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Multi-stakeholder perception analysis of the status, characteristics, and factors affecting small-scale carp aquaculture systems in Bangladesh

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Inland aquaculture is essential for the food and livelihoods of millions of small-scale producers across the global South. Very diverse actions from national governments, civil sector and international organizations have been seeking to enhance the performance of small-scale aquaculture systems. However, many of these efforts are constrained by the general lack of information about the status and characteristics of the sector. In many cases, data are unavailable, highly aggregated or outdated, thus failing to provide a clear picture of the situation on the ground to inform relevant efforts. Bangladesh is one such country, where, on the one hand, the aquaculture sector is extremely important for national economic growth, rural development and food and nutrition security, but on the other hand suffers from a general lack of quality data to inform relevant actions. In this study, we report the findings generated though eight workshops that engaged 215 stakeholders involved in the Bangladesh small-scale carp aquaculture sector. By leveraging the expertise of the participants, we obtain an overarching picture of the characteristics of small-scale carp production models around the country. The findings suggest a large variability of production models and levels of intensification, which are mainly based on polyculture involving species such as rohu, catla, and mrigal. These systems have been roughly categorized in four types characterized by different levels of intensification and dominant species, which are present across the country with varied socio-economic, infrastructure and environmental conditions. The study also identified an unfolding shift in the last years, from subsistence-based to commercially oriented production. In terms of market preference, quite different carp attributes are valued among small-scale producers across the country, with large size of carp, its rapid growth and the availability of improved strains being the most valued. As aquaculture, and particularly carp aquaculture, is important for rural development in Bangladesh by sustaining households' income and livelihoods in different ways, we argue for the need to undertake more detailed studies to understand the characteristics and performance of these types of small-scale aquaculture systems. This will be indispensable for informing policies and actions that aim to target more effectively the different types of producers, and to improve the overall performance and sustainability of the sector.

KEYWORDS

aquaculture, carp, food security, intensification, multi-stakeholder workshop, polyculture

1. Introduction

The inland aquaculture sector has been expanding rapidly in the past decades to cater for the increasing demand for protein and food more generally (Subasinghe et al., 2009; Tacon, 2020). This increase has been particularly significant in some developing countries, especially those located in South and Southeast Asia (Tacon, 2020; FAO, 2022). For example, the output of the aquaculture systems in Vietnam increased 5-fold between 2003 and 2018, from approximately 0.5 million tonnes to 2.8 million tonnes (FAO, 2020). Similarly, production statistics from Myanmar point to the substantial expansion of the aquaculture sector from around 0.2 million tonnes in 2005 to 1.1 million tonnes in 2020 (FAO, 2022). In Bangladesh, inland aquaculture output in 2003 was 0.8 million tonnes, which increased by more than 3-fold to 2.6 million tonnes in 2021 (DoF, 2022). Amid this rapid expansion, related data and statistics are still scarce, often incomplete, and not easily accessible to inform small-scale aquaculture[1] development policy and actions, especially in relation to smallholders in developing countries. Research suggests that most small-scale aquaculture systems are in developing countries (FAO, 2022), and that their multiple benefits discussed below have prompted domestic and international actors to promote their expansion through multiple types of actions (Béné et al., 2016; Nasr-Allah et al., 2020; Dam Lam et al., 2022).

Several studies have pointed to the centrality of small-scale aquaculture systems for rural livelihoods and poverty alleviation in many developing country contexts (Kawarazuka and Béné, 2010; Hernandez et al., 2018). First, small-scale aquaculture systems support income generation via the sale of produced fish/aquatic foods to domestic and foreign markets (Shrestha and Pant, 2012). Second, evidence suggests that small-scale aquaculture systems contribute to improved food and nutrition security at the household level through various mechanisms. For instance, they can increase household food availability all year round (Ahmed and Lorica, 2002; Bondad-Reantaso and Subasinghe, 2010; Béné et al., 2016) or improve household food access by enhancing their ability to purchase food items using the income generated from fish sales (Béné, 2007; Beveridge et al., 2013; Dam Lam et al., 2022). Third, such systems have the potential to improve food utilization by allowing households to consume nutritious food (i.e., small indigenous species rich in key micronutrients; Kawarazuka and Béné, 2010; Chan et al., 2019), and in some cases support the coping ability of many small-scale aquaculture households during shocks such as the recent COVID-19 pandemic (Manlosa et al., 2021). The ability of small-scale aquaculture systems to generate other socioeconomic benefits, such as empowering women to engage in food production and marketing activities through capacity-building can be equally as important (Dam Lam et al., 2022).

Despite these multiple benefits, literature suggests that there is great diversity between small-scale aquaculture systems in developing countries, especially in terms of their underlying production models. For example, in many developing contexts small-scale aquaculture systems can be characterized by different production intensities, ranging from rather extensive systems to highly intensive systems (Edwards, 2010; Hernandez et al., 2018). Furthermore, the diversity of the production, in terms of fish species, and the degree of market orientation also vary markedly between small-scale aquaculture systems, even within the same region. Recent studies have revealed the large diversity within small-scale aquaculture systems with mixes of monoculture and polyculture approaches (Zongli et al., 2017; Ferdoushi et al., 2019; Tran et al., 2021), or different market orientations. These orientations can range from systems predominately geared toward household consumption to systems catering to different types of market such as urban areas, low-income consumers, or foreign markets (Kaminski et al., 2018).

What is relatively constant in many of these developing contexts, however, is the difficulty of small-scale producers to adopt advanced technologies and improved production practices (Béné, 2007; Kumar et al., 2018). This tends to negatively affect the yields and profitability of such systems (Biswas et al., 2019), as well as their broader socioeconomic (Belton, 2010) and environmental performance (Hukom et al., 2020). Some of the major constraints include, among others, the often-significant financial investments needed to adopt improved production practices and technologies (Harohau et al., 2020; Brugere et al., 2021), the lack of knowledge and capacity to adopt and fully utilize such technologies/production models (Salazar et al., 2018), including the constraints in accessing high quality seed and feed, and improved strains of fish (Karim et al., 2016).

As a means of enhancing the performance of small-scale aquaculture systems, there have been many actions in developing country contexts focusing on different production and management decision areas such as: species choice; feed type and use; disease reduction; post-harvest processing and distribution; financial tools; trade and linkage to markets; spatial planning, access and infrastructure; farm technologies and practices; and genetic improvements (Henriksson et al., 2021). Among these, the dissemination of high-quality fish feed, fish seed, and improved fish strains (Karim et al., 2016), knowledge transfer for the adoption of improved production practices (Wang et al., 2020), and value chain development (Bjørndal et al., 2015), are some of the most common components of small-scale aquaculture development actions.

1 Small-scale aquaculture denotes aquaculture systems characterized by access (household or communal) to an aquatic resource in a relatively small landholding allocated for aquaculture. There is no uniformly defined cutoff point in terms of the size of the landholding allocated for aquaculture, which can depend on the geographical location and other contextual factors (FAO, 2023). Small-scale aquaculture systems can range from systems with very low input and output mainly for subsistence purposes, to systems with larger investments in terms of time, labor, and capital for commercial purposes (Edwards, 2010). However, previous studies on carp small-scale aquaculture in Bangladesh have reported yields ranging from 1.3 tonnes/ha to 5.1 tonnes/ha per season (Jahan et al., 2015; Castine et al., 2017).

