of fish. A concerted effort is needed to upgrade producer capacity in postharvest methods and to raise awareness of their importance.

The study points to limited participation by women in most aquaculture technologies as both family and hired labor, with a small number of exceptions. Gender disparities in wage rates of 10%–20% were also observed. Women in rural Bangladesh are, to a great extent, subjected to a restrictive gender-based division of labor and to social taboos that limit mobility and reduce their participation in income-generating activities beyond the homestead. To overcome these obstacles, development projects and government agencies should work together with community members and social development and gender experts to develop gender-sensitive approaches to account for these practical barriers, while creating greater space for women's agency through skills development to support participation in income-generating activities.

Measures that result in further increases in access to rural credit are necessary for facilitating technology transfer, stimulating productivity increases, generating employment and increasing producer incomes. Lack of financial capital was identified by producers as a major constraint to commercialization of aquaculture. The study shows that considering both formal and informal sources, only 30% of farmers had access to credit for aquaculture. Farmers reported that the collateral requirements of public and commercial banks and the high rates of interest and inflexible repayment schedules of microfinance providers were major obstacles to accessing formal credit. Special attention to farmers' practical needs and a supportive policy framework are therefore required to develop appropriate financial instruments that increase fish producers' access to credit.

Finally, aquaculture development must be compatible with the environment and dependent surrounding communities if it is to be sustainable over the long term. Proper planning in consultation with community members and other relevant stakeholders is urgently needed to avert or resolve existing and potential environmental problems and associated conflicts. These are mainly related to intensive pond-based commercial aquaculture systems and saline *gher*-based shrimp farming technologies, which result in problems such as effluent discharge, saline intrusion and waterlogging.

The impacts of climate change on aquatic ecosystems and aquaculture are currently not well understood. The study indicates that climatic shocks such as more frequent and severe floods and cyclones can have serious negative impacts on aquaculture. The overarching need in these instances is to develop adaptation and mitigation measures that will improve the ability of producers to respond rapidly to the threats to livelihoods and food security, as well as the opportunities climate change may provide. Disease was also shown to be a critical risk, most importantly for producers of shrimp and prawn, but also of concern for carp, tilapia, pangas and koi. Greater investment in targeted research and effective veterinary services is needed to develop effective preventative and mitigation strategies against fish disease.

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ANNEX 1. LIST OF FISH SPECIES REPORTED IN PRODUCTION ECONOMICS FARM SURVEY

Bangla name	English name	Scientific name	Species category
Catla	Catla	*Catla catla*	Indian major carp
Mrigel	Mrigal	*Cirrhinus mrigala*	Indian major carp
Rui	Rohu	*Labeo rohita*	Indian major carp
Bata	Bata	*Labeo bata*	Indian minor carp
Bhangan	Boga labeo	*Labeo boga*	Indian minor carp
Gonia	Kuria labeo	*Labeo gonius*	Indian minor carp
Kalibaus	Orange fin labeo	*Labeo calbasu*	Indian minor carp
Bighead carp	Bighead carp	*Aristichthys nobilis*	Exotic carp
Black carp	Black carp	*Mylopharyngodon piceus*	Exotic carp
Common carp	Common carp	*Cyprinus carpio*	Exotic carp
Grass carp	Grass carp	*Ctenopharyngodon idellus*	Exotic carp
Sarputi	Silver barb	*Puntius gonionotus*	Exotic carp
Silver carp	Silver carp	*Hypophthalmichthys molitrix*	Exotic carp
Pangas	Striped catfish	*Pangasianodon hypophthalmus*	Pangas
Koi	Climbing perch	*Anabas testudineus*	Koi
Nilotica	Nile tilapia	*Oreochromis nilotica*	Tilapia
Tilapia	Mozambique tilapia	*Oreochromis mossambica*	Tilapia
Magur	Walking catfish	*Clarias batrachus*	Shing
Shing	Stinging catfish	*Heteropneustes fossilis*	Shing
Darkina	Flying barb	*Esomus danricus*	Small indigenous species
Deshi puti	Puntio barb	*Puntius puntio*	Small indigenous species
Dhela	Minnow	*Osteobrama cotio*	Small indigenous species
Ghora machh	Small fish	*Labeo dyocheilus*	Small indigenous species
Gura chingri	Spider prawn	*Macrobrachium tenuipes*	Small indigenous species
Mola	Mola carplet	*Amblypharyngodon mola*	Small indigenous species
Ayre	Long-whiskered catfish	*Aorichthys aor*	Other fish
Bou or rani fish	Victory loach or queen loach	*Botia dario*	Other fish
Chanda	Elongate glass perch	*Chanda nama*	Other fish
Gajar	Giant snakehead	*Channa marulius*	Other fish
Chang	Asiatic snakehead	*Channa orientalis*	Other fish
Taki	Spotted snakehead	*Channa punctatus*	Other fish
Shol	Striped snakehead	*Channa striatus*	Other fish
Khalisha	Striped gourami	*Colisa fasciatus*	Other fish
Chapila	Indian river shad	*Gadusia chapra*	Other fish
Baila	Tank goby	*Glossogobius giurus*	Other fish
Vetki	Barramundi or Asian seabass	*Lates calcarifer*	Other fish
Parsha	Goldspot mullet	*Liza parsia*	Other fish
Baim	Zig zag eel	*Mastacembelus armatus*	Other fish
Tengra	Striped dwarf catfish	*Mystus vittatus*	Other fish
Bheda	Mud perch	*Nandus nandus*	Other fish
Chitol	Humped featherback	*Notopterus chitala*	Other fish
Foli	Grey featherback	*Notopterus notopterus*	Other fish
Pabda	Butter catfish	*Ompok pabda*	Other fish
Datina	Silver bream	*Pomadasys hasta*	Other fish

Bangla name	English name	Scientific name	Species category
Piranha	Red piranha	*Pygocentrus nattereri*	Other fish
Kharsola	Mullet	*Rhinomugil corsula*	Other fish
Chela	Minnow	*Salmostoma bacila*	Other fish
Crab	Mud crab	*Scylla sp.*	Other fish
Boal	Freshwater shark	*Wallagu attu*	Other fish
Prawn or golda	Giant freshwater prawn	*Macrobrachium rosenbergii*	Prawn
Shrimp or bagda	Giant tiger prawn	*Penaeus monodon*	Tiger shrimp
Chaka chingri	Indian white shrimp	*Penaeus indicus*	Other shrimp
Harina chingri	Brown shrimp	*Metapenaeus monoceros*	Other shrimp
Chali chingri	Yellow shrimp	*Metapenaeus bravicornis*	Other shrimp

ANNEX 2. SOURCE OF FISH SEED STOCKED IN DIFFERENT AQUACULTURE SYSTEMS, BY SPECIES (% OF HOUSEHOLDS STOCKING)

