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COVID-19's effects and adaptation strategies in fisheries and aquaculture sector: An empirical evidence from Bangladesh

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ABSTRACT

The COVID-19 pandemic has wreaked havoc on the aquaculture and fisheries sector all around the world, with the impact being exacerbated in developing countries. This study is an endeavor to identify consequences of the COVID-19 on fisheries and aquaculture sectors based on primary data collected from Bangladesh as an empirical case study. The data were collected through face-to-face interviews with different supply chain actors while analyzed using descriptive statistics and a problem confrontation index. As results depicted, income and employment across fish farmers, fishers, and traders were severely hurt, with a drastic fall in the market demand, coupled with a severe drop in their fish consumption. As market demand declined, fish farmers must be stocked mature fish for an extra period, and feed costs raised, eventually increasing the overall production cost. Besides, inaccessibility to inputs also made fish production and catch more troublesome. The price of all the major cultured and captured species plunged, leading to a depressing return to farmers, while inputs price underwent a significant increase except for labor and fingerling. However, traders seemed to be the worst sufferers amid striking disruption in fish value chain, which ostracized the preponderance of the traders from the chain. Some of the prime obstacles that constrained the production and trading process were but not limited to higher transportation costs, labor shortage, inability to pay for the wage, and reduced consumer demand across fish farmers, fishers, and traders. Nevertheless, our article further identified a myriad of strategies that the fish farmers, fishers, and traders followed to heal the scar of the fisheries and aquaculture sector with hands-on actions.

1. Introduction

Globally COVID-19 pandemic has been identified as an economic threat to both developed and developing economies, which is even more in underdeveloped economies (Erokhin and Gao, 2020; Hossain et al., 2021). It is because of its impacts on livelihood, employment, buying and consumption behavior, food and nutritional security. Empirical evidences have shown that it has caused decline in major macro-economic indicators across the globe because of the measures undertaken controlling spread of the virus (Erokhin and Gao, 2020; White et al., 2021; Shah et al., 2020 and Azra et al., 2021; Béné et al., 2021).

Fisheries and aquaculture are no exception and thus, has been greatly affected by the pandemic because of its interconnectedness with other sectors of the economy. However, the stability of the sector is crucial to the global food and nutritional security, and livelihood of

millions, mostly in developing countries where the sector plays an important role contributing to employment, economic empowerment, and improving diet quality of the vulnerable people. Globally fisheries and aquaculture has achieved all time highest production (179 million tonnes) before pandemic i.e., in 2018 with major contribution from aquaculture (FAO, 2021). As a result, fish intake as a primary source of protein among the poorest people has increased dramatically in recent decades (FAO, 2021).

However, COVID-19 pandemic has brought about real sufferings for the people engaged in fish supply chain ranging from fishing or aquaculture production to wholesale or retailing. It is because each of the fish supply chain activities is critical to the success of the chain and is susceptible being disrupted by the COVID-19 containment measures undertaken affecting the livelihoods and food nutrition. Among the agricultural sub-sector, the pandemic hurts the fisheries sector most

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through shifting consumers' demand, border restrictions, transportation problems, which, in turn, devastates the income and livelihood of fish farmers, fishers, and all the people engaged in the aquaculture and fisheries sector (FAO, 2020).

Nevertheless, among all actors, fish farmers were the most affected by the COVID-19 preventive measures since they are unable to trade their large volumes of fish due to a lack of traders from distant markets, the closure of *arat* (local auction site), transit movement restrictions, and other factors. Consequently, they had to stock mature fish for a longer length of time and subsequently increase feed cost and other production costs (FAO, 2021). On the other hand, fishers are unable to roam to capture fish during the COVID-19 enforced movement restriction, resulting in a severe loss of their income. Besides, fishers had almost nothing to do during the ban period, making them more vulnerable to the COVID-19 pandemic due to a lack of alternative sources of income (Sunny et al., 2021). The pandemic further limited the fish farmers, and fishers' access to credit, commercial inputs and markets (Sunny et al., 2021).

Despite the fact that the COVID-19 did not directly impair aquaculture and fisheries production, the task of guaranteeing uninterrupted aquatic food production and supply, fair prices for products, and healthy food for all have been elevated as a result of the global pandemic (Sunny et al., 2021). Several pieces of research have been conducted around the world to quantify the influence of COVID-19 on aquaculture and fisheries (Waiho et al., 2020; van Senten et al., 2020; Manlosa et al., 2021; Azra et al., 2021; Jamwal and Phulia, 2021; van Senten et al., 2021; Love et al., 2021), and the summary of the previous findings are presented in Table A1. According to these research, the pandemic increased transportation expenses, production costs, food inflation, and reduced demand for fish and fisheries products in many developing nations.

Fish farming has grown dramatically in Bangladesh in recent decades because of the commercialization of aquaculture farms (Khan et al., 2018; Mitra et al., 2020; Mitra et al., 2019). Around 17 million people rely on the fishing, farming, fish handling, and processing industries for livelihood (BFTI, 2016). With such a large labor force involvement and contribution to economy, the COVID-19's effects on the fisheries and aquaculture sectors of Bangladesh is undeniable. Studies on impact of COVID 19 on aquaculture and fisheries in Bangladesh pointed that, the pandemic has negatively influenced livelihood assets and activities of those who rely on fishing while a positive effect has been on the ecosystem and the wild fish stock (Islam et al., 2021). Furthermore, reduced income, difficulties in starting a new production season, inputs collection, labor shortages, transportation abstraction, low consumer demand, and creditor's pressure were identified as the main drivers affecting aquaculture (Hoque et al., 2021; Sunny et al., 2021; Hasan et al., 2021).

Although a few empirical studies conducted in Bangladesh, there is scarce information on (i) changes in capture and culture fish prices due to pandemic; (ii) changes in fisheries-related activities and income of fish farmers, fishers, and fish traders due to COVID-19; (iii) changes in fish supply chain and value chain activates because of the pandemic; (iv) challenges faced by the fishers, fish farmers, and traders due to COVID-19 in input and output market; and (v) strategies followed to overcome the challenges. Therefore, this study aims at producing information that may instrumental in designing action plan for facing pandemic induced future challenges both at functional level and at policy level. In light of these considerations, the current research was conducted considering the impact of COVID-19-related preventive actions and their cascading effect on the aquaculture and fisheries in Bangladesh from all the stakeholder's points of view. This research aims to provide recommendations for interventions that could aid in the development of mitigation measures and policy responses for the sustainable aquaculture farming and fishing in Bangladesh and other countries with similar socio-economic background.

The rests of the paper are structured as follows: Section 2 describes materials and methods of data analysis. Third section describes results

and provides discussion on results. Fourth section concludes the paper with policy implication.

2. Materials and methods

2.1. Study areas and sample

For this study, we selected three types of respondents, i.e., fish farmers, fishers, and fish traders, to present a better substantiated and nationwide overview of fisheries and aquaculture actors. Responses were obtained from 350 respondents hailing from five districts of Bangladesh, namely Mymensingh, Rajshahi, Rangpur, Khulna, and Barishal (Fig. 1). Two hundred (200) fish farmer's data were collected from the first three districts mentioned above because of extensive fish farming in these areas. In contrast, 100 fisher's data were collected from Barishal and Khulna due to prevalent capture fisheries in this district. In addition, 50 fish trader's data were gathered from all the selected five districts. These districts were selected based on the production volume, fish farming intensity, and availability of fish farmers, fishers, and traders. Since convenient sampling is one of the most common non-probability sampling techniques (Paul et al., 2021), the sample size of this study was determined using this method.

2.2. Survey instrument and data collection

This research was carried out using primary data by employing individual interviews. Data were collected through an interview schedule, which was designed according to the objectives of the study. The interview schedule was developed in English, but local language was used when enumerators contacted the respondents.

This interview schedule had both qualitative and quantitative questions with detailed narrative and probable numeric outcomes. The interview schedule was divided into five sections. Section A was designed to gather information regarding the changes in the respondent's fish farming and fishing practice, i.e., self and hired labor involvement, income, farming operations, fish sale and purchase information, fish consumption, etc. Section B was about the changes in the different input accessibility, inputs, and output price during the pandemic period. Questions of Section C dealt with the major issues of COVID-19 on the respondent's aquaculture and fisheries activities, