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Impact of COVID-19 Pandemic on Aquaculture Production and Profitability in Bangladesh: A Comprehensive Analysis

REZAUL HOQUE[1], MD. INJA-MAMUN HAQUE[2], MAHMUD HASAN[2], RANAJIT KUMAR[3], TAPAN MAZUMDER[3], A.F.M. NAZMUS SALEHIN[3], RIPON KUMAR GHOSH[3], MD. ZAKIUL ALAM[4], SHANKAR CHANDRA MANDAL[2,*]

[1]CGIAR Research Program on Fish Agri-food Systems (FISH), WorldFish Bangladesh, Dhaka, Bangladesh
[2]Department of Fisheries, University of Dhaka, Dhaka, Bangladesh
[3]Department of Fisheries (DoF), Ministry of Fisheries and Livestock, Dhaka, Bangladesh
[4]Department of Population Sciences, University of Dhaka, Dhaka, Bangladesh

*E-mail: shankar@du.ac.bd | Received: 20/04/2022; Accepted: 03/09/2023

Abstract

In March 2020, the COVID-19 pandemic rapidly spread across Bangladesh, affecting various sectors, including aquaculture. However, there is a lack of evidence regarding the effects on aquaculture production and profitability in the country. The present study addresses this gap and investigates the impact of the COVID-19 pandemic using a convenience questionnaire survey utilising face-to-face and telephonic interviews with 499 fish farmers from five prominent fish-culture regions (Satkhira, Khulna, Madaripur, Bhola, and Mymensingh) in Bangladesh from April to August 2020. The results show aquaculture production losses averaging 29.1 % during the pandemic compared to the pre-pandemic period. Before the COVID-19 pandemic outbreak, the farmers reported a profit of USD3813 per hectare, which turned into a loss of USD2565.4 per hectare during the pandemic period. The standard multiple linear regression analysis indicated that large farms experienced a more significant impact on aquaculture production loss and economic loss during the pandemic period compared to small farms [$\beta = 0.15$, $P = 0.029$]. The causes for the production loss were identified by rank based quotient (RBQ), indicating that increased fish transportation costs and prices of seed and feed dominated during the lockdown. The lockdown and movement restrictions also reduced selling prices because of fewer buyers. The government provided financial support to the fish farmers, but only one-third (36 %) of the respondents received financial aid. The study suggests implementing medium and long-term measures, such as strengthening communication networks, digital marketing strategies and developing strategic planning initiatives to improve disaster management and resilience to mitigate the effects of the pandemic.

Keywords: lockdown, COVID-19 pandemic, production loss, financial support

Introduction

Economically, aquaculture is one of Bangladesh's most dynamic and productive sectors, contributing significantly to the livelihoods of 18 million poor and marginalised people, both directly and indirectly. During the fiscal year (FY) 2020–21, this sector produced 4.62 metric tons (mt) of fish and earned USD501 million through exports (DoF, 2022). Furthermore, the fisheries sector contributed to 60 % of the animal protein intake in Bangladesh as reported by the Department of Fisheries in 2022 (DoF, 2022), and fisheries and aquaculture together accounted for 3.57 % and 26.5 % of the national and agricultural gross domestic products (GDPs), respectively (DoF, 2022). The aquaculture and fisheries value chain also provided livelihoods for 12 % of the country's population, as reported by the Bangladesh Bureau of Statistics (BBS, 2018; Shamsuzzaman et al., 2020).

Aquaculture is practised in all eight divisions of the country, and the practice methods include ponds, seasonal cultured waterbodies, shrimp and prawn farms, and pen and cage culture (DoF, 2020). However, several districts dominate fish and shellfish production, including Mymensingh, Madaripur, Khulna, Satkhira and Bhola (Table 1). In these regions, extensive, semi-intensive and intensive culture systems are practised. These regions contributed significantly to the country's total aquaculture production in 2019–20.

Table 1. Aquaculture production and major culture fish species of some selected regions of Bangladesh during 2019–2020 (DoF, 2020).

Major culture fish species	Production (mt)				
	Madaripur	Mymensingh	Khulna	Satkhira	Bhola
Labeo rohita (Hamilton, 1822)	1904	16254	3292	10419	8304
Labeo catla (Hamilton, 1822)	1276	7744	1757	5450	6179
Cirrhinus cirrhosus (Bloch, 1795)	1188	10351	1559	4624	2896
Hypophthalmichthys molitrix (Valenciennes, 1844)	1154	10348	2442	1463	3687
Ctenopharyngodon idella (Valenciennes, 1844)	246	7046	795	186	762
Cyprinus carpio Linnaeus, 1758	498	4074	1170	165	526
Pangasius pangasius (Hamilton, 1822)	2137	166341	754	9015	7101
Anabas testudineus (Bloch, 1792)	457	22109	25	79	151
Heteropneustes fossilis (Bloch, 1794)	142	15057	86	86	79
Clarias batrachus (Linnaeus, 1758)					
Oreochromis niloticus (Linnaeus, 1758)	2096	23684	3412	7121	4471
Penaeus monodon Fabricius, 1798	0	0	12549	24088	8.89
Macrobrachium rosenbergii (De Man, 1879)	8.61	0.83	13325	8631	8.0
Culture system	Extensive, semi-intensive and intensive				
Total culture area (ha)	2885	29144	4785	13112	7884
Total aquaculture production (mt)	12362	339859	16040	39599	36248
Production rate (mt.ha^{-1})	4.28	11.66	3.35	3.02	4.60

The outbreak of COVID-19 in early 2020 (WHO, 2020) significantly impacted the daily activities of fish farmers in Bangladesh, mainly because the government declared countrywide or area-specific lockdown and movement restrictions to combat the spread of coronavirus (Bodrud-Doza et al., 2020). These restrictions disrupted fish and shrimp production by creating obstacles in Bangladesh's aquaculture sector (Hasan et al., 2021; Bashar et al., 2022).

