12 Value chains in aquaculture and fisheries in Bangladesh

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Introduction

The importance of fish[1] in the Bangladeshi culture is captured by the adage 'māchey bhātey Bangāli'—that is, 'fish and rice make a Bengali.' The typical daily diet in Bangladesh consists of rice, some vegetables, small quantities of pulses and fish, depending on the availability (Bhattacharjee, Saha and Nandi, 2007). Fish is the most frequently consumed animal-sourced food in Bangladesh.[2] Fish consumption contributes to positive human outcomes by supplying macronutrients such as proteins, lipids and micronutrients, such as vitamins, minerals, essential fatty acids and amino acids. For example, Dasgupta et al. (2017) show that the risk of child mortality in Bangladesh is lower for children born during peak fishing season and to mothers who prefer to eat fish than for those born outside of peak fishing season and to mothers who do not prefer fish. Consumption of fish, including those sourced from capture fisheries, improves nutritional and dietary diversity in Bangladesh, a country with inadequate diversity of dietary items. Given the multiple roles fish play in the Bangladeshi diet, changes in the consumption and supply patterns of fish have wider implications for food and nutritional security in the country.

According to Needham and Funge-Smith (2014), per capita fish consumption in Bangladesh stands at 11.9 kg per year, and fish constitutes 11.1% of total protein consumption in the country. The statistics on per capita fish consumption and on fish's share of animal protein consumption reported by Needham and Funge-Smith (2014) for Bangladesh are considerably smaller than those in other studies. For example, Dey et al. (2005) and Dey, Alam and Paraguas (2011), both using data collected in 1998–1999, find average per capita fish consumption in Bangladesh was 22.2 kg per year. Dey et al. (2005) estimated that fish protein consumption constitutes more than 50% of total animal protein consumption. This finding is supported by other studies such as Dey, Bose and Alam (2008), FAO (2014) and Reardon et al. (2014). Dey et al. (2005) report Bangladesh residents in the lowest income quartile consume 13.05 kg of fish per capita annually and those in the highest income quartile consume 33.64 kg per capita. Toufique and Belton (2014) use the Household Income and Expenditure Survey (HIES) conducted by the Bangladesh Bureau of Statistics

(BBS) in 2000, 2005 and 2010. National average per capita fish consumption in 2000 was 14.1 kg, which grew to 15.4 kg in 2005 and to 18.1 kg in 2010. This discrepancy in per capita consumption statistics in different studies could be due to differences in the characteristics of data used for the analyses. As noted by Dey et al. (2005), BBS databases do not cover consumption of fish sourced through informal trade from neighboring countries. Nor do official statistics in Bangladesh include the consumption of many small and non-commercial fish species obtained from artisanal and subsistence fisheries, though 'assorted small fish' are one of the largest fish groups in terms of consumption, with a 20%–27% share of total consumption expenditures on fish (Dey, Alam and Paraguas, 2011).

Despite these differences in numbers attributable to the characteristics of databases, irrefutable evidence supports a substantial positive trend in per capita fish consumption over time in Bangladesh. Dey et al. (2005) find a consistent increase in per capita fish consumption during the 1981–2000 period, with the later years showing faster growth in consumption. Toufique and Belton (2014) show that fish consumption in urban and rural areas increased between 2000 and 2010, with urban areas showing stronger increases. Belton, van Asseldonk and Thilsted (2014) use survey data collected in 1996–1997 and 2006–2007 on the poverty impacts of development initiatives to analyze changes in fish consumption patterns across income quartiles. Per capita fish consumption increased between the two time periods, increasing strongly for higher income quartiles. Per capita consumption of fish from non-aquaculture sources declined, with stronger declines for lower-income quartiles. However, this decline was compensated for by increases in consumption of farmed fish, with lower-income groups showing stronger increases. Al Hasan et al. (2019) use the FAOSTAT Food Balance Sheets data to find fish consumption increased 2.25 times between 1961 and 2013. Substantial increases in per capita fish consumption in Bangladesh are impressive when seen in the context of the population's rapid growth, the country's small geographical area and the negative impacts of anthropogenic pressures on resources and other ever increasing constraints on production.