Technology	Hatchery	Nursery	Mobile seed trader	Postlarvae trader	Seed commission agent	Neighboring farmers	Open source
Fish (HS pond)							
Exotic carp	18	13	78	-	-	3	-
Indian major carp	21	25	73	-	-	-	-
Indian minor carp	23	12	66	-	-	-	-
Koi	-	-	100	-	-	-	-
Pangas	19	6	75	-	-	-	-
Prawn	-	-	-	-	-	-	100
Shing	-	-	100	-	-	-	-
Small indigenous species	-	-	-	-	-	44	56
Tilapia	19	23	56	-	-	12	-
Fish+SIS (HS pond)							
Exotic carp	7	4	91	-	-	-	-
Indian major carp	7	4	90	-	-	-	-
Indian minor carp	3	5	92	-	-	-	-
Prawn	100	-	-	-	-	-	-
Shing	-	-	100	-	-	-	-
Small indigenous species	-	-	-	-	-	33	67
Tilapia	-	-	100	-	-	-	-
Pangas (pond)							
Exotic carp	38	56	17	-	0.45	-	-
Indian major carp	30	58	16	-	0.37	-	-
Indian minor carp	28	67	8	-	-	-	-
Pangas	22	76	1	-	1	-	-
Shing	14	57	29	-	-	-	-
Tilapia	32	50	18	-	-	-	-
Koi (pond)							
Exotic carp	50	20	30	-	-	-	-
Indian major carp	50	25	42	-	-	-	-
Koi	62	40	-	-	-	-	-
Shing	37	61	9	-	-	-	-
Tilapia	83	25	-	-	-	-	-
Tilapia (pond)							
Exotic carp	28	35	49	-	2	-	-
Indian major carp	29	34	41	-	3	-	-
Indian minor carp	17	50	33	-	-	-	-
Koi	23	38	38	-	-	-	-
Pangas	17	33	50	-	-	-	-
Prawn	33	-	-	-	67	-	-
Shing	-	50	50	-	-	-	-
Small indigenous species	-	-	-	-	-	50	50
Tilapia	48	38	11	-	-	4	-

ANNEX 2

Technology	Hatchery	Nursery	Mobile seed trader	Postlarvae trader	Seed commission agent	Neighboring farmers	Open source
Carp (pond)							
Exotic carp	57	45	48	-	-	-	-
Indian major carp	44	45	22	-	-	-	-
Indian minor carp	46	48	7	-	-	-	-
Koi	-	-	100	-	-	-	-
Pangas	-	50	50	-	-	-	-
Prawn	50	-	-	50	-	-	-
Shing	60	17	23	-	-	-	-
Small indigenous species	-	-	-	-	-	-	100
Tilapia	35	33	33	-	-	-	-
Carp+prawn (pond)							
Exotic carp	2	34	76	-	1	-	-
Indian major carp	2	32	68	-	1	-	-
Indian minor carp	-	60	40	-	-	-	-
Koi	-	-	100	-	-	-	-
Pangas	-	14	86	-	-	-	-
Prawn	58	6	-	31	1	-	4
Shing	-	-	100	-	-	-	-
Tilapia	56	40	-	-	-	4	-
Fish (*gher*)							
Exotic carp	11	46	58	-	-	-	-
Indian major carp	11	56	38	-	-	-	-
Indian minor carp	13	71	21	-	-	-	-
Koi	-	-	100	-	-	-	-
Pangas	7	29	64	-	-	-	-
Prawn	92	-	-	2	-	-	6
Shing	11	-	89	-	-	-	-
Tilapia	20	65	17	-	-	-	-
Shrimp (*gher*)							
Exotic carp	3	15	84	-	2	-	-
Indian major carp	5	18	81	-	1	-	-
Indian minor carp	11	11	78	-	-	-	-
Other shrimp	-	-	-	62	-	-	38
Pangas	-	100	-	-	-	-	-
Shing	-	-	100	-	-	-	-
Tiger shrimp	31	11	-	3	56	-	-
Tilapia	13	5	72	3	12	-	-
Shrimp+rice (*gher*)							
Exotic carp	-	-	100	-	-	-	-
Indian major carp	-	-	100	-	-	-	-
Indian minor carp	-	-	100	-	-	-	-
Other shrimp	-	-	-	94	6	-	-
Tiger shrimp	33	2	-	52	13	-	-
Tilapia	6	-	94	2	3	-	-