The sudden disruptions in the supply channels and movement restrictions of supporting workers and technical staff, especially across the border, as well as the unavailability of vehicles, blocked the import of raw materials and initiated a scarcity of aquaculture inputs, such as feed, seed, labour, and capital, thereby increasing the production costs (Reardon et al., 2020; Sharma et al., 2020). In addition, the export and domestic use of aqua products were limited, which created a gap in the demand and supply channels of international and domestic markets (Alam et al., 2022). Therefore, the aquaculture sector's stakeholders might have faced economic and financial crises in Bangladesh and other countries during this period.

The dire consequences of the COVID-19 pandemic on fisheries and aquaculture have been extensively studied in different parts of the world, including the USA (Smith et al., 2020), China (Newton et al., 2021), Canada (Webb, 2021), Indonesia (Wiradana et al., 2021), Malaysia (Waiho et al., 2020), Kenya (Fiorella et al., 2021), Thailand (Chanrachkij et al., 2020), and Bangladesh (Islam et al., 2021; Sunny et al., 2021; Mandal et al., 2021). Ferrer et al. (2021) conducted a comprehensive study on the effects on small-scale fisheries and their responses to the COVID-19 pandemic in six Southeast Asian countries: Indonesia, the Philippines, Thailand, Malaysia, Myanmar, and Vietnam.

The pandemic disrupted aquatic food supply systems in many countries (Belton et al., 2021). The pandemic also disrupted the agricultural value chain, including input supplies, production, processing, marketing, logistics, retail, and consumption in Bangladesh (FAO, 2020a, b, c). Recent studies demonstrated that the COVID-19 pandemic caused economic losses through the disruption of the aquaculture supply chain, logistics, farming, processing, and marketing (Kumaran et al., 2021), business losses to aquaculture entrepreneurs, loss of sales, increase in inventory maintenance costs, decrease in labour availability, and loss of employment (van Senten et al., 2020).

In addition, many studies reported a reduction in the consumption frequency of fish, shrinkage of wet market activity (Mandal et al., 2021), increased vulnerability of small-scale fish farmers in terms of livelihoods, nutrition, and health (Knight et al., 2020; Islam et al., 2021), and adverse effects on the ornamental fish supply chain (Nanayakkara et al., 2021) as a consequence of the COVID-19 pandemic. Sunny et al. (2021) assessed the influences of the pandemic on small-scale fisheries and aquatic food systems in Bangladesh, while Hoque et al. (2021) identified the economic impacts of the pandemic on small-scale coastal fishing communities in Bangladesh. Islam et al. (2021) studied the effects of the pandemic on capture fisheries in Bangladesh. In addition, the decline in profit for finfish growers and disparities within the supply chain were identified as dire consequences of the pandemic in Bangladesh (Hasan et al., 2021). However, to date, the impact of the pandemic on fish and shrimp culture in Bangladesh has not been reported. Most previous studies, particularly those focusing on Bangladesh, analysed how the COVID-19 pandemic affected the fisheries sector but overlooked the impacts on aquaculture production and profit regarding volume and value at farm levels.

Additionally, there is a lack of understanding of the causes of the loss of aquaculture production and the reasons for higher production expenses compared to the previous year in Bangladesh's aquaculture sector due to the pandemic. Identifying the people's expectations from the government and, most importantly, mitigating the forfeiture incurred on Bangladeshi aquaculture stakeholders due to the pandemic. Therefore, the present study was designed to investigate the effects of the COVID-19 pandemic on the Bangladeshi aquaculture sector's production and profits. The study recommends several strategies and tactics to help tackle future pandemic-related impacts on aquaculture in Bangladesh and other countries.

Materials and Methods

Ethical approval

Ethics approval for the interviews and survey was obtained through the Faculty of Biological Sciences of the University of Dhaka before recruitment and written/typed informed consent was obtained from participants using electronic and physical consent forms (Ref. No. 210/Biol. Scs.).

Survey area and sampling

The study was undertaken in five districts prominent for fish production in Bangladesh from April to August 2020 to investigate the effects of the COVID-19 pandemic on aquaculture production. Among the regions surveyed, Satkhira and Khulna, located in the southwestern coastal areas of Bangladesh, are the regions of offshore marine fisheries. Satkhira dominates in shrimp production, while Khulna is in prawn farming. In addition, the saline water area of Satkhira is suitable for the culture of Asian sea bass, *Lates calcarifer* (Bloch, 1790), and polyculture of *Oreochromis niloticus* (Linnaeus, 1758) with *Penaeus monodon* Fabricius, 1798 (Tran et al., 2019; Haque et al., 2020). Mondal (2017) stated that the adjacent coastal area is suitable for the culture of *Planiliza parsia* (Hamilton, 1822), which favours the aquaculture of the species in Satkhira, country's coastal region. The annual fish production rate in Khulna and Satkhira regions was 3.35 and 3.02 $mt.ha^{-1}$ in 2019–2020 (Table 1) (DoF, 2020).

Bhola is a flood-prone estuarine area in the country's south-central region where onshore fisheries are commonly found. Among the culture species in Bhola, Indian major carp are dominating (Table 1). Madaripur is also located in the country's south-central region, where mostly riverine and culture fisheries are common. Indian major carps also dominate among the culture species in Madaripur (Table 1). Mymensingh, located in the western region of Bangladesh, is famous for floodplain and culture fisheries. Mymensingh region is renowned for carp and catfish production, particularly stinging catfish, *Heteropneustes fossilis* (Bloch, 1794), *Pangasius pangasius* (Hamilton, 1822), and *Ompok pabda* (Hamilton, 1822) (DoF, 2018; Tran et al., 2019). The mono-sex technology has advanced the culture potential of tilapia in the Mymensingh and Madaripur regions (Salam et al., 2019). Thus, because of the significance of these regions in aquaculture production in Bangladesh, these regions were selected for this study.

The data were collected through face-to-face and telephonic interviews with fish and shrimp farm owners. Convenience sampling was chosen due to the lockdown in the country. The study was conducted during the peak period of the COVID-19 pandemic, which limited the ability to conduct face-to-face interviews with a larger number of farmers. Telephone interviews used as an alternative had limitations, such as restricted scope for rapport building and challenges in asking long descriptive questions. In addition, there were limited control variables and difficulties implementing random sampling due to the absence of comprehensive farm lists. Despite these limitations and non-random sampling, the information gathered was carefully interpreted using a multiple linear regression method to gain insight into the situation.

The sample size was determined using the formula given by Cochran (1977), which is presented as n = $z_{\alpha/2}^2$P(1-P)/d^2*deff, where P is the sample proportion, α is the level of significance, $z_{\alpha/2}^2$ is the critical value from a normal distribution, d is the margin of error, deff is the design effect due to sampling variability, and n is the sample size. The α of 0.05, $z_{\alpha/2}^2$ of 1.96, d of 0.05, and deff of 1.30 was chosen for this study. As there is no prior information for the value of *P*; hence, *P* = 0.5 was used, which gives the maximum sample size, and, therefore, got n = 499, the initial sample size for the study. The data were collected from 450 fish and shrimp farmers, with a non-response of 9.9 %. The final sample size for data analysis was 423 fish and shrimp farms as some incomplete responses were not considered: Satkhira (n = 117), Khulna (n = 100), Madaripur (n = 63), Bhola (n = 60), and Mymensingh (n = 83) (Fig. 1).

The questionnaire included a range of inquiries delving into the essential aspects. These included the dimension of the pond area, type of ownership, culture species of finfish and shellfish, the production figures from the previous year (2019), and the financial outcomes of profit or loss before and during the COVID-19 pandemic. Furthermore, the price fluctuation of fish before and during the COVID-19 pandemic is shown in Table 2. The study investigated the reason for the decline in aquaculture production and the factors contributing to increased production costs through structured questions. In addition, the research explored the extent of the support provided to the fish farmers and their expectations from the government.

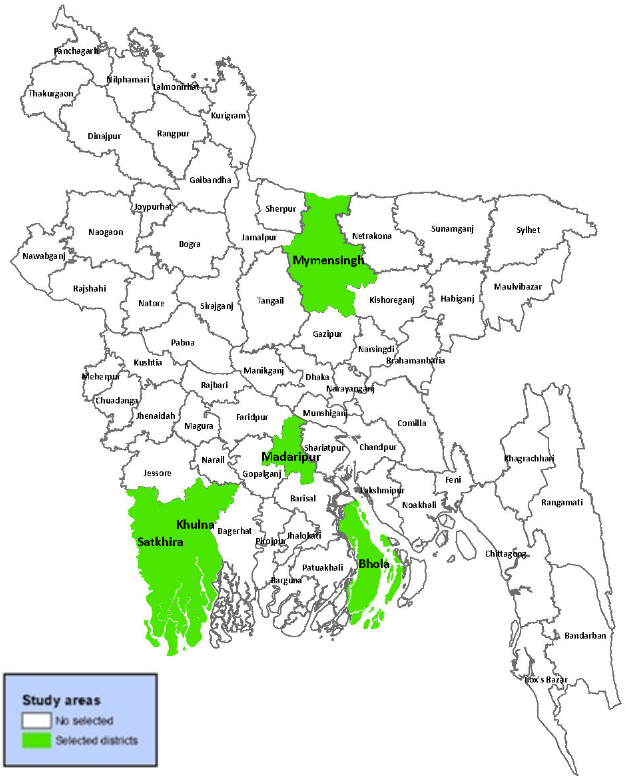

Fig. 1. Map of Bangladesh illustrates the five districts highlighted in green shades selected for the study on the impact of COVID-19 pandemic on aquaculture production.

Table 2. Descriptive statistics of the study population to assess the impact of the COVID-19 pandemic on aquaculture production and profitability in Bangladesh. The data were analysed to present them according to survey area, pond size and type of ownership.

Background	Number of respondents	Per cent of total respondents
Survey area		
Satkhira	117	27.7
Mymensingh	83	19.6
Khulna	100	23.6
Bhola	60	14.2
Madaripur	63	14.9
Pond size		
<1 ha	306	72.3
1–2 ha	78	18.4
>2 ha	39	9.2
Mean of pond area (SD)	0.88 (1.7)	
Type of ownership		
Own	254	60.0
Lease	91	21.5
Partial	78	18.4
Production before COVID-19 pandemic		
Small production (<1.0 mt.ha^{-1})	202	47.8
Large production (≥1.0 mt.ha^{-1})	221	52.2
Total	423	100.0

Statistical analysis

Descriptive statistics were utilised to analyse the data using Microsoft Excel and SPSS version 26.0. The area of the ponds was grouped as <1, 1–2, and >2 hectares (ha) in each sampling region. The ponds' size and ownership type were presented graphically for each study area to grasp the data visually rather than in tabular form. The frequency of fish species cultured in each survey region was counted using

Microsoft Excel and shown in a heatmap. Aquaculture production loss during the COVID-19 pandemic was calculated as follows:

$$\text{Production loss (mt.ha}^{-1})(\%) = \frac{\text{Expected production (mt.ha}^{-1}) - \text{Actual production (mt.ha}^{-1})}{\text{Actual production (mt.ha}^{-1})} \times 100$$

The collected values were recorded in the local currency Bangladeshi Taka (BTD) and converted to USD using a conversion rate of USD1.0 = BDT84.8 as per the data from Bangladesh Bank 2020.