Apart from supplying macronutrients such as protein and lipids, fish is an important source of micronutrients such as vitamins and minerals. Small indigenous fishes, mostly sourced from inland and marine capture fisheries, play a significant role as a source of micronutrients. These fish do not grow more than 25 cm in length (Roos, Islam and Thilsted, 2003). About 140 species of 260 freshwater fish species in Bangladesh can be considered small indigenous fishes (Thilsted and Wahab, 2014). Seasonal and spatial dispersion in the composition of catches of this large number of species indirectly promotes dietary diversity. On average, fish consumers receive significantly higher intakes of energy content and fats from farmed fish, but small fish are significantly better sources of essential micronutrients such as iron, zinc, calcium and vitamins A and B_{12} than farmed fish (Bogard et al., 2017). Small fish usually are consumed whole (eyes, head, bones and/or viscera) and hence contribute to nutritional diversity.

However, the falling amounts of catches and rising prices of small indigenous fish are hindering their potential to contribute to food and nutritional security in Bangladesh.

Fish consumption in Bangladesh is highly responsive to prices and income (Dey, Alam and Bose, 2010; Toufique, 2015). Lower-income groups respond more strongly (i.e., more elastically) to changes in fish prices. Therefore, compared to affluent households, poorer households benefit more from falling prices (for example, from increased supply), but they also are harmed more by increasing prices (say, from falling catches). Belton, van Asseldonk and Thilsted (2014) found that poorer households showed greater declines in their consumption of captured fish and stronger increases in their consumption of farmed fish in 2006–2007 compared to 1996–1997. This period was characterized by a transition from capture fisheries to aquaculture as the major source of fish production in Bangladesh. Trade-offs in the types of fish consumed has implications in the context of the second Sustainable Development Goal, which is to achieve food security and improve nutrition while promoting sustainable agriculture. Bangladesh's economy, as measured by its gross domestic product (GDP), has grown impressively at an average rate of 6% per year since the year 2000, helping reduce the poverty level from 44.2% in 1991 to 13.8% in 2016–2017 (World Bank, 2018). However, given the poor dietary diversity and the low elasticity of nutrient intake with respect to income in developing countries such as Bangladesh, malnutrition has not been controlled effectively. Therefore, besides producing enough fish, value chains in aquaculture and fisheries need to be made more 'nutrition-sensitive' to achieve Sustainable Development Goals.

Structural transformations in fish value chain in Bangladesh

Fish production comes from two sources: aquaculture and capture fisheries. Aquaculture is the farming of aquatic organisms including fish, mollusks and crustaceans. Capture fishery production is the quantity of wild (non-fed) fish harvested from undomesticated ecosystems for all commercial, industrial, recreational and subsistence purposes. Seafood and fish are among the few food items in modern food systems for which harvests from the wild (as opposed to farmed or domesticated food) still play an important role in value chains. However, wild-harvested fish's share of total fish production has been shrinking continuously worldwide. Bangladesh is no exception to this, with aquaculture expanding rapidly and production from capture fisheries shrinking. Activities related to aquaculture and fisheries in Bangladesh can be classified broadly into three main subsectors: aquaculture (56% of total production), inland capture fisheries (28%) and marine and coastal capture fisheries (16%), with the total production estimated at 4,276,641 metric tons (MT) in 2017–2018 (Department of Fisheries Bangladesh, 2018).

Though the terms 'value chain' and 'supply chain' often are used interchangeably, there are some basic differences (Dey, Bjorndal and Lem, 2015; Nguyen et al., 2019). Value chains add incremental value to the product in the nodes of a chain by either adding or creating value. Seafood and fish value chain activities include value-adding or value-creating activities at each node in the supply chain to meet consumers' demand for the product. The smooth functioning of seafood/fish value chains requires not only factors of production and technology but also of efficient transport, market information systems, governance and management. Fish value chains in Bangladesh are generally long and complex, with many intermediaries between producers and final consumers of fish products in the country. Fish production/landing points are scattered all over the country, and many are quite distant from the final consuming markets. The four main types of domestic fish markets are: primary markets, located near the source of production; secondary markets, usually located in the subdistrict (upazila) headquarters; higher secondary markets, located in big cities; and terminal markets.

Four major changes can be observed in the fish value chain in Bangladesh over the recent decades: the emergence of aquaculture, specifically inland aquaculture, as the main source of fish supply, replacing inland capture fisheries; the impressive growth of entrepreneurial/intensive aquaculture, as opposed to homestead and semi-intensive aquaculture; the diversification of species for aquaculture; and the proliferation of value chain actors. These changes imply that in Bangladesh, aquaculture has emerged as the major source of fish production even as the aquaculture sector itself has undergone remarkable transformation. In fact, the transformation of the aquaculture sector from mostly homestead or semi-intensive production systems to entrepreneurial and commercial production has been a major factor responsible for aquaculture's rising position in overall fish production. Bangladesh is now the world's fifth-largest producer of farmed fish (FAO, 2018).