One may argue that the successful implementation of such actions is affected by a lack of understanding of the characteristics of the sector, in terms of the prevailing production system (e.g., levels of intensification, dominant species and production practices), their geographical distribution, the needs, preferences and constraints of the local producers, among others (Belton, 2010; Harohau et al., 2020; Brugere et al., 2021; Henriksson et al., 2021). This is because, in most developing countries it is difficult to obtain general production information from smallholder aquaculture producers, let alone know their actual distribution on the ground and the dominant production practices. This is usually due to a diverse set of factors, ranging from capacity constraints of national and local government agencies to develop comprehensive registries (Belton and Azad, 2012) to the very dynamic nature of the sector in some countries that renders any such information obsolete even within a short time span (Hernandez et al., 2018).

Bangladesh is one of the developing countries where small-scale aquaculture plays a significant role for local livelihoods and food security (Belton and Azad, 2012; Hernandez et al., 2018; Dam Lam et al., 2022). While statistics about fishpond area in the country are not fully accurate, early estimates that there were up to 5 million ponds in the country at the beginning of the aquaculture boom (Asian Development Bank, 2005), indicating that as many as 20% of rural households had ponds (Belton and Azad, 2012). Aquaculture in Bangladesh has also regional and global relevance, as the country is the third largest inland water fish producer in the world, after India and China. Bangladesh has also experienced one of the most remarkable increases in inland water fish production in the last decade among the top five producers (FAO, 2022).

Carp is the dominant group of species used in small-scale aquaculture systems in Bangladesh, produced either in monoculture or polyculture (Salam et al., 2005; Karim et al., 2016).[2] Carp can offer multiple competitive advantages to small-scale producers in Bangladesh in terms of its growth and high market value (Karim et al., 2016), and owing to cultural sensibilities and taste preferences in the country this leads to a high market demand (Belton and Azad, 2012). As a result, carp production has almost doubled in the past 10 years from approximately 0.9 million tonnes in 2008 (DoF, 2009), to 1.6 million tonnes in 2021 (DoF, 2022) (estimates include major, exotic and other carp species), representing approximately 35% of the inland aquaculture production in the country (DoF, 2022). This expansion trend is even more significant, considering that in the last decade the capture fishery production has decreased or remained stable due to changes in the area of the capture habitat (Shamsuzzaman et al., 2020). Thus, small-scale aquaculture, and most importantly small-scale carp aquaculture (considering their dominance in terms of prevalence among fish farmers and total output), becomes increasingly relevant to meet local fish demand and food and nutrition security needs in Bangladesh.

However, given the very dynamic nature of the Bangladesh aquaculture sector and the ever-changing production landscape (WorldFish Center, 2008; Hernandez et al., 2018), it is not always easy to identify or characterize, even geographically, these production systems. This is also exacerbated by the lack of quality and availability of aquaculture statistics, particularly in relation to lower administrative levels (i.e., production statistics at the Upazila or Union levels).[3] These data and information gaps are a real lock-in that undermines effective decision-making processes and business intelligence, with the result that policy development and industry investment in Bangladesh can occur suboptimally (Shikuku et al., 2021). This is also the case for donor-based development actions. Filling these gaps may require an important amount of resources (e.g., in terms of time, funds, and expertise) as in the case of nationally representative aquaculture studies. However, stakeholder consultation processes could offer an alternative and, in specific cases, could be used in preparation for appropriate local-level characterization and baseline studies. Such multi-stakeholder processes[4] have been extensively used to understand the characteristics of food systems, especially in developing countries characterized by a lack of reliable, fine-grained, and timely data (Van Staaveren et al., 2019; Kiatkoski Kim et al., 2022).

Here we used a multi-stakeholder approach to help fill the data and information gaps about the status, distribution, characteristics, and factors affecting small-scale carp aquaculture in Bangladesh. We gathered this information through eight multi-stakeholder workshops that were conducted across the country (Figure 1). These workshops engaged 215 stakeholders, mostly from the District and Upazila levels, as well as fewer from the National and Divisional levels. Collectively these stakeholders have very extensive knowledge of aquaculture systems (and especially small-scale systems) in their respective regions at various stages of the value chain. Section 2 of the paper outlines the process followed in each workshop and how information was gathered. Section 3 presents their main findings, while Section 4 puts the findings in context given the perspective of the existing literature. Furthermore Section 4 identifies their implication for informing the design of relevant actions, and proposes possible future options for research and practice.

2. Methods

2.1. Study site

Due to a demographic transition, the population has been increasingly concentrated in Divisions with large cities such as Dhaka, Chottagram and Sylhet, while other regions have progressively lost population (UNFPA, 2015). Despite this urban expansion, the country remains predominantly rural, and approximately 50% of the population still depends on agricultural activities as the livelihood (Belton and Azad, 2012; UNFPA, 2015).

2 The group of species corresponding to carps (i.e., carps, barbels, and other cyprinids) is the most produced at the global level, accounting for 18% of aquatic animals production (FAO, 2022).

3 Rural administrative units in Bangladesh are organized at three levels: zilas (districts), upazilas (sub-districts), and unions (Commonwealth Local Government Forum (CLGF), 2018).

4 Multi-stakeholder approaches to knowledge generation include, through different mechanisms, representatives from different stakeholder groups (e.g., government, civil society, private sector, consumers, producers) that are involved, are relevant or have an interest in the system under study, as a means of synthesizing their different knowledge, understanding and perspectives (Häring et al., 2009; Schwilch et al., 2012).

Most of the agricultural production in Bangladesh is characterized as traditional subsistence agriculture which is based on family labor and a low level of technological development. However, the lack of remaining arable lands and the limited natural resources for the ever-increasing population have posed serious challenges in the fight against poverty (Belton et al., 2012; UNFPA, 2015). Thus, in the last decades, the national government, private sector, and national and international development organizations have paid great attention to the development of aquaculture and fisheries to utilize the vast water resources of the country (Belton et al., 2012; Shamsuzzaman et al., 2020). The aquaculture sector in the country has experienced a rapid expansion as suggested above, with estimates suggesting that 94% of aquaculture output is used domestically (Hernandez et al., 2018). As such it is particularly important for food and nutrition security (Belton et al., 2014), accounting for as much as 50% of the average *per capita* intake of animal protein (FAO, 2022), and up to 40% of vitamin A intake and 30% of calcium intake needs in some regions (Kawarazuka and Béné, 2010; Thilsted, 2012).

At the global level, Bangladesh is among the top ten fish producers (farmed and capture production) and ranks as the 5th largest producer in terms of aquaculture production (FAO, 2022). The overall fish production in the country has experienced a 2.7-fold increase in the last 20 years, from 1.7 million tonnes in 2001 to 4.6 million tonnes in 2021 (Shamsuzzaman et al., 2020; DoF, 2022) in large part due to the expansion of aquaculture production which currently represents 57.1% of the total fish output (around 2.6 million tonnes; DoF, 2022). On the other side, during that time, inland and marine fisheries production has remained relatively stable or increased at a slow rate, due to the impact of climate change and measures taken to counteract the exploitation and habitat loss of destructive fishing gear and illegal practices (Shamsuzzaman et al., 2020). Furthermore, it has been argued that aquaculture statistics are considerably underreported, due to the use of outdated methodologies since the 1980s, which overlook small ponds in the sampling procedures used by the Department of Fisheries (DoF) Fisheries Resource Survey System (Belton and Azad, 2012). However, statistics from 2019 to 2020 might have addressed this issue through updates in the estimated pond areas (DoF, 2021).