The difference in aquaculture production between the pre-COVID-19 pandemic and during the COVID-19 pandemic period (continuous dependent variable) was evaluated using a t-test, one-way ANOVA, and pairwise comparison using Bonferroni post hoc analysis. To assess the effect of COVID-19 pandemic on aquaculture, a dummy variable was made using the farm production before the pandemic, distinguishing between small and large production. The large production was defined as fish or shrimp production ≥1.0 mt.ha^{-1}, whereas the small production was defined as production <1.0 mt.ha^{-1}. The assumption was that, though all the farms might be affected by the pandemic, large farms might be particularly affected. Although non-probability sampling is not the ideal approach for inferential statistics, standard multiple linear regression analysis to better understand the association between selected covariates and determine the effect of the COVID-19 pandemic on aquaculture production was employed considering the different variables. The independent variables included pond size, survey areas, type of ownership, and production before the COVID-19 pandemic. Two models were presented to assess the effect of the COVID-19 pandemic on aquaculture: (Model 1) aquaculture production loss (mt.ha^{-1}) as a percentage of the pre-pandemic period, and (Model 2) economic loss between pre and during the COVID-19 pandemic as another dependent variable. A check for the absence of multicollinearity was done (mean VIF <2) to ensure the reliability of each model.

The rank-based quotient (RBQ) was used to prioritise the identified problems in the present study. The constraints were ranked according to their prevalence (the number of interviewees who reported them). The overall and the area-wise RBQ was calculated. The RBQ for each constraint was calculated using the widely used formula proposed by Sabarathnam and Vennila (1996), which was further adapted for the agricultural sector by Kumaran et al. (2021).

$$\text{RBQ} = \frac{\Sigma(\text{Fi})\,(\text{n} + 1 - \text{i})}{\text{Nn}} \times 100$$

where RBQ = Rank Based Quotient, Fi = Number of respondents reporting a particular problem under ith rank

N = Number of respondents

i = Number of ranks

n = Number of constraints identified.

Results

Pond area and type of pond ownership

The ponds surveyed were categorised into <1, 1–2, and >2 hectares (ha) in area. In Khulna and Madaripur, all the ponds were less than 1 ha, while in Satkhira, the area of more than half of the fish farms ranged between 1 and 2 ha (Fig. 2A and Table 2). In Satkhira and Mymensingh districts, a few ponds larger than 2 ha were also identified.

In Khulna, Madaripur, and Mymensingh districts, all or most of the fish farms were owned by private fish farmers, whereas in Satkhira, most farms were leased. In Bhola, most fish farms were partially owned and partially leased (Fig. 2B and Table 2).

Cultured fish and shellfish species

A total of 23 fish and shellfish species were cultured in all five surveyed regions, with Satkhira having the highest number of 16 species (Fig. 3). Of the fishes cultured, *Labeo rohita* (Hamilton, 1822) and *Labeo catla* (Hamilton, 1822) were common in all the five regions. Among the shellfishes, *P. monodon* was cultured and found only in Satkhira, and *Macrobrachium rosenbergii* (De Man, 1879) in Satkhira and Khulna regions. Some other fishes, including *P. parsia* and *L. calcarifer* were reported in Satkhira, whereas *O. pabda* and *P. pangasius* were only cultured in the Mymensingh region.

Aquaculture production in the pre-COVID-19 pandemic and during the COVID-19 pandemic

During the COVID-19 pandemic, the expected aquaculture production decreased compared to pre-pandemic levels in all the survey regions (Table 3). The percentage of production loss per hectare during the survey period ranged from 22.7 to 35.1 %, with an average of around 29.1 % (Table 3). Among the surveyed regions, the fish farmers in Satkhira reported the highest production loss per hectare at (35.1 %), while the lowest was reported from Bhola (22.7 %). Before the COVID-19 pandemic, the total profit in the surveyed regions was USD3813 per hectare. In contrast, during the COVID-19 pandemic and throughout the survey period, the collective fish farms experienced an average loss of USD2565.4 per hectare. The production loss during the pandemic was significantly higher in the larger ponds (>2 ha), with a loss of 1.12 mt.ha^{-1} compared to smaller ponds

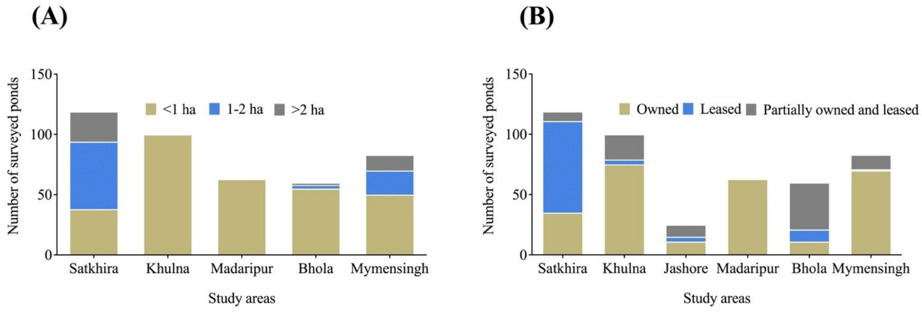

Fig. 2. Area of the ponds and type of ownership of the farms in the surveyed regions. The ponds were grouped into three categories based on their size (A) and their type of ownership (B).