Shift from capture fisheries to aquaculture

Traditionally, the major source of Bangladesh's fish supply was inland capture fisheries. Unlike most other countries with substantial marine and coastal resources, production from inland capture fisheries in Bangladesh has been substantially larger than production from marine and coastal capture fisheries. In fact, Bangladesh is the only country with a larger share of inland capture fisheries (64%) than marine capture fisheries (36%) among the eight South Asian and Southeast Asian countries analyzed by Fernandes (2019). This is because the whole country can be considered a floodplain of the Ganga–Brahmaputra–Meghna river system. This is the second-largest river system in the world and drains into the Bay of Bengal via Bangladesh. This river system has endowed the country with a vast resource of inland and coastal water bodies that support a multitude of ecosystem services, including the third-greatest fish biodiversity in Asia. Water bodies in Bangladesh total 44,080 km^2, of which 91.8% are open water bodies and 8.2% are closed water bodies (Bangladesh Delta Plan 2001, 2018). Flooded lands (64.3% of the total area of water bodies), rivers and estuaries (23.4%), ponds (4.9%), coastal lowlands (3.2%), beels and haors (2.6%), Kaptai lake (1.5%) and baors (0.1%) are the major types of water bodies constituting the wetlands of Bangladesh. The Ganga–Brahmaputra–Meghna river system is the source of many of the 230 riverine tributaries and distributaries that traverse the length and breadth of the country (FAO AQUASTAT, 2014).[3] The riverine floodplains are inundated during monsoons, leading to rich fish harvests that sustain the livelihoods of landless and marginalized fisherfolk (Craig et al., 2004).

However, open water bodies that support rich fishery are under threat, leading to losses of fishery habitats and declines in fish catches (Bangladesh Delta Plan 2001, 2018). The amount of permanent wetlands has been depleted alarmingly, especially in Dhaka and the surrounding areas (Rai et al., 2017), leading to severe habitat loss. Satellite image analysis shows that the total dry period wetland area in the northwest region of Bangladesh decreased from 1,208.72 km^2 in 1989 to 903.54 km^2 in 2000 and to 867.18 km^2 in 2010 (Shopan et al., 2013). Interventions in riverine systems for flood control, drainage and irrigation systems also have been observed, obstructing the lateral migrations of rheophilic whitefish species and the passive drift of larvae from the main channel to the modified floodplains (Craig et al., 2004). Full flood control is the most obstructive in terms of its negative impacts on fish catches, fish movements and fish breeding. The impact levels of controlled flooding and partial flood control vary, but catch composition becomes less diverse after flood controls are implemented (Bangladesh Delta Plan 2001, 2018). Some other major causes of declining fish catches are industrial pollution, infrastructure building, encroachment of resources, agricultural intensification and runoffs and industrial pollution (Dey, Bose and Alam, 2008; Belton et al., 2011).

Figure 12.1 shows the *area plot* of contributions of different sources of fish production in Bangladesh from 1950 to 2017. The plot shows that until the mid-1970s, production from inland capture fisheries constituted about 70% to 75% of total fish production. From then on, the share of inland capture has declined continuously and appears to have settled at about 25% for the last few years. On the other hand, inland aquaculture had about a 10%–20% share of total fish production until the mid-1980s, before showing explosive growth in subsequent years. There can be two inflection points in the inland aquaculture production trend—one around 1995 and another around 2009. Around these time periods, the share of inland aquaculture increased substantially and irreversibly. The other two sources of fish production—marine/coastal capture and aquaculture—have contributed steadily to fish production. Marine/coastal capture fisheries' share of fish production has remained about 15%–20% over the last two decades, and marine/coastal aquaculture contributes about 5% of total fish production. Therefore, the rapid and sustained increase in inland aquaculture more than compensated for the decline in production from inland capture fisheries.