ANNEX 2

Technology	Hatchery	Nursery	Mobile seed trader	Postlarvae trader	Seed commission agent	Neighboring farmers	Open source
Shrimp+prawn+rice (*gher*)							
Exotic carp	4	12	86	-	-	-	-
Indian major carp	2	22	77	-	-	-	-
Indian minor carp	-	-	100	-	-	-	-
Pangas	-	67	33	-	-	-	-
Prawn	97	-	-	1	1	-	-
Tiger shrimp	27	-	-	21	52	-	-
Tilapia	17	-	-	-	-	83	-
Prawn+rice (*gher*)							
Exotic carp	7	42	53	4	1	-	-
Indian major carp	4	41	53	5	0.47	-	-
Indian minor carp	-	37	58	5	-	-	-
Koi	-	-	100	-	-	-	-
Prawn	85	-	-	4	11	-	-
Tilapia	14	29	57	-	-	-	-
Pangas (*beel*)							
Exotic carp	46	62	8	-	-	-	-
Indian major carp	43	59	-	-	-	-	-
Indian minor carp	52	48	-	-	-	-	-
Pangas	38	62	-	-	-	-	-
Tilapia	18	82	-	-	-	-	-
Rice-fish							
Exotic carp	12	28	68	-	-	-	-
Indian major carp	13	27	67	-	-	-	-
Indian minor carp	13	23	65	-	-	-	-
Koi	-	7	93	-	-	-	-
Pangas	-	-	100	-	-	-	-
Shing	-	60	40	-	-	-	-
Tilapia	20	60	20	-	-	-	-

Note: Mobile fish seed trader (locally called *patil wallah*): independent trader who transports small quantities of fish seed in a big pot (local name: *patil*), usually on foot, bicycle or rickshaw, or public transportation (buses or trains), and sells to fish farmers at the pond side.

ANNEX 2

ANNEX 3. CROSS-HUB COMPARISON OF FISH YIELDS BY TECHNOLOGY (kg/ha)

Technology	Barisal	Dinajpur	Faridpur	Jessore	Khulna	Mymensingh	Outside
Fish (HS pond)							
Total productivity	2,129	1,478	1,588	2,012		1,808	
Carp	1,690	1,345	1,446	1,691		1,603	
Tilapia	241	22	119	174		135	
Other	198	111	23	146		70	
Pangas (pond)							
Total productivity				22,195		41,575	28,198
Pangas				18,450		38,513	24,703
Carp				3,053		2,554	2,877
Other				691		508	614
Tilapia (pond)							
Total productivity	6,029	12,686	4,514			19,326	
Tilapia	4,090	10,883	2,012			15,246	
Carp	1,725	1,789	2,500			2,050	
Other	214	15	2			2,030	
Carp (pond)							
Total productivity		3,592	3,817	3,729		5,247	6,278
Carp		3,499	3,738	3,380		4,893	6,025
Tilapia		30	57	301		331	47
Other		63	22	48		24	206
Carp+prawn (pond)							
Total productivity	2,156		2,866				
Carp	1,709		2,327				
Prawn	145		536				
Other	302		3				
Fish (*gher*)							
Total productivity	3,612			3,061			
Carp	3,243			1,885			
Tilapia	142			1,101			
Other	227			74			
Shrimp (*gher*)							
Total productivity	881				999		382
Tiger shrimp	239				357		81
Tilapia	21				387		96
Other	621				255		205
Prawn+rice (*gher*)							
Total productivity			2,414	2,209	1,109		
Prawn			377	522	379		
Carp			2,033	1,644	605		
Other			4	42	125		

ANNEX 4. AVERAGE FARM GATE PRICE OF FISH BY HUB AND SPECIES (BDT/kg)

Fish species	Hub						
	Barisal	Dinajpur	Faridpur	Jessore	Khulna	Mymensingh	Outside
Indian major carp	104	97	96	116	135	88	170
Exotic carp	88	85	78	92	98	75	117
Indian minor carp	85	99	111	96	140	85	175
Small indigenous species	129	69	98	54	59	104	145
Shing	166	327	354	315	350	335	460
Pangas	84	100	-	82	80	69	70
Tilapia	88	82	90	85	54	73	88
Koi	95	121	140	180	133	102	346
Other fish	135	144	206	108	165	260	287
Prawn	745	550	798	695	680	-	-
Tiger shrimp	642	-	-	-	522	-	579
Other shrimp	172	-	-	175	184	-	203