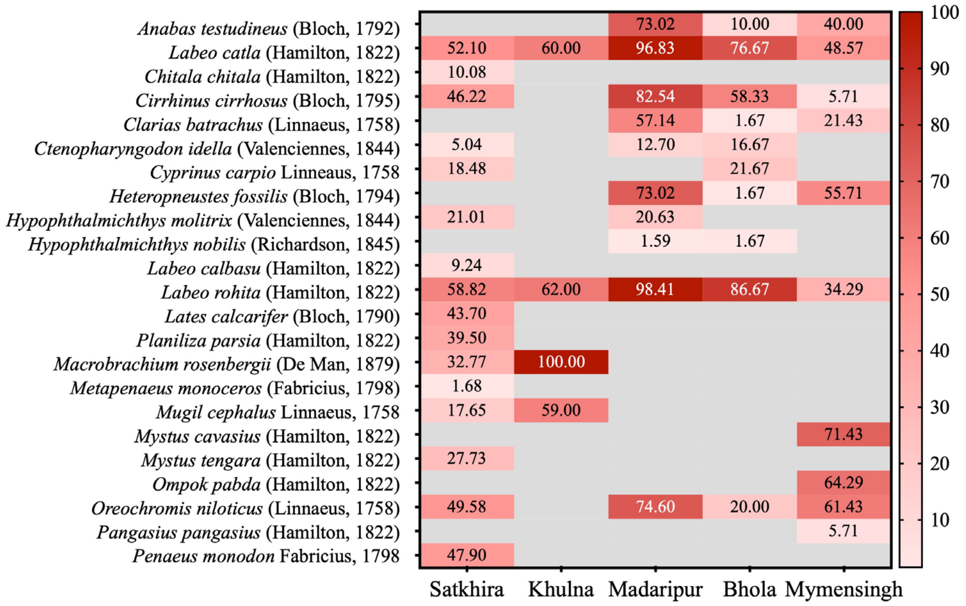

Fig. 3. List of fish and shellfish found in the survey regions. Colour code represents the percentage of fish farms that reported the species' culture in their respective region. Blank areas represent the absence of cultured species in the specified area.

Table 3. Aquaculture production, profit, and loss before and during the COVID-19 pandemic in the study areas. The pre-COVID-19 pandemic data represented the information of 2019.

Background	Aquaculture production					Economic loss or profit	
	($mt.ha^{-1}$) pre-COVID-19 pandemic	($mt.ha^{-1}$) during COVID-19 pandemic	Difference	Loss (% of $mt.ha^{-1}$)	*P*-value	Profit ($USD.ha^{-1}$) (pre-COVID-19 pandemic)	Loss ($USD.ha^{-1}$) (during COVID-19 pandemic)
Production before COVID-19 pandemic[a]					0.209		
Small production	1.84	1.36	0.47	25.8		2914.5	1895.8
Large production	4.94	3.44	1.49	30.2		4634.3	3177.6
Survey area[b]					0.918		
Satkhira	3.38	2.20	1.19	35.1		5971.7	4695.8
Mymensingh	5.24	3.70	1.54	29.3		2345.9	1585.2
Khulna	0.95	0.72	0.23	24.5		2927.9	1772.9
Bhola	4.52	3.50	1.02	22.7		4983.5	2493.2
Madaripur	4.22	3.04	1.19	28.1		2027.2	1227.2
Pond size[b]					0.015		
<1 ha	3.36	2.39	0.97	29.0		3493.3	2234.3
1–2 ha	3.95	2.88	1.07	27.2		5328.2	4100.7
>2 ha	3.23	2.11	1.12	34.7		3290.9	2093.0
Type of ownership[a]					0.057		
Own	3.55	2.59	0.97	27.2		2973.0	1929.1
Lease	3.32	2.04	1.28	38.5		5893.4	4652.3
Partial	3.31	2.49	0.82	24.8		4121.2	2203.1
Total	3.46	2.45	1.01	29.1		3813.0	2565.4

[a]*P* - value based on t-tests, [b]*P* - value based on ANOVA.

(less than or equal to 2 ha), which had a loss of 0.97 $mt.ha^{-1}$ ($P < 0.05$). However, the ownership type did not significantly affect the production loss during the pandemic ($P > 0.05$).

Table 4 presents the pairwise comparisons of aquaculture production before and during the COVID-19 pandemic in different regions in Bangladesh. There was a significant difference in production before and during the pandemic between areas except Satkhira vs. Mymensingh, Khulna vs. Bhola, and Khulna vs. Madaripur.

Association between the COVID-19 pandemic and different components of aquaculture

Linear regression analysis was employed to assess the effect of the COVID-19 pandemic on aquaculture production loss (Model 1) and economic loss between pre- and during COVID-19 (Model 2 in Table 5). The pandemic was found to have a greater effect on larger farms than small farms [$\beta = 0.15$, $P = 0.029$]. Furthermore, the results revealed that an increase in pond size corresponded to a higher total loss in USD during the COVID-19 pandemic ($\beta = 0.05$, $P = 0.001$). All the surveyed regions experienced higher production losses during the COVID-19 pandemic than Satkhira. Additionally, the type of farm influenced the levels of losses. Self-owned farms showed a higher loss ($\beta = 0.17$, $P = 0.023$); however, leased farms incurred even higher losses ($\beta = 0.24$, $P = 0.002$).