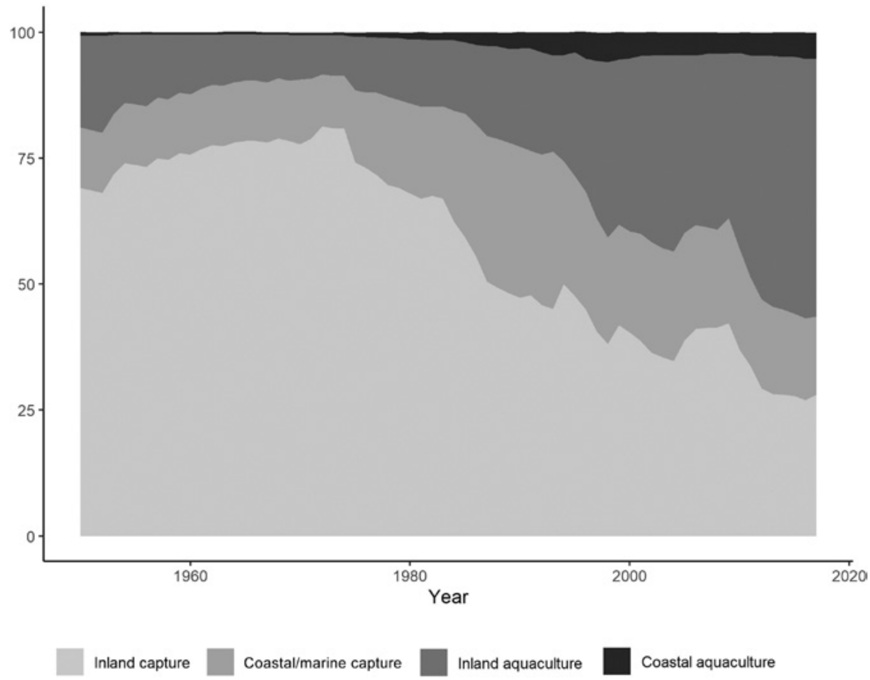

Figure 12.1 Share contribution to total fish production in Bangladesh by source of production, 1950–2017

Sources: FAO, 2019.

Figure 12.2 shows the decadal growth rates of fish production for the four sources of production in 10-year moving periods from 1950–1959 to 2008–2017. These growth rates have been estimated using the regression model,

$$\ln\left(Y_t\right) = \beta_0 + \beta_1 T + \epsilon_t$$

in 10-year rolling windows, where $\ln$ is the natural logarithm function, Y_t is the quantity of production from each source, β_0 is the intercept, β_1 is the coefficient on T the linear time trend thus representing estimated decadal growth rate, and ϵ_t is the residual term. Inland capture fisheries production grew about 5%–9% from 1950–1959 to 1966–1975, and then the growth rate decreased with negative growth (decreased production) in many periods, especially until the late 1990s. Growth rates of inland aquaculture remained steady at just over 2% until around the 1971–1980 period, then increased to about 8% until 1983–1992. Its fastest growth (rates of more than 10%) occurred between the 1988–1997 and 1995–2004 periods, with the highest growth rate

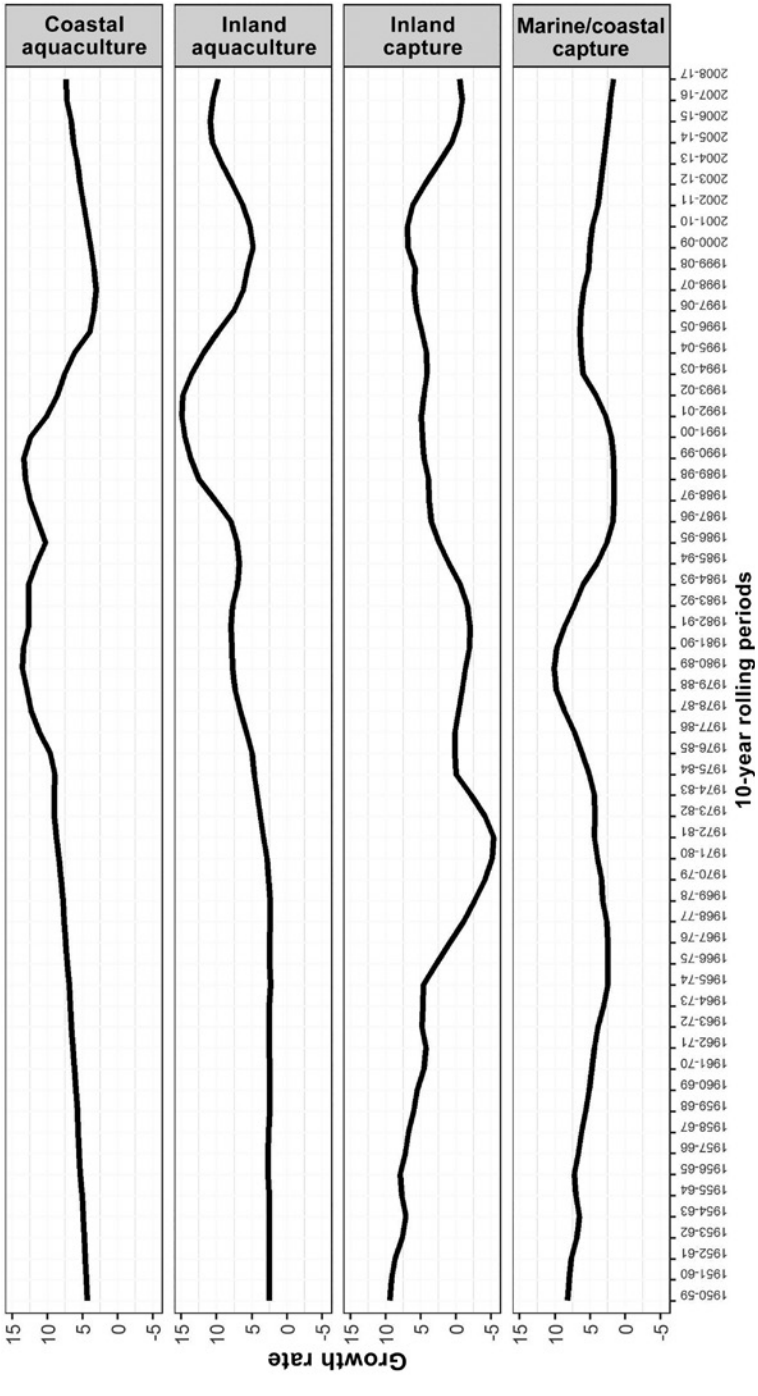

Figure 12.2 Growth rates in fish production, by sources of fish production, over 10-year moving windows.

Source: FAO, 2019.

of 14.97% achieved in the 1992–2001 period. After 1995–2004, growth has been more moderate, with rates of about 7%–9%.

Inland capture fish production shows growth in recent years, but some authors (e.g., Belton et al., 2011) are skeptical of these growth numbers. Given the widely reported severe problems affecting inland capture fisheries, statistics indicating consistent growth during recent years may not be reliable. At the same time, Belton et al. (2011) contend that aquaculture production statistics, especially those of tilapia and pangasius from inland aquaculture, are underestimated mainly due to the inadequacy of the official statistical procedures. This only reinforces the belief in substantial growth in inland aquaculture in Bangladesh in recent years.

Rise of entrepreneurial aquaculture

Aquaculture in ponds (as opposed to production in floodplains, modified rice fields, cages and lakes) comprises more than 85% of total aquaculture production. The vast and consistent increase in inland aquaculture production in Bangladesh over the last decades can be attributed to impressive growth in pond aquaculture. Specifically, pond aquaculture has been transformed by the increasingly important role of entrepreneurial, intensive and commercial aquaculture. For example, Belton et al. (2011) classify pond production into three distinct sources: homestead and extensive farming (producing 399,000 tons from 265,000 ha); commercial semi-intensive carp farming (390,000 tons from 110,000 ha); and commercial intensive and entrepreneurial farming by small and medium-sized enterprises (SMEs) of Nile tilapia and pangasius (and to some extent the climbing perch or koi), with a combined production of 395,000 tons from just 15,000 ha.

Although aquaculture in ponds always has been a major source of fish production, it was dominated by carp. Consumers readily accept Indian Major Carps (catla, rohu and mrigal) and indigenous carps. Chinese carps (silver carp and grass carp) also are important in aquaculture production. These carps were introduced in the 1960s from Hong Kong (Dey, Bose and Alam, 2008). Using survey data from 1998–1999, Dey et al. (2005) found that about 73% of rural Bangladesh's population practice polyculture of Indian and Chinese carps, along with a few other exotic species in ponds. The average pond size was 0.20 ha, and Indian carps and silver carp constituted 78% of total pond production. The study found that only 52% of the total sampled ponds were stocked with fingerlings and used limited inputs. Monoculture of pangasius and tilapia was in only the initial stages of adoption. Recent statistics show a dramatic change in species composition in aquaculture production. Table 12.1 shows the share of 20 major aquaculture species in Bangladesh's total aquaculture production from 2009 to 2017, ranked by their share in 2017. Carps are still important, but their combined share plummeted from about 75% in 2009 to about 45% in 2017. During the same time, the combined share of striped catfish and tilapias increased, from about 7% in 2009 to about 36% in 2017. Striped catfish and

Table 12.1 Share of major aquaculture species in the total aquaculture production in Bangladesh, 2009–2017