ANNEX 5. LIST OF MARKETING INTERMEDIARIES

Type of intermediary	Description
Arat	An *arat* is generally an office, store or warehouse in a marketplace from which an *arotdar* conducts his business.
Arotdar	An *arotdar* is the largest actor in the fish distribution system. An *arotdar* arranges or negotiates sales for sellers on a commission basis, and often acts as a wholesaler. The *arotdar* sometimes provides credit to fish farmers.
Paiker or *bepari*	A *paiker* or *bepari* is a trader performing the assembly function in the marketing chain, buying from farms and transporting to wholesale markets for resale. In some cases, particularly in shrimp production, the *paiker* acts to provide credit to the farmer during the production cycle.
Nikari	A *nikari* is a trader who acts as a broker. A *nikari* does not own the fish traded, but acts as a bridge between farmers and buyers, receiving a commission for brokering the sale.
Depot	Depot owners are wholesale traders who have their own fixed premises and staff in markets and primarily trade in shrimp and prawn. They are the main intermediaries between farmers and shrimp commission agents or processing plants.
Faria	A *faria* is a trader who purchases small quantities of fish, shrimp or prawn from fish farmers based far from markets and transports them to a wholesale trader (*arotdar*) or retailer for sale.
Mahajan or *dadandar*	Traditional moneylenders or wholesalers who provide output-tied credit (*dadan)* to some fish and shrimp or prawn producers on the condition that the fish or shrimp produced using the loan are sold exclusively to the loan provider. Sometimes, the prices received by the farmer are determined at the time the credit is extended.

ANNEX 6. LIST OF DISEASES IDENTIFIED BY FARMERS

Disease name	Symptoms as reported by farmers	Fish species
White spot disease	White spots on carapace, shell and tail, gill damage, sluggish movement, move to water surface, gather near the pond dike, reduced food intake, reduced preening activities, loose cuticles, reddish discoloration	Shrimp and prawn
Black gill disease	Black gills, bacterial erosion on carapace and gill, less appetite, lethargic	Shrimp and prawn
Antenna and rostrum broken disease	Antenna and rostrum broken, removal of the rostrum and antenna, lethargic	Prawn
Black or brown spot disease	Black or brown spots on shell, tail and gills; lethargic, less appetite	Shrimp and prawn
Soft shell disease	Shell is thin and persistently soft, dark spots on shell, shell is rough and wrinkled, lethargic, slow growth rate	Prawn
Gill disease	Reddish, whitish or greenish mottled spots on gill, swollen gills, lethargic, gather near pond dikes, loss of appetite	Pangas and koi
Parasitic disease	Abnormal swimming, lethargic, gather near pond dikes, loss of appetite, abnormal coloration, excess mucous, skin lesions, swollen belly, extended eyes	Carp, pangas and tilapia
Tail and fin rot disease	Gather near pond dikes, lethargic, lesions on tail and fin, extrusion of tail and fin, hemorrhagic tail and fin, reddened areas at base of fins, cloudy eyes, exposed fin rays, skin ulcers with gray or red margins	Carp, pangas and koi
Dropsy	Swollen abdomen, protruding scales, black color on body, lethargy, loss of appetite	Carp, pangas, koi and tilapia
Anal protrusion	Swollen anus, anal protrusion, reddish or yellowish discoloration of anus, loss of appetite	Pangas and koi
Fungal disease	Cotton wool-like growth on the skin and fin, lethargy, ulceration and erosion on skin and muscle, greenish discoloration of fin	Carp, pangas and koi
Epizootic ulcerative syndrome (EUS)	Red spot on operculum, eye and anal surrounding; deep ulcers at the base of fin and over the body	Carp and koi
Scale loss	Protruding scale, ulceration on tail portion, red spot on body	Koi
Pop eye	Swollen and eye protrusion, reddish discoloration of eye and mouth, deep black eye	Carp, pangas and koi

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