Constraints of aquaculture during the COVID-19 pandemic

Ten principal constraints were identified from five survey regions affecting the aquaculture industry. The most critical constraint was the lower selling price followed by higher production cost and unavailability of labourers with an RBQ value of 89.13, 64.04 and 56.36, respectively (Fig. 4A). Additionally, the lack of customers and transport facilities were also significant constraints with RBQ values of 42.7 and 30.64, respectively.

Further, investigation and analysis using RBQ revealed the causes of higher production costs were due to higher labour cost, feed, and transport costs, with RBQ values of 45.00, 36.46 and 26.18, respectively (Fig. 4B). The constraints identified in the current study are interrelated. For example, the lower selling price is related to the lack of customers. Similarly, the lack of transport and fish preservation facilities forced the sellers to sell their fish at low prices, which is responsible for further economic loss to the fish farmers.

The RBQ analysis covering the different regions showed that in Satkhira, the lower selling price had the highest RBQ value of 97.46, while in Khulna, the lack of customers was the principal constraint identified by the RBQ values of 100.00 (Table 6). Meanwhile, in Madaripur, a lack of customers and lower selling prices were the main constraints, while in Bhola, the unavailability of fish seed was the

Table 4. Pairwise comparisons of aquaculture production before and during the COVID-19 pandemic in the study areas.

Areas		Pre-COVID-19 pandemic aquaculture production	Production during the COVID-19 pandemic
I[a]	J[b]	Mean difference (I-J)[c]	Mean difference (I-J)[d]
Satkhira	Mymensingh	-0.22	-0.21
	Khulna	4.19*	2.80*
	Bhola	3.11*	1.97*
	Madaripur	3.87*	2.59*
Mymensingh	Satkhira	0.22	0.21
	Khulna	4.41*	3.00*
	Bhola	3.33*	2.18*
	Madaripur	4.10*	2.79*
Khulna	Satkhira	-4.19*	-2.80*
	Mymensingh	-4.41*	-3.00*
	Bhola	-1.08	-0.83
	Madaripur	-0.31	-0.21
Bhola	Satkhira	-3.11*	-1.97*
	Mymensingh	-3.33*	-2.18*
	Khulna	1.08	0.83
	Madaripur	0.77	0.62
Madaripur	Satkhira	-3.87*	-2.59*
	Mymensingh	-4.10*	-2.79*
	Khulna	0.31	0.21
	Bhola	-0.77	-0.62

Data were analysed using SPSS version 26.0. *P* - value was based on Bonferroni pairwise comparison. *means $P < 0.05$.
[a]'I' represent the production rate of that particular area in the column below 'I'.
[b]'J' represents the production rate of the areas below 'J'; [c]'I–J' represents the mean differences between areas in column below 'I' and below 'J' during Pre-COVID-19 pandemic; [d]'I–J' represents the mean differences between areas in column below 'I' and below 'J' during COVID-19 pandemic.

Table 5. Effects of the COVID-19 pandemic on aquaculture production and total economic loss using multiple linear regression analysis in the study regions.

Variables	Model 1: Production loss between pre and during COVID-19 pandemic		Model 2: Total economic loss (USD) during the COVID-19 pandemic	
	Standardised Beta (95 % CI)	*P*-value	Standardised Beta (95 % CI)	*P*-value
Aquaculture production before COVID-19 pandemic				
Small-scale fish production	[REF]		[REF]	
Large-scale fish production	0.15 (0.02, 0.28)	0.029	0.07 (0.28, 0.23)	<0.001
Pond size	-0.08 (-0.18, 0.02)	0.117	0.05 (0.02, -0.14)	0.001
Survey area				
Satkhira	[REF]		[REF]	
Bhola	0.17 (0.03, 0.30)	0.013	0.07 (0.30, -0.22)	0.000
Khulna	0.20 (0.04, 0.35)	0.013	0.08 (0.35, -0.29)	<0.001
Madaripur	0.11 (-0.03, 0.25)	0.110	0.07 (0.25, -0.36)	<0.001
Mymensingh	0.08 (-0.06, 0.22)	0.262	0.07 (0.22, -0.45)	<0.001
Type of farm ownership				
Partial	[REF]		[REF]	
Own	0.17 (0.02, 0.32)	0.023	0.07 (0.32, -0.03)	0.665
Lease	0.24 (0.09, 0.40)	0.002	0.08 (0.40, 0.09)	0.208
Production loss due to COVID-19 pandemic			0.00 (0.00, 0.06)	0.165
Model summary				
Mean variance inflation factor (VIF)	1.54		1.52	
Mean tolerance	0.67		0.70	
F statistics *P*-value	0.018		0.000	
R^2	0.043		0.30	
Adjusted R^2	0.025		0.28	

Standardised beta coefficients with 95 % confidence interval (CI); REF is the reference category; value 0.000 means less than 0.001.

Table 6. Area-wise rank-based quotient (RBQ) of the principal constraints of aquaculture production during the COVID-19 pandemic identified in the present study. Rank based quotient was calculated from the number of respondents who identified specific constraints in a particular region.