Fish/Group	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
Striped catfish*	5.6	9.6	10.3	15.0	15.0	18.5	19.3	22.5	21.4
Tilapias NEI**	1.5	1.9	6.9	7.2	11.3	14.5	15.7	15.5	14.3
Rohu	21.3	19.4	18.2	17.1	14.3	12.0	12.6	11.9	12.3
Silver carp	16.2	14.9	9.1	10.5	12.6	10.3	9.0	8.2	8.9
Mrigal	12.5	11.4	10.4	9.4	9.4	8.4	8.3	7.7	7.7
Catla	16.8	15.0	14.1	12.9	10.8	8.9	8.1	7.2	7.6
Marine fishes NEI‡	4.5	5.6	4.0	3.7	3.9	4.8	4.7	5.1	5.0
Common carp	3.8	3.5	4.0	3.8	4.6	3.8	3.7	3.4	3.7
Giant tiger prawn‡	4.7	3.3	3.7	3.3	3.7	3.7	3.7	3.1	2.9
Freshwater fishes NEI	1.4	2.2	4.6	2.7	1.6	2.1	2.1	2.0	2.5
Giant river prawn	2.5	2.3	2.6	2.6	2.4	2.3	2.0	2.1	2.1
Grass carp	2.1	2.1	1.4	1.0	2.0	2.3	1.9	1.8	2.0
Cyprinids NEI	1.1	0.9	0.8	2.3	1.2	1.4	1.8	1.7	1.9
Climbing perch	0.2	0.5	0.9	1.8	2.1	1.8	2.7	2.6	1.8
Silver barb	0.7	0.9	3.1	2.5	1.7	2.1	1.7	1.9	1.8
Orangefin labeo	0.8	3.0	2.4	0.9	0.8	1.4	0.8	0.7	1.1
Orange mud crab‡	—	—	—	—	—	—	—	0.6	0.6
Freshwater prawns, shrimps NEI	0.5	0.5	0.2	0.3	0.3	0.2	0.3	0.3	0.4
Stinging catfish***	0.3	0.6	0.2	0.2	0.3	0.3	0.3	0.3	0.4
Philippine catfish****	0.2	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.4

Source: Department of Fisheries, Ministry of Fisheries and Livestock, Government of Bangladesh, Dhaka (various issues).

* *Pangasionodon hypophthalmus*.

** NEI: not elsewhere included.

*** *Heteropneustes fossilis*.

**** *Clarias batrachus*.

‡ Farmed in brakish water areas.

tilapias were the top-ranked species in terms of share of aquaculture production in 2017. Their impressive growth shines despite the contention that production of these species is underrepresented in official statistics.

Striped catfish was imported from Thailand into Bangladesh in 1990, and different species of tilapia have been introduced since 1954. Genetically improved farmed tilapia (GIFT), a faster-growing strain of Nile tilapia (*Oreochromis niloticus*), was imported in 1994 from the Philippines. The two species are more robust in a range of water qualities and are better suited than carp for commercial farming strategies such as higher stocking densities and manufactured feeds.

These species gained popularity among farmers as candidates for intensive aquaculture and became alternatives to extensive carp production in ponds that faced constraints such as inadequate water resources and financial limitations (Hussain, 2009). In contrast to extensive and semi-intensive types of aquaculture, small and medium-sized enterprises devote significant capital investment and operating costs to pond aquaculture, characterized by intensive management practices such as employing hired labor and the use of pelleted feed. Fish yields can be 40–70 tons of pangasius per hectare per year and 10 tons of tilapia per hectare per year.[4] The average culture period of pangasius is about seven to eight months and for tilapia, about three to four months. Farmers therefore often produce two crops of tilapia a year. Besides contributing substantially to fish production, these enterprises generate two permanent jobs per hectare, whereas homestead farming does not generate direct employment (Belton, Haque and Little, 2012).

Diversification of aquaculture

The intensification of aquaculture is one aspect of successful aquaculture ventures in Bangladesh, but the other equally impressive aspect is the trend toward diversification. Dey, Bose and Alam (2008) provide a timeline of exotic species introduced into Bangladesh for aquaculture purposes. As shown in Table 12.1, many of the introduced species such as pangasius (striped catfish) and tilapia now play significant roles in total production. Diversification began with a shift from farming of traditionally important native carps to the farming of exotic and introduced species, mainly tilapia, pangasius, silver carp and grass carp. The Department of Fisheries Bangladesh (2018) notes that farming of native species koi (climbing perch, *Anabas testudineus*) has expanded massively in recent times. Farming of other native species such as shing (stinging catfish, *Heteropneustes fossilis*), magur (walking catfish, *Clarias batrachus*), padba (butter catfish, *Ompok pabda*), gulsha (Gangetic mystus, *Mystus cavasius*), mola (*Amblypharyngodon mola*) and miscellaneous carps also is gaining popularity. This new wave of aquaculture diversification is induced by the high market demand for indigenous species (Department of Fisheries Bangladesh, 2018). Bangladesh is thus witnessing market-led diversification (product differentiation) following the intensification and commodification of aquaculture. Small indigenous fish species can be brought into this aquaculture diversification and intensification to achieve nutrition-sensitive fish value chains. To harness greater benefits from aquaculture development, subsequent efforts must ensure that aquaculture production of diversified products are intensified. This requires innovations along the value chain for the promising species—from technology of seed production and supply of other inputs to harvesting, post-harvest technology and marketing.