Aquaculture systems have large variation in the degree of intensification but can be generally categorized as: extensive, improved extensive, semi-intensive, and intensive; depending on the level of additional feed, seed and inputs used and/or managed in the farming activity (WorldFish Center, 2008; DoF, 2022). In general, homestead production has been predominantly extensive, with some level of improved extensive practices and incipient levels of semi-intensive practices. For instance, a study in Noakhali District found that 39% of households engaged in improved extensive practices and only 6% in semi-intensive practices, with the rest (55%) corresponding to extensive systems (Belton and Azad, 2012). Despite its intensity, aquaculture production in Bangladesh is dominated by pond farming which contributes to ~80% of the total inland aquaculture production of the country (DoF, 2022).

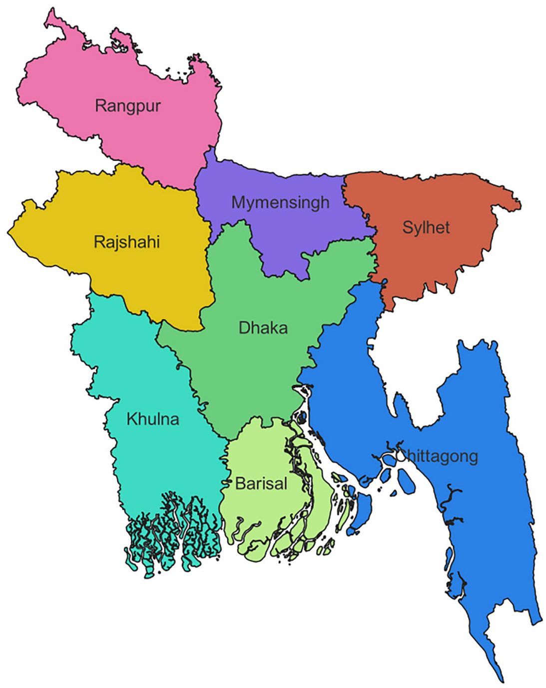

FIGURE 1
Map of Bangladesh showing the location of Divisions.

2.2. Data collection and analysis

A total of 8 workshops were conducted between January and February 2021, each focusing on a specific geographical region of the country: North (N), Northwest (NW), Chittagong Hill Tract (CHT), Southeast (SE), South (S), Southwest (SW), Northeast (NE) and Central (C). These regions covered all Divisions (Table 1). The purpose of the workshops was to obtain a general picture of the small-scale carp aquaculture sector in the country, in particular understanding the different farming systems, and the current challenges, constraints, and potential for each region. These workshops brought together 215 stakeholders and were organized and moderated by WorldFish and the Development Research Initiative (dRi). Participants, who were identified based on their knowledge of the sector, represented the four most relevant stakeholder groups, such as: (i) government (e.g., Department of Fisheries, DoF; Bangladesh Forest Research Institute, BFRI); (ii) international organizations (e.g., Worldfish) and civil society (e.g., BRAC); (iii) academia/research (e.g., University of Rajshahi); and (iv) private sector (e.g., fish producers, hatcheries, and traders). In general, the selected participants from each region came from Districts where carp aquaculture is prevalent and representative (e.g., in terms of number of farmers and production levels).

Due to the COVID-19 situation in the country and movement restrictions at that period, the workshops were conducted virtually, through the online platform Zoom. Each workshop had an average duration of 2–3 h and engaged approximately 27 stakeholders. On average 23% of participants in each workshop came from government agencies, 20% came from development/civil society organizations, 8% from academia/research, and 49% were value chain actors such as farmers, hatcheries, nurseries, and feed private sector actors (i.e., feed dealers).

As shown in Table 2, there was special consideration to have a balanced representation between stakeholder groups in all workshops. Considering the greater relevance and knowledge of value chain actors on the topic of the study (i.e., on-the-ground aquaculture practices by

TABLE 1 Characteristics of the multi-stakeholder workshops by region.

Date	Region	Division	Participants	Main districts represented in workshops
07.01.2021	North (N)	Mymensingh	28	Mymensingh, Sherpur, Jamalpur, Netrokona
21.01.2021	Northwest (NW)	Rajshahi, Rangpur	27	Rajshahi, Bogura, Dinajpur, Natore, Rangpur
25.01.2021	Chittagong Hill Tract (CHT)	Chattogram	26	Rangamati, Bandarban, Cox's Bazar, Khargrachori
27.01.2021	Southeast (SE)	Chattogram	26	Cox's Bazar, Chottagram, Cumilla, Noakhali
31.01.2021	South (S)	Barisal	29	Chandpur, Barisal, Jhalkathi
01.02.2021	Southwest (SW)	Khulna	26	Khulna, Bagerhat, Satkhira, Jashore
03.02.2021	Northeast (NE)	Sylhet	26	Sylhet, Habigonj, Mulvibazar
04.02.2021	Central (C)	Dhaka	27	Dhaka, Gazipur, Manikgonj, Gopalgonj, Faridpur

TABLE 2 Number of participants per stakeholder group and type of organization in each workshop.

Stakeholder group	Type of organization	Region								Total number of participants (by stakeholder group)
		N	NW	CHT	SE	S	SW	NE	C	
Academia/research	University	3	2	2	2	2	2	2	2	17
Civil society/ international organizations	NGO	1	3	3	3	3	4	2	3	22
	WorldFish	3	0	3	3	3	2	3	3	20
Government	BFRI	2	1	1	1	1	1	1	1	9
	DoF	4	6	5	5	5	5	5	6	41
Private sector	Feed supplier	4	5	3	3	4	3	4	3	29
	Farmer	3	4	3	3	4	3	3	3	26
	Hatchery/nursery	8	6	6	6	7	6	6	6	51
Total number of participants (by workshop)		28	27	26	26	29	26	26	27	215

small-scale producers), they were included in slightly larger numbers in all workshops when compared with other stakeholder groups. In terms of demographic characteristics, while detailed information was not captured, the participants age was 35–60 years old, and most of them were men (approximately 90%). While the gender distribution of participants is far from being equal, it reflects the gender gap in the aquaculture sector in Bangladesh (Kruijssen et al., 2018).

Each of the workshops started with a brief introduction about the purpose of the workshop, background information, and WorldFish projects regarding carp aquaculture technologies. Subsequently, the facilitator started presenting each of the pre-established topics for the participants to provide their opinion. The topics that were discussed include the: (a) status of small-scale carp production in each region (Section 3.1), (b) main production practices in each region (Section 3.1), (c) areas with high current production, or potential (Section 3.1), (d) carp characteristics valued by small-scale producers (Section 3.2), and (e) factors affecting small-scale carp production (Section 3.3). Regarding (c) the participants were asked to identify areas with large existing small-scale carp production (termed "hotspots") and areas with large potential to become such. In more detail, the term "hotspot" was used to identify areas where small-scale carp aquaculture activities were already established, thriving, and had the potential for further promotion in the near future. Conversely, areas with "hotspot potential" referred to: (a) areas with available waterbodies able to support carp production, but with limited current carp production due to the prevalence of other intensified aquaculture systems; (b) areas close to urban areas with advantageous market conditions but currently used for the intensive production of other species (e.g., tilapia, catfish, local catfish and others); and (c) areas with competitive advantages for aquaculture, such as long history in seed production through hatcheries and nurseries.