Principal constraints	Satkhira	Khulna	Madaripur	Bhola	Mymensingh
	RBQ values				
Lack of customer	0.00	100.00	98.41	7.00	86.75
Lack of transport facility for fish to the market	61.02	6.00	74.92	14.17	36.27
Less facility for fish preservation (lack of ice)	10.85	0.00	74.92	1.33	0.48
Lower selling price	97.46	89.10	98.41	19.00	97.59
Unavailability of medicine or other treatment	5.85	1.20	12.38	3.67	0.48
Occurrence of diseases	3.56	0.30	0.00	23.33	0.00
Unavailability of fish feed	51.02	30.00	85.71	34.50	13.01
Unavailability of fish seed	24.58	30.00	64.44	43.33	4.22
Unavailability of labour	39.66	77.60	85.71	29.33	54.94
Higher production cost	70.17	63.70	64.44	10.00	97.59

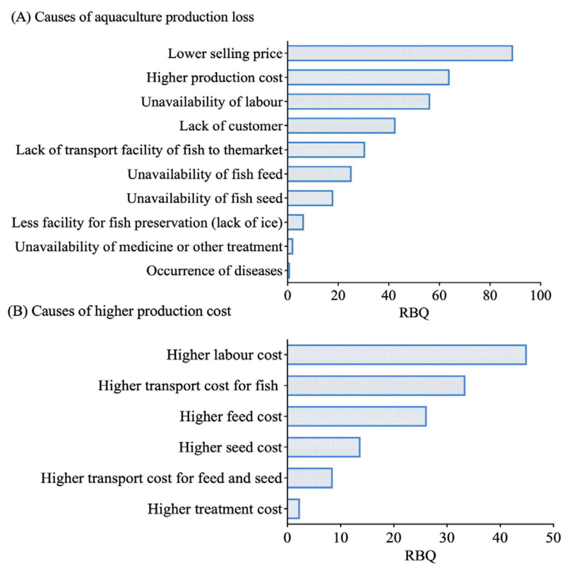

Fig. 4. Overall rank based quotient (RBQ) of the constraints experienced by the fish farmers during the COVID-19 pandemic in the survey regions; (A) causes of aquaculture production loss and (B) causes of higher production cost. The number of respondents for a particular constraint was used to calculate rank based quotient.

principal constraint. Whereas in Mymensingh, lower selling prices and higher production costs were the most significant constraints.

Government support and people's expectations

Among the fish farmers surveyed, approximately 36 % reported receiving government support, including cash in hand, foodstuffs, and loans with low or no interest (Table 7). In addition to the support they received, respondents were also asked about their expectations from the government. Most respondents (81.37 %) expressed the expectation of receiving financial assistance during the pandemic and proper distribution of money or foodstuff among the people experiencing poverty. People also expected the government to take appropriate steps to effectively control the spread of the pandemic. Furthermore, nearly 15 % of the respondents expressed their desire to avail of a bank loan at low or no interest to resume their aquaculture business.

Discussion

The present study highlights the severe impact of the COVID-19 pandemic on the culture fisheries (finfish and shellfish) in selected regions of Bangladesh. During the pandemic, aquaculture production was lower than in the pre-pandemic period, resulting in an average production loss of approximately 29.1 % in the survey regions, amounting to an average economic loss of USD2565.4 per hectare. The bigger ponds experienced higher losses compared to smaller ponds.

The effect of the COVID-19 pandemic on aquaculture was seen across all five surveyed areas. The respondents reported decreased fish prices, attributing it to factors such as reduced demand, lack of customers and inadequate storage and transport facilities. The findings concur with a previous study by Kumaran et al. (2021), which estimated a probable production loss of 40 % in the Indian shrimp industry due to the COVID-19 pandemic. Similarly, Alam et al. (2022) stated that lower demand and prices and increased inputs and transportation costs are leading obstacles affecting aquaculture production and supply chain. The observed loss in value might be attributed to the reduced production and selling prices, as highlighted by Hussain (2021), who reported a reduction in fish production in Mymensingh and Satkhira of 10 % and 33 %, respectively, due to the COVID-19 pandemic.

The present study identified the constraints faced by aquaculture production during the COVID-19 pandemic. In response to the pandemic, the Government of Bangladesh imposed a countrywide lockdown restricting public movement as well as economic activity to control the infection rate leading to restriction to public movement and economic activities, including the closure of businesses, restaurants, and education sectors (Hale et al., 2020; White and Hébert-Dufresne, 2020). The lockdown and the movement control affected the demand and supply of fish in the market (Belton et al., 2021). Zabir et al. (2021) reported a reduced purchasing power of ordinary people due to declining average income. As a result, people turned to more diversified low-cost food items, sacrificing fish consumption (Sunny et al., 2021). In addition, health safety protocols and limited fish market hours (8.00–11.00 am) created an artificial vacuum in demand, limiting buyer and seller transactions and forcing farmers to sell their products at lower prices due to panic. The reduced diversity and availability of fish and the fear of virus transmission triggered a decline in fish prices (Zabir et al., 2021). Similarly, reductions in fish prices were reported due to a decrease in fish demand in local restaurants and hotels (Minahal et al., 2020), while

Table 7. Types of support received and expectations of the beneficiaries from the government during the COVID-19 pandemic. The number of respondents was categorised based on whether they received government support, and those who received support were further categorised according to the types of support they received. The respondents were further categorised according to their expectations of the government, where a single respondent might have more than one option.

Categories	Number of respondents (n)	Per centage (%)
Received government support (n = 424)		
Yes	154	36.32
No	270	63.68
Types of support received (n = 154)		
Cash support	40	25.97
Foodstuff support	104	67.53
Loan support	10	6.49
Expectations from the government (n = 424) during the pandemic. Multiple responses were applicable		
Financial assistance for fish farmers	345	81.37
Proper distribution of financial assistance	29	6.84
Proper management to control the COVID-19 pandemic	43	10.14
Low/No interest bank loan	61	14.39
Transport facilities improvement	3	0.71
Medical support	2	0.47

declining export-led contributed to a 50 % decrease in prawn prices (Manlosa et al., 2021). To ensure the long-term sustainability of the fisheries and aquaculture sector, strategic planning involving relevant local stakeholders and locally based international agencies should be undertaken to anticipate and address further obstacles.