Proliferation of value chain actors

Hatcheries, fish feed mills, feed dealers and other non-farm enterprises have developed rapidly and proliferated throughout Bangladesh's fish value chain

(Bush et al., 2019; Hernandez et al., 2018; Uddin et al., 2019). These enterprises, many of them small and of medium scale, provide essential inputs, logistics, marketing and other services to fish farmers (Hernandez et al., 2018).

Aquaculture practices in Bangladesh started with seed collection from rivers, which now has been replaced almost entirely by hatchery-produced seeds. Private hatcheries supply most of these fingerlings (Department of Fisheries Bangladesh, 2018). A survey conducted by Hernandez et al. (2018) shows that hatcheries increased about 207% from 2004 to 2014. This growth in fish hatcheries has been accompanied by rapid expansions of nurseries, which buy hatchlings or fry from hatcheries and raise them to fingerling size for sale to farmers.

Fish feed production and its use in Bangladesh aquaculture have increased dramatically over the last decade or so. Feeding fish with formulated pelleted diets is common in many species, including shrimp, pangasius, koi, Nile tilapia and major carps. Most of these pelleted feeds are made by medium- and large-scale commercial mills. Pelleted feed is the largest cost component, accounting for 82% of the total cost of pangasius production in Bangladesh (Belton et al., 2011). Trade credit is a common practice in transactions involving feed in Bangladesh, whereby input suppliers provide farmers with short-term financing or deferred payment options under specified and agreed-upon terms and conditions. The availability of trade credit provides credit-constrained buyers with access to sufficient quality and quantity of feeds, thus facilitating the functioning of aquaculture product markets. Farmers start buying feed on credit from their supplier at the beginning of the crop and pay back their credit at the time of harvest (Ahmed, 2015). Suppliers incur risk when they grant trade credits, so they indulge in practices such as screening buyers carefully and charging higher prices on feed when farmers buy it on trade credit terms. Charging higher prices should not lead to situations of market power. Governments need to investigate whether local suppliers have sufficient capital to meet the requirements of larger small and medium-sized enterprises (SMEs). The government could also assess whether the SMEs have the capacity to absorb higher risks and longer exposure times.

Implications of transformation in fish value chains

The rapid growth and transformation of fish value chains in Bangladesh need to be analyzed in greater detail to better understand the implications of these changes and the possibilities for improvement. In this sense, the fish value chain in Bangladesh presents tremendous opportunities for research into the production, distribution and socio-economics of changes in food value chains. Some aspects of this transformation, such as consumption patterns, production agglomeration, clustering and welfare, have received attention, but several other aspects deserve to be better analyzed. Here we identify some promising research prospects and related suggestions in the context of Bangladesh's fish value chain.

The modern aquaculture sector in Bangladesh provides an excellent setting for the analysis of entrepreneurship and its determinants in a developing country's food value chain from macroeconomic and microeconomic frameworks. There is a growing body of evidence on the relationship between entrepreneurship and economic growth (Lundström and Stevenson, 2006). Entrepreneurship research is concerned with why, when and how individuals identify and exploit opportunities (Shane and Venkataraman, 2000). The sector or industry on which entrepreneurs choose to focus—and the problems, conditions and possibilities in the sector or industry—are important research settings in entrepreneurship analysis. However, such research has focused mostly on the digital world, and agricultural and food industries have not yet been analyzed (Alsos, Carter and Ljunggren, 2011; Pindado and Sánchez, 2017; Fitz-Koch et al., 2018; Kuckertz, Hinderer and Röhm, 2019). Moreover, even within agricultural and related sectors, most of the studies have focused on developed countries; developing countries, where agriculture and related activities play larger roles in the society and the economy, have been mostly ignored (Dias, Rodrigues and Ferreira, 2018). Entrepreneurship in the context of developing countries is seen as a major tool to eradicate poverty and help countries meet their development goals (Lundström and Stevenson, 2006). Hence, national and regional governments seek to support entrepreneurs through tax breaks, subsidies and other incentives (Rupasingha and Goetz, 2013). Given the importance of fish as food in Bangladesh and the role of entrepreneurial aquaculture in employment generation and food production, entrepreneurship in fish value chains in Bangladesh needs to be analyzed in a rigorous and contextualized framework to better understand factors influencing entrepreneurs' entry (and exit) decisions, the drivers of entrepreneurial investment at regional and national levels and approaches to improving rural economic opportunities.