Whenever necessary, the facilitators used PowerPoint slides as a visual aid for the participants (e.g., to present data or remind them the topic currently being discussed). The "Raise hand" function was utilized to allow the participants to express their opinions in an orderly manner. In general, not much dissent or debate was found during the sessions, and the participants were well engaged, with approximately half of them considered to participate very actively in the discussions. However, facilitators also encouraged participants who were not as active to provide their opinion at some points of the sessions. Besides the facilitator role, one member of the organizing team was designated as a note-taker to collect all the information from each workshop session.

Subsequently, experienced staff from the organizing team, compiled the information and drafted internal reports for each workshop that contained the data across the topics outlined above. These reports were revised and edited for accuracy and consistency by experts from WorldFish Bangladesh that were present in the workshops. The content of these reports was critically synthesized in this paper through an iterative process of consultation with the co-authors who participated in the workshops and reflection of existing literature and datasets. Although the authoring team collectively has a good understanding of the characteristics and current debates about small-scale aquaculture in Bangladesh (including for carp), to avoid bias we followed an inductive approach in the development of the paper by critically identifying the main themes emerging for each topic above, and putting them into perspective of existing literature and data. This was a conscious decision considering the very dynamic nature of the small-scale carp aquaculture sector in the country as outlined in Sections 1 and 2.1.

3. Results

3.1. Status and practices adopted in small-scale carp aquaculture

The information collected from the workshops revealed that the most common species of carp across all regions are rohu (*Labeo rohita*), catla (*Catla catla*), and mrigal (*Cirrhinus mrigala*), followed by other Indian major carps[5] such as kalibaush (*Labeo calbasu*), and Chinese carps such as silver carp (*Hypophthalmichthys molitrix*) (C, CHT, SE regions). Polyculture is the preferred culture method for carp across all regions, with practically non-existent monoculture practices for this group of species. In that regard, the polyculture practices are often carried out between two or more species of carp, within various subgroups such as: (a) Indian major carp (i.e., rohu, catla, mrigal, kalibaush); (b) exotic Chinese carps (i.e., bighead, grass carp, silver carp); and (c) common carp. There are also polyculture practices combining carp species with other fish species such as tilapia (*Oreochromis nilotica L.*), pangash (striped catfish) (*Pangasius pangasius*), shingh (stinging catfish) (*Heteropneustes fossilis*), magur (walking catfish) (*Clarias batrachus*), pabda (*Ompok pabda*), gulsha (*Mystus cavasius*), kalibaush, koi (*Anabas testudineus*) or bata fish (minor carp) (*Labeo bata*). In specific regions such as Khulna, carp is cultured with prawn and shrimp. A wide array of waterbodies such as baor, beels, canals, creeks, floodplains, haor, khals, rice fields, and rivers are used for all types of farming activities.[6]

Participants reported the prevalence of small-scale carp aquaculture in terms of share of total fish production or share of farmers producing the species in each region. In both cases, the numbers reported varied significantly within and across regions. For instance, in some areas like Sherpur (N) approximately 50% of producers farm carp in polyculture systems, while in other Districts in the same region such as Jamalpur the share is as high as 90%. In other districts such as Dinajpur (NW) 80–90% of small-scale producers produce carp. Regarding the share of carp in total fish production, the output from SE region seems to be more homogenous, with most of the districts reporting between 20 and 30% of the fish production coming from carp species. However, in some other regions such as Jashore (SW), the share of carp can be as high as 80% of the total fish production.

When it comes to hotspots and areas with hotspot potential, participants identified relevant areas at different administrative levels and with different criteria. For instance, regarding the administrative levels, in the Northern region, Mymensingh Sadar, Trishal, Melandoho, and Dewangonj Upazilas were identified as hotspots, while in Netrokona, only Komlakanda Union was considered as such. In other Districts/Regions no clear identification was possible, as the participants only indicated that in general, most areas with fish culture in the region are hotspots. As a large share of participants belonged to Districts where there was already some level of aquaculture practices, the identification of coldspots was unclear in most cases, hence it is not reported as part of the results. A summary of the status, practices and hotspots identified in all workshops is presented in Table 3.

Based on the stage of the fish growth cycle there are three different actors involved in carp farming, namely hatcheries (spawn, fry), nurseries (fry, fingerlings); and grow-out production (from fry/fingerlings to harvest). These types of productions rely mostly on ponds. Participants from all regions mentioned the existence of hatcheries within their territory, but with different levels of prevalence. Regions such as C, CHT, NE, and S seem to have a lower prevalence of hatcheries. Hatcheries are largely privately-owned, with few of them managed by the DoF and even fewer by the Bangladesh Fisheries Research Institute (BFRI). When it comes to grow-out production, most participants reported a mix of commercial and household consumption, however ponds with commercial purpose seem to be predominant.

Similarly, the participants identified four different small-scale carp systems within, and across regions. These can be roughly categorized as intensive polyculture systems with dominance of other species; intensive polyculture systems with dominance of carp species; semi-intensive polyculture systems; and extensive polyculture systems.

The first category corresponds to intensive polyculture systems dominated by other fish species, with carp included in minor proportions. These systems are directly linked to the use of commercial feed (e.g., production of catfish, tilapia and other fish species using commercial pelleted feed), and are considered to have the highest productivity. The second category corresponds to intensive systems of carp in polyculture with other exotic and endemic species of carps, including minor carps, in some cases along with small proportion of other species. These systems largely depend on commercial feed and have high productivity, although comparatively lower than the first category. The third category corresponds to semi-intensive systems of carp in polyculture with a small proportion of other fish species including small indigenous species (SIS) rich in micronutrients (e.g., mola, *Amblypharyngodon mola*). In most cases, these systems rely on homemade supplementary feed, with occasional use of commercial feed, and the application of fertilizers for natural feed production, resulting in moderate productivity. The fourth category corresponds to extensive systems of mainly carps, stocked at high density, and largely depend on natural feed in small ponds. These systems are practiced mostly in small ponds in remote areas with difficulties to get input and access to technology for fish culture.

As detailed in Table 3, participants reported the prevalence of production practices ranging from semi-intensive to intensive in most regions, while extensive practices were mentioned particularly in the

5 The four species that are grouped as Indian Major carps in Bangladesh are: rohu (*Labeo rohita*), catla (*Catla catla*), mrigal (*Cirrhinus mrigala*), and kalibaush (*Labeo calbasu*; Rahman, 2008).

6 Some of the waterbodies are named with the original word used for them in Bangla language. Beel is a lake-like wetland with relatively large surface, static water body. Baor is usually a dead river creating a free-standing body of water for fish culture. Haor is a marshy wetland ecosystem shaped as a bowl or saucer. Khal is a canal or ditch of moving water (DoF, 2022).

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TABLE 3 Main characteristics of small-scale carp production systems by region.