Moreover, the prediction of a further drop in fish prices in the market instigated panic harvesting of their small and medium-sized standing stock by fish farmers. However, the farmers overlook the inadequate access to a skilled workforce, limited customer availability, and transport facilities, which were claimed to be the main obstacles they faced. Besides, the staggered harvesting practices initiated restocking, causing a sudden surge in demand for seeds and feed, ultimately contributing to the loss of production by the farmers. The lack of workers and fewer feed and treatment facilities available during the pandemic also played a role in reduced production. As a result, the farmers were compelled to sell their produce at lower prices in what is often termed 'distress sale' (Kumaran et al., 2021). The combined reduction in demand and the collapse of fish prices during the pandemic created what is referred to as a 'twin disaster' (Bennett et al., 2020). Therefore, digital marketing, especially in areas where fish is an essential part of the diet, presents a valuable opportunity to enhance the management of fish and aqua-products demand and supply during the crisis.

Sustainable aquaculture production depends heavily on the availability of labourers, mainly migrant fish workers, at numerous supply and marketing junctures. The timing of workers' requirements is inflexible for producing perishable food items like fish. However, the countrywide lockdown and movement restrictions forced migrant fish workers to stay home, resulting in increased joblessness. Love et al. (2021) reported that the cessation of fish markets in India had rendered migrant fish workers jobless. In Bangladesh, nearly 60 % of the labourers involved in fish processing, harvesting, and marketing were unemployed due to the COVID-19 pandemic (Sunny et al., 2021). Moreover, shrimp farming in Kenya was affected due to the unavailability of migrant workers and implementing quarantine procedures severely impacted fish workforces in essential farming operations Aura et al. (2020). With the disruption of transport facilities, uncertainty, and the non-availability of labourers, the shrimp hatcheries in India had to discard the available seed stock (Kumaran et al., 2021).

The higher production costs reported by the fish farmers in the present study could be attributed to multiple reasons, including the lack of fish feed and treatment facilities. Implementing proper health safety guidelines, fear of infection, and unavailability of the workforce created an artificial vacuum in the labour market, increasing labour wages. In addition, the transportation delay and scheduled cancellations disrupted the timely supply of feed ingredients, further contributing to an increase in feed prices. Besides, access to machinery and other essential parts for the feed industry was also severely affected (Kumaran et al., 2021). Although the government recognised aquaculture inputs and services as an essential activity, the farmers or mediators were hesitant to transport fish and other food products due to the risk of unsold products due to the lack of customers.

Moreover, they faced numerous questions and obstacles from law enforcement when returning with empty vehicles (Sunny et al., 2021). The same study also reported that vehicle owners or drivers had to pay fines and face the hassle of filing cases against them. These factors collectively discourage the fish farmers or middlemen from transporting fish to cities, leaving unsold fish or selling at low prices in local markets. To address this issue, developing an interconnected communication network for fish trading throughout the country could prove beneficial during such a crisis. In addition, forming an observatory cell to address the constraints associated with fish production, export, transport, and labour would be beneficial.

The present study identified different forms of support received by the fish farmers in the survey regions. The respondents received cash support, foodstuff, and loans from the government at low or no interest, which was crucial during the lockdown. Ferrer et al. (2021) reported that the governments of Indonesia, the Philippines, Thailand, Malaysia, and Vietnam provide financial assistance to vulnerable fish farmers to overcome the economic crisis caused by the COVID-19 pandemic. The COVID-19 pandemic affected the aquatic food production system and affiliated communities worldwide. One-third of the farmers in the survey regions were found to be benefited from governmental support. Malek et al. (2021) demonstrated that about one-fourth of the vulnerable fishers of Bangladesh received governmental support at the early stage of the pandemic, with food recipients outnumbering cash support recipients. Since the fisheries sector of Bangladesh is primarily a micro-enterprise, it often lacks deficits in the economic reserve to recover the loss due to lockdown; therefore, support from the state is essential to overcome insolvencies and unemployment. In response, the Government of Bangladesh declared a stimulus package of USD 578.5 million to assist the agriculture sector in 2020. As a part of this contingency plan, three million USD (with an interest rate of 4 %) was disbursed to 1,326 fishers and farmers in the country to overcome the challenge triggered by the COVID-19 pandemic (Habib, 2020). The expectation of financial assistance and bank loans with low interest during the pandemic emerged through this assistance. The Government of India also declared similar financial assistance (USD 267 million) through the Prime Minister Fisheries Development Scheme to boost the 'Blue Revolution' initiatives and advance aquaculture production (Zabir et al., 2021). The appropriate understanding of local livelihood and community structures is crucial in selecting the beneficiary group during a crisis. The stimulation package offered by the government of Bangladesh appears to be focused and adequate for the purpose with considerations such as low or no interest with an extended-term payback facility targeting specific communities.

Conclusion

The COVID-19 pandemic, with countrywide lockdown and movement restrictions, caused a significant impact on the loss of income and aquaculture production in Bangladesh. The study revealed a reduction of approximately 29 % in aquaculture production. As a consequence of the pandemic. The fish farmers faced several challenges with lower selling prices and a lack of customers being the dominant constraints. The government provided financial and food assistance to around 36 % of the total respondents to support the affected families. However, the level of support proved insufficient, necessitating immediate, medium, and long-term measures to ensure the sector's long-term sustainability. A further detailed study is necessary to measure the severity of the constraints faced by the stakeholders due to the pandemic and identify viable options for mitigation.

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