Another important issue is gaining better knowledge of the nutritional impacts of structural transformations in fish production. On a positive note, much of the aquaculture production in Bangladesh is destined for domestic consumption, and only a small share is exported. The aquaculture revolution has brought about better market availability of a limited number of species, whereas capture fisheries produces a diverse fish harvest with spatiotemporal variations. Both urban and rural households are relying more on the market than on their own production for food consumption. Increasingly, more aquaculture takes place in public water bodies such as floodplains, which poor households used earlier for capture fisheries. And many of the wild-caught fisheries are under stress. Newton et al. (2007) show that poorer societies rely more on ecosystem services for subsistence and cash generation. Therefore, declines in Bangladesh's coastal and inland wild fishery resources would impact, in particular, the livelihoods and food security of poorer households. Using disaggregated data on species- or group-level fish prices and quantities, studies need to be performed on how different population segments' patterns of fish supply and dietary substitution respond to price fluctuations. Microeconomic theory–based analytical models relating nutritional outcomes of value chain interventions are absent (Allen and de Brauw, 2018). The basic model derived by Allen and de Brauw (2018) can be extended to understand the interplay between aquaculture intensification and diversification in terms of nutritional impacts. Their model shows that focusing on improving yields of only major crops will lead to stagnation in the yields of nutritious food crops.

Commercialization of aquaculture in Bangladesh has been accompanied by regional agglomeration and clustering of production to achieve lower transaction costs and facilitate co-innovation along the value chain (Hu et al., 2019). Lower transaction costs are expected to lead to better integration of spatial markets. The drivers and linkages of such clustering need to be better understood for identifying future sources of growth in entrepreneurial aquaculture. Implications of production clustering for product market integration need to be investigated. A higher degree of market integration reduces price volatility, and food price volatility is an important determinant of food security (Kalkuhl, 2016).

Procedures (sampling schemes, questionnaire structure) used in the collection of official databases such as the Household Income and Expenditure Survey data of the Bangladesh Bureau of Statistics and the 'Fisheries Statistics of Bangladesh' published by the Department of Fisheries need to be improved to understand the real contributions of the fisheries and aquaculture sectors. The HIES data can be improved with respect to fisheries and aquaculture sectors by seeking information on small indigenous fish consumption, at least as aggregate groups of fish. The Fisheries Statistics of Bangladesh survey sampling design needs to be improved to reflect the changes in fish production characteristics of Bangladesh. Another important publicly available database is the 'Commodity-wise Report' on prices, published by the Department of Agricultural Marketing. Although this database is a good source of information on wholesale- and retail-level prices, its coverage of producer-level prices needs much improvement. Real-time availability of information on market prices can help improve producers' marketing decision making, thereby augmenting their income.

In general, integrated Information and Communication Technology (ICT) facilities need to better meet producer's information needs. Better information flow through the optimal use of ICTs can improve consumer welfare (lower prices, reduced waste, efficient supply–demand matching), improve adoption of smarter farming technologies and incentivize producers through higher incomes (World Bank, 2017). Such an ICT facility could answer producers' questions on sources of improved seed and feeds, land availability, better market prices, credit facilities available, risk management, best aquaculture practices and extension and other public service provisions. Such ICT facilities would better serve their purposes if they are customized to different regional requirements. With the rapid penetration of mobile phones, wireless and Internet services into rural areas, such ICT platforms hold immense promise for solving problems related to information flow in supply chains.

Notes

1 The term 'fish' is used in this chapter in the broadest sense to include all aquatic animals, including finfish (both fed and non-fed), crustaceans (e.g., shrimp, prawns, crabs), molluscs (e.g., oysters, mussels, snails) and other aquatic invertebrates.
2 Belton, van Asseldonk and Thilsted (2014) find that almost all households consumed fish at least once in the 14-day period over which consumption was recorded.
3 Bangladesh Delta Plan 2100 (2018) reports the total number of rivers in Bangladesh to be 405.
4 While these yields are impressive, substantially higher yields have been achieved in Vietnamese pangasius aquaculture where it is common to produce 300 tons per hectare per crop (Phan et al. 2009).

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