	North	Northwest	Chittagong Hill tract	Southeast	South	Southwest	Northeast	Central
Carp species	Rohu, catla, minor carp, common carp	Rohu, catla, mrigal	Common carp, kalibaush, silver barb	Rohu, catla, mrigal, common carp	Rohu, common carp, silver carp, kalibaush, minor carp	Rohu, common carp, major carp, catla, silver carp, kalibaush	Carfu, baush, rohu, catla, mrigal, grass carp, silver barb	Rohu, catla, mrigal, kalibaush, silver carp
Polyculture practices	Yes, with shingh, pabda, gulsha, pangash	Yes, with pabda, gulsha, tengra	Yes, with different carp species	Yes, with tilapia and pangash	Yes, with tilapia and pangash	Yes, with shrimp, prawn, koi, magur, shing	Yes, with different carp species, tilapia and bata	Yes, with pabda, gulsha, prawn, koi, shing, magur
Prevalence of carp culture	• Mymensingh: 12% of farmers practice carp polyculture • Nandail: 20% of production is carp • Jamalpur: 90% of farmers practice carp polyculture • Sherpur: 50% of farmers practice carp polyculture	• Rajshahi: 50% of stocking rate for rohu, 25% for catla/bighead, 25% for Mrigal • Bogura: 60% of production is carp • Dinajpur: 80–90% of farmers practice carp-mola polyculture	• Rangamati: 50% of carp polyculture • Baghaichori: 60–70% of stocking rate for carp	• Chottagram: 25–30% of stocking rate for carp • Noakhali: 20–30% of production • Cox's bazar: 20–30% of carp polyculture	• Barishal: 20% of production is carp • Jhalkathi: stocking rates of 30–35% catla/silver carp; 30% rohu; 35% mrigal, kalibaush and minor carp	• Shatkhira: Carp is second in importance after prawn • Jashore:30–35% of production	Carp is produced but further disaggregation is not available	Carp is produced but further disaggregation is not available
Hatcheries	• Public: Few, run by BFRI and DoF • Private: Few	• Public: Several, run by DoF. Large one in Parbatipur Upazila (Dinajpur) • Private: Several, especially in Bogura (Bogra)	• Public: Few, one run by Bangladesh Fisheries Development Corporation (BFDC) • Private: Few	• Public: Several, run by DoF. Large one in Raipur • Private: Several, especially in Cumilla	• Public: Few, run by DoF • Private: Few	• Public: Few, run by DoF. Large one in Kotchandpur • Private: Several. Hub in Jashore	• Public: Few, run by DoF. • Private: Few • Large one run by international organization BRAC in Moulvibazar	• Public: Few • Private: Few
Nurseries	• Public: Few, run by DoF • Private: Several	• Public: Few • Private: Several Districts Rangpur, Niphamari, Kurigram, Gaibandha and Lalomonirhat are very developed	• Public: Very few • Private: Very few	• Public: Few • Private: Several	• Public: Few • Private: Few	• Public: Few • Private: Several. Hub in Jashore	• Public: Few • Private: Few	• Public: Few • Private: Few
Grow-out farms	Private: Several. For commercial purposes	Private: Several. For commercial and subsistence purposes	Private: Few. For commercial and subsistence	Private: Several. For commercial and subsistence	Private: Few. For commercial and subsistence	Private: Several. For commercial and subsistence	Private: Few. For commercial and subsistence	Private: Few. For commercial and subsistence
Waterbodies used	Ponds	Ponds	Ponds, creeks	Ponds, khals, beels	Ponds and canals	Ponds, haors, ghers, canals	Ponds, haors, baors	Ponds, haors

(Continued)

TABLE 3 (Continued)

Prevalence of intensive systems (polyculture with dominance of other species)	High prevalence	Low prevalence. Feed-based intensive in Dinajpur	Very low prevalence	High prevalence	Low prevalence	High prevalence	Low prevalence	Low prevalence
Prevalence of intensive systems (polyculture with dominance of carp species)	Low prevalence	Low prevalence. More in Natore, Rajshahij	Ver low prevalence. Some in Rangamati	Low prevalence	Low prevalence	Low prevalence	Low prevalence	Low prevalence
Prevalence of semi-intensive systems	High prevalence	High prevalence	Low prevalence	High prevalence	Low prevalence, but increasing	Low prevalence. Lower in coastal areas, higher in areas with fresh water	Low prevalence but increasing rapidly	Low prevalence
Prevalence of extensive systems	Very low prevalence. Found among poor farmers in remote areas (e.g., Netrokona district)	Very low prevalence. Found among poor farmers culturing in small ponds	High prevalence	Very low prevalence. Found among poor farmers in remote areas	High prevalence, gradually transforming to semi-intensive. Some found in Chandpur	Very low prevalence, rapidly transforming to semi-intensive	High prevalence. Found among farmers in condition of poverty	Low prevalence
Hotspots of carp production	• Mymensingh District: Sadar, Trishal • Jamalpur District: Melandoho, Dewangoni • Netrokona District: Komlakanda	Most Districts, specifically the areas of Rajshahi and Natore: • Rajshahi District: Durgapur, Putia, Mohonpur • Bogura District: Kahaloo, Adamdighi • Natore District: Gurudashpur, Shingra, Boraigram • Dinajpur District: Birgonj, Bochangonj, Kaharool, Bikrompur • Rangpur District: Majority of upazilas	• Rangamati District: Baghaichori, Kaukhali • Bandarban District: Sadar, Laikkhangchorri, Lama, Kualong, Nowapotong	Most areas (excepts those with high salinity), such as: • Lohagora, Chondonaish and Satkania Upazilas	Most areas with fish culture	Most areas, particularly: • Jashore District • Satkhira District: Satkhira sadar, Kolarua, Tala • Jashore District: Chougach • Bagerhat District: Fakir hat, Chitolmari, Sadar	Most areas with fish culture: • Sylhet District: Sadar and Rajnagar • Moulvibazar District: Kamalganj, Tea garden area • Habigonj District: Moulvibazar, POligoni, Teghoria	Most areas with fish culture: • Gazipur District: Joydebpur, • Kishoregonj District: Pakundia, Hosenpur, Kotiyadi

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NE and CHT regions. NE region, and particularly the Sylhet division, is characterized by high inequality, as despite having better economic conditions than other regions in the country, it has the highest levels of children stunting and lowest educational levels.[7] Furthermore, CHT faces constraints for inputs supply due to the remoteness and poor infrastructure of the region.

Among additional aquaculture inputs, the participants mentioned the use of biofloc[8] across some regions (N, C) to improve water quality in the ponds. Feeding activities present certain particularities such as the combination of sinking and floating feed throughout the day, which has been mentioned as particularly prevalent in the Rajshahi district (NW). Participants suggested that small-scale producers in other districts such as Jashore (SW) use whole maize grain powder, mustard oilcake, or other natural food, while some small-scale producers in CHT do not use feed at all. There seem to be multiple reasons affecting these choices, namely the affordability of fish feed; physicochemical characteristics of waterbodies; and feed supply networks location and accessibility. Small-scale producers in multiple regions reportedly engage in seasonal culture practices (5–8 months of the year) due to changes in waterbodies from droughts and flash floods (N, NW, CHT, SE, S, SW), and saline water intrusion (Bagerhat and Khulna districts in SW, Cox's Bazar district in SE). Related to the feeding characteristics is the existence of fattening or on-growing practices (NW, C).

Finally, another important aspect relates to the capacity development activities carried out mainly by the DoF and WorldFish through training, extension programs, value chain development and network creation through local service providers (LSPs). For instance, participants from Dinajpur (NW) mentioned the use of online training and social media (i.e., Facebook) groups and pages. Such trainings have a special focus on diversifying the skills of farmers to create value chains (i.e., spawn producers, fry producers, fingerling producers, foodfish producers). Similarly, in other areas such as Bandarban (CHT) the focus has been to connect hatcheries and nurseries to improve the seed quality. Conversely, training in other Districts such as Jashore (SW) focused on grow-out production and reducing inbreeding in hatcheries.

3.2. Carp characteristics valued by small-scale producers

As detailed in Table 4, participants identified the most important carp characteristics or attributes valued by small-scale producers. This information is particularly valuable to understand market and consumer trends and as an element for the development of carp improvement programs in Bangladesh. In relation to the consumption-related attributes, small-scale producers tend to prefer fish that are more appealing for the consumers in their specific region. As reflected

7 For a more detailed description of the demographic and socioeconomic characteristics of the region, the interested reader is referred elsewhere (Chowdhury et al., 2022).

8 Biofloc technology consists in "enhancing water quality through the addition of extra carbon to the aquaculture system, through an external carbon source or elevated carbon content of the feed" (Crab et al., 2012, p. 351).

TABLE 4 Highly valued carp characteristics among small-scale producers by region.

Region	Species	Consumption-related characteristics			Production-related characteristics			
		Large size	Appealing color	Others	Rapid growth	Low fry/ fingerlings price	Improved strains (G3)	Others
North	Rohu, Catla	✓	✓	Shape		✓		
Northwest	Rohu, Catla	✓			✓		✓	
CHT	Catla, Rohu, Mrigal	✓		Taste	✓	✓		Availability of good quality fry/fingerlings, lower mortality rate
Southeast	Rohu, Silver carp	✓	✓					
South	Rohu		✓	Price	✓		✓	
Southwest	Rohu	✓		Farmed in natural waterbodies	✓		✓	
Northeast				Price	✓	✓	✓	Availability of good quality fry/fingerlings
Central	Rohu		✓	Freshness, farmed in natural waterbodies				Cost-benefit performance

TABLE 5 Factors affecting small-scale carp production by region.

Region	Socio-economic						Environmental			
	Good quality fish seed cost/ availability	Ponds rental cost	Electricity cost	Feed cost	Labour cost	Transport for broodstock/ fish seed/ foodfish	Flash floods	Salinity intrusion	Water pollution	Droughts
North	✓			✓			✓			✓
Northwest	✓	✓	✓	✓	✓		✓		✓	
CHT	✓					✓	✓			✓
Southeast	✓					✓	✓	✓		✓
South	✓	✓		✓	✓		✓		✓	
Southwest	✓						✓	✓		
Northeast	✓					✓	✓			
Central	✓		✓	✓		✓				

by the prevalence of different carp species in production activities (Section 3.1), species such as rohu followed by catla are the most popular among consumers across most regions (N, NW, SE, S, SW, C). The popularity of rohu and catla is related to their large size (and taste in the case of rohu), which has traditionally made them suitable for the preparation of dishes for familial and other types of social celebrations. Besides the cultural aspects, participants mentioned that the preference for large sizes of fish is also related to the dislike of consumers for fish bones in smaller fish (CHT). Additionally, color seems to be a relevant aspect in various regions (N, SE, S, C) as it would be an indicator of the freshness of fish, and visual appeal in general.

Regarding the production-related attributes, farmers value characteristics that make their business more profitable such as: fry/fingerlings with fast growth rate; fry/fingerlings with low or reasonable price; and fry/fingerlings with "good quality" in general. The importance given to each of these characteristics is not completely clear. However, in some regions, quality seems to be a more important factor than price (CHT). Some areas mention the Genetically Improved Strain of rohu (G3 rohu) provided by WorldFish as a preferred option (NW, S, SW, NE) as this variety would grow up to 30–40% faster than the local rohu (SW).

3.3. Factors affecting small-scale carp production

Participants noted the main socio-economic and environmental factors affecting small-scale carp production in Bangladesh (Table 5). These factors are not uniform throughout Bangladesh, but there are some commonalities within and across regions.

Regarding the socio-economic factors, the overall profitability of aquaculture practices is an aspect that was frequently mentioned by participants, and that is considered responsible for shifts in production preferences from carp to other species (e.g., pangasius, shing, pabda) that are considered more profitable (N,S). Across all regions, the price of carp aquaculture inputs, and particularly fish seed (i.e., spawn, fry, fingerlings), seems to keep increasing, while the price of the carp products has remained stable. In the case of the fish seed, this issue of high prices is combined with its scarcity and poor quality in some areas, which seems to be related to: difficult access of hatcheries to improved quality broodstock; limitations in the implementation of hatcheries rules and regulations (e.g., requirements in the number and area of ponds, protocols for broodstock development, restrictions on hybridization and inbreeding);[9] and overall lack of investment capacity of the private and public sector, that results in few hatcheries in some regions, and even fewer public hatcheries (compared to private hatcheries) across all regions. According to the participants, this problem is being partially tackled by the establishment of government-operated hatcheries that sell better quality seed, but at a higher price than the private sector (N,C). Other factors with a significant influence in aquaculture profitability include the rental costs of ponds, labor costs, and electricity costs.

Participants from multiple regions mentioned that transportation is a major factor influencing both the production and the distribution of fish from small-scale aquaculture, with transportation also affected by environmental conditions. For instance, in districts such as Bandarban (CHT) and Sylhet (NE) the geographical features (i.e., hills and haors) and poor road infrastructure, make it extremely difficult to transport seed or growout fish, and lead to high mortality during this stage (up to 50% of fish seed in Sylhet). The problems in transportation combined with poor marketing channels also have an impact on the fish produce quality, and consequently its final price (NW, CHT).

In terms of the environmental factors, flash floods and landslides were consistently mentioned as the main cause of considerable production loss, particularly in areas near large rivers such as Barisal (S, NE). Conversely, many of these areas also experience very high temperatures at specific times of the year, leading to dry ponds and the need to use additional irrigation (N, CHT, SE). Salinity is also an important factor in specific areas (SW, SE). While small-scale producers in these regions have adapted their carp aquaculture

9 Limitations in the implementation of rules and regulations for hatcheries are usually related to hatcheries that were created before the establishment of instruments regulating the quality of hatcheries in recent years. It has been challenging for the government to stop the operation of these hatcheries, and although the government has attempted to support them to progressively improve their practices, some have yet to reach the required standards. This situation is explained in more detail by Shikuku et al. (2021).

practices producing fish in saline water (particularly during wet months when the salinity levels drop and become close to freshwater levels), shrimp has become the priority species in these areas.

It is worth noting that the participants commonly mentioned the COVID-19 pandemic and extreme climate events as catalyzing many of the impacts associated with the above factors in the last years. For instance, the existing challenges related to supply chains and logistics worsened due to the restrictions during the pandemic, which impacted not only the fish distribution channels but also the timely availability of inputs such as fish seed and feed (N, NW, CHT, SE). In turn, these distribution problems caused disruptions in fish supply and demand, which led to a decrease in selling prices to the consumers (N, NW, SE, SW, NE) and an increase in production/transportation costs (S, C). However, in some regions farmers were able to bypass restrictions by using alternative transportation/distribution channels (e.g., Dinajpur in NW), or through direct governmental support (C), and as results seem to have been less impacted. Conversely, a few other regions experienced an increase in their profits due to the use of carp as a substitute of other foods (e.g., Bagerhat in SW). Similarly, the frequency and severity of some of the natural hazards that affect small-scale aquaculture in the different parts of the country was mentioned as an important factor. Practically all regions reported problems related to flash floods, causing production losses. While climate change was not directly attributed to these natural disasters, some areas such as Rangamati (CHT) mentioned the occurrence of particularly extreme weather events in recent years. However, it is important to stress that the nexus between carp farming and climate change is something to be explored further and better in future research.

4. Discussion

4.1. Characteristics of small-scale carp aquaculture systems in Bangladesh

The results from the multi-stakeholder workshops reveal the complexity of the small-scale carp aquaculture systems in Bangladesh, as well as their crucial role for rural livelihoods across the country. Below we critically discuss some of the most important findings, in view of the relevant literature.

First, it was difficult to quantitatively synthesize the prevalence of the different species and small-scale production systems around the country (and the different regions), as participants reported information using disparate references (e.g., percentage of carp in total aquaculture production, percentage of farmers adopting different production systems, percentage of carp in total stocking rate) (Section 3.1). However, it was evident that carp culture is ubiquitous across most parts of the country, except in areas where specific conditions make it unsuitable (e.g., coastal areas with salinity intrusion). This dominance of carp aquaculture reflects well the existent literature and production statistics at the country level (Jahan et al., 2015; Karim et al., 2016; DoF, 2022), as well global trends, where carp species are the dominant species group for inland water (FAO, 2022).

Second, the results of the workshops indicate that carp monoculture is practically non-existent in Bangladesh. In fact, polyculture practices are predominant in small-scale carp production systems throughout all regions, across very different systems with diverse combinations of species, stocking rates and input selection. This reflects quite well the literature on the positive role of carp species in polyculture settings (Milstein et al., 2006; Rahman, 2015), as its beneficial effect on fish production and water quality has been traditionally known by farmers (Milstein, 1992; Kestemont, 1995). Here it is worth noting that research during the past decades has revealed that the often-positive effects of carp in polyculture systems are related to the species feeding behavior and physiology, which have synergistic interactions with natural feeding sources (e.g., phytoplankton) and other fish species (Milstein, 1992; Szücs et al., 2007; Mungkung et al., 2013; FAO, 2022). For instance, some other carp species in Bangladesh such as the common carp (*Cyprinus carpio*) are ideal for polyculture due to its "broad diet and mild behavior" (Zhao et al., 2018, p. 682). Similarly, carp species commonly found in Bangladesh such as the silver carp (*Hypopthalmichthys molitrix*), common carp (*Cyprinus carpio*) and bighead carp (*Aristichthys nobilis*) are valued as filter-feeding species, for the control of phytoplankton and water quality improvement in non-fed aquaculture, although their benefits for fed aquaculture have also been identified (Ma et al., 2010; Rahman, 2015; FAO, 2022). However, many of these ecological mechanisms remain unclear, with significant research trying to identify the adequate conditions under which polyculture of each specific carp species provides the best performance and the best sustainability outcomes (Milstein et al., 2006; Rahman et al., 2006; Mungkung et al., 2013; Pucher et al., 2015; Karim et al., 2017).

The workshop participants roughly divided the carp polyculture systems identified in this study in: carp polyculture with other species; and carp polyculture among species belonging to the carp group. The participants suggested that the decision as to what species are to be combined in polyculture systems (and their proportion) closely linked to the level of intensity of the farming activities.

First, when it comes to polyculture with other fish species, one of the most common combinations (particularly in the N, S and SW regions) is with species such as pangash and tilapia. Usually this corresponds to highly commercialized systems that have the highest levels of intensification and are characterized by the use of commercial feeding (Section 3.1). In most of these polyculture systems, carp was reportedly produced in smaller proportions compared to the other fish species (e.g., pangash, tilapia). Its role is mainly related to water quality improvement and low consumption of supplemental feed, which contributes to the productivity of the whole system (Fitzgerald and Tamuning, 1988; Abdelghany and Ahmad, 2002; Nabi et al., 2020). These findings concur with existing literature on the emergence of "niche" high-value species (e.g., pangash, tilapia, koi) in the North and East of the country (Jahan et al., 2015; Hernandez et al., 2018).

The other major combination of carp with other fish species as reported by the participants was with SIS (e.g., mola), in which carps were often predominant in proportion. These polyculture systems were semi-intensive and mainly geared toward a mix of commercial and subsistence purposes. These systems seem to exist predominantly in the North, Northwest, and Southeast regions, and to be less reliant on supplemental feed (Section 3.1). Some of the literature reports that these polyculture systems (i.e., carp-SIS) have higher productivity and profitability in comparison with monoculture practices (Karim et al., 2017), while others have found no significant differences (Roy et al., 2002). Regardless of these results, overall, carp-SIS polyculture is quite advantageous for homestead ponds. As the two types of species do not interfere with each other, carp production can be commercialized for income generation, while the SIS production can be self-consumed contributing to household nutrition and food security (Roy et al., 2002; Milstein et al., 2006; Rai et al., 2014; Karim et al., 2017).

Second, when it comes to polyculture using solely different species within the carp group, the systems identified by the participants were either intensive or extensive. The intensive systems had the second highest productivity among the four categories identified in Section 3.1 and relied heavily on the use of commercial feed. They usually relied in combinations of carp species (e.g., rohu, catla, common carp/ mrigal) with different characteristics in terms of behavior and feeding preference. For instance, common carp (*Cyprinus carpio*) and mrigal are omnivorous and bottom feeder species that are often referred as "ecological engineers" due to their capacity to modify the ecological characteristics of their environment (Rahman, 2015), which, under appropriate management can increase the productivity of other carp species such as rohu (Rahman et al., 2006).

Conversely, extensive carp polyculture systems, while progressively transforming into semi-intensive systems, are still quite prevalent in deprived areas of the CHT, South and Northeast regions (Section 3.1). They are characterized by the stocking of multiple carp species, (some studies report up to 9 different carp species), with the expectation to enhance production in homestead ponds (Roy et al., 2002; Dam Lam et al., 2022). These systems are also characterized by their high fish density and dependance on natural feeds (i.e., non-fed aquaculture).

Here we should point out that while various carp species have been found to be optimal for non-fed aquaculture, the literature indicates that many small-scale farmers in Bangladesh still lack the knowledge and capacity to determine and control: (a) the exact combination of species (both within the carp group and others), and (b) their proportions, which can often cause serious ecological disruption and production losses (Milstein, 1992; Wahab et al., 1995; Haque et al., 2003; Rahman, 2015).

In terms of marketing, most Indian major carps (i.e., rohu, catla, mrigal), and particularly rohu, seem to be highly preferred by final consumers due to their size, taste, appearance, and cultural value for familial, religious, and social celebrations (Section 3.2). In fact, the rapid expansion of aquaculture production in Bangladesh during the last decades (Section 1) seems to have resulted in the greater availability of the previously "high-end" rohu, leading to its massive consumption (Hernandez et al., 2018; Mehar et al., 2022). However, the existing research in Bangladesh argues that quick shifts in the aquaculture sector have been occurring, with tilapia and perch (koi) taking a significant and increasing market share in recent years (Belton et al., 2014; Hernandez et al., 2018).

Finally, it was difficult to synthesize the "hotspots" identification, given the different criteria and administrative levels that the participants used as reference and the generally scarce relevant datasets in Bangladesh. However, it has been possible to corroborate some of them within the existing literature. For instance, districts such as Mymensingh (N), Jamalpur (N), Bogura (NW), Natore (NW), Rangpur (NW), Jashore (SW), Satkhira (SW), and Bagerhat (SW) have been mentioned in the literature as particularly important areas for carp aquaculture in Bangladesh, although in some studies the reported "target" study species was not carp (e.g., pangash in Bogura, shrimp in Satkhira and Bagerhat; Jahan et al., 2015). Mymensingh (N) is the most important hub for small-scale aquaculture in general in Bangladesh (Asian Development Bank, 2005; Ahmed, 2009; Hernandez et al., 2018). The pre-eminence of this area for small-scale aquaculture was achieved through multiple actions that provided technical and academic support from the government and international organizations, which collectively created an enabling environment for aquaculture (Asian Development Bank, 2005; Hernandez et al., 2018).

4.2. Factors influencing small-scale carp aquaculture in Bangladesh

The factors that reportedly influence small-scale carp aquaculture that were most frequently mentioned across the regions were: the cost and timely availability of good quality fish seed; feed and transport costs; and incidence of flash floods (Table 5). The first two factors are related to upstream (i.e., supply of seed and feed) and downstream (i.e., production transport) value chain activities, while the third is an environmental factor. Overall, the negative effects of these factors on small-scale carp aquaculture seem to have been exacerbated in recent years by the COVID-19 pandemic and climate change, increasing the vulnerability of many small-scale producers (Section 3.2).

The availability and access to high quality seed and feed is one of the critical aspects for achieving sustainable aquaculture intensification, not only in Bangladesh but globally (FAO, 2022). In Bangladesh, feed has been identified as one of the major expenses for commercial producers, while seed-related expenses are the highest for homestead systems (Jahan et al., 2015). However, commercial carp systems are comparatively less feed-intensive than other systems, with feed representing approximately 31% of overall costs vs. 80% for koi, 75% for pangash and 52% for tilapia (Jahan et al., 2015).

The incorporation of genetic improvement techniques into breeding programs is contributing to the development of varieties with more desirable characteristics, while the adoption of best management practices and biosecurity strategies in hatcheries and nurseries is critical to produce healthy seed fish and avoid production losses (Siriwardena, 2007; FAO, 2022). However, for farmers to be able to access seeds with these characteristics, multiple additional challenges need to be overcome, such as: seed quality monitoring and control activities; knowledge transfer for hatcheries, nurseries and grow out farmers; distribution channels infrastructure; and private investment in hatcheries/nurseries (Jahan et al., 2015; Shikuku et al., 2021). Regarding carp seed in Bangladesh, research indicates that the predominant source of seeds for commercial purposes are hatcheries (around 50%), while in the case of homestead farmers are mobile fish traders (up to 90%; Jahan et al., 2015). This difference might be related to the scarcity of hatcheries in multiple regions of the country and the lack of transportation means for homestead farmers to be able to buy directly from hatcheries, which in turn would result in an increase in costs. In our study, areas such as CHT, Northeast and Central reported the lowest prevalence of hatcheries and nurseries (Section 3.1), and unsurprisingly were the ones who also mentioned transport as an important factor affecting their activities (Section 3.3).

4.3. Policy and practice implications and future directions

This study synthesized the insights of stakeholders about the status, characteristics and factors affecting small-scale carp aquaculture in Bangladesh. As we argue below, this type of information can help improve the targeting and actions seeking to support small-scale carp producers and have valuable benefits for the socioeconomic and environmental performance of the small-scale aquaculture sector.

In particular, the identification of the hotspot areas and potential hotspot areas, and the prevalence of the different systems within them can help prioritize what support and in which areas to roll it out. For example, it might prove to be much more cost-effective to concentrate efforts in areas with many potential beneficiaries and/or design and co-design actions and extension services that reflect the capacity and needs of different producers. In this sense, concentrating support to existing hotspot areas might benefit particularly from the existing infrastructure and marketing options. Potential hotspot areas might also be particularly promising targets of such intervention, but care should be paid to ensure that carp species are appropriate for such areas. For example, in areas experiencing salinity intrusion, carp might not be the most appropriate species for viable production (see above).

It is important to keep in mind the high variability of production systems within the sector in terms of the carp/non-carp species used in polyculture systems, the degree of intensification, and the extent of commercialization. While literature from the last decade indicates that subsistence-based aquaculture is the predominant model in the country (Section 2.1), our results suggest a shift to mixed and commercial aquaculture in most regions of the country (Section 3.1). Such information can be particularly useful to customize the different elements of actions to cater for the specific needs and characteristics of the systems most prevalent in each targeted region. For example, this could provide an added lens to consider carefully whether when pushing efforts toward increasing intensification, by carefully looking at best practices options to avoid environmental disruption based on the characteristics of each region.

Furthermore, it was pointed out by participants that there is a crucial need for improved carp seeds such as G3 Rohu, which can grow up to 30% faster than conventional Rohu strains (Hamilton et al., 2022). The availability of improved strains to large numbers of small-scale producers could considerably improve carp production in Bangladesh. However, as the price of carp is currently declining, the participants suggested the need for processing units in every district, where the fish can be frozen and stored by farmers for longer periods to avoid spoilage. While these solutions require further research and evaluation to identify the most viable alternatives and strategies, they are essential for farmers to get fair prices for their fish.

Although these multi-stakeholder workshops served to provide some more fine-grained information about the small-scale carp aquaculture sector in Bangladesh, this is only the first step in characterizing it properly. This information should be used as a qualitative reference of the recent changes and current state of the small-scale carp aquaculture sector in the different regions of the country. The results of this study can inform the design of future studies which should seek to identify through robust quantitative analysis the main characteristics and differences of systems, and whether and how their distribution and performance might vary. This would require extensive on-farm surveys, and especially in the areas identified as hotspots or having hotspot potential. Such fine-grained quantitative information can inform the design and implementation of future actions in the sector.

5. Conclusion

This study gathered the perceptions of 215 stakeholders in Bangladesh about the status, characteristics and factors affecting small-scale carp aquaculture. This was achieved through eight online workshops conducted in February 2021 that covered the entire country. The stakeholders re-affirmed the importance of carp aquaculture within the country and identified the main producing areas (hotspots) and the areas that have such potential. However, this identification was done at disparate administrative levels, restricting further analysis or discussion in the study. Overall, the participants identified four major types of small-scale carp aquaculture systems in terms of the species used and degree of intensification and commercialization. At the same time, despite some variability across and within regions about the factors affecting small-scale carp aquaculture, the stakeholders identified the availability of high-quality seed, the transport and flash floods as having particularly strong effects. The COVID-19 pandemic and climate change were reportedly intensifying the effects of these factors on the sector. The information provided by the stakeholders sheds light on the variability within the sector, something that is generally not visible in the highly aggregated available production data. Although such information is only the first step, it can help understand better the sector and inform the design and implementation of relevant actions, by for example identifying better the areas to be targeted and whether and how to customize the assistance and extension services for farmers. Such a nuanced approach to targeting and design could improve the performance of the sector, having considerable benefits for the large population of small-scale producers within the country.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the participants was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

CR, BB, RD, RM, and AG designed the study. BB, RD, CR, and AP supported the workshop implementation and the data gathering process. DL, AP, RD, QW, BB, and AG analysed the data and reports from the workshops. CR, DL, AG, TM, QW, BB, and ED wrote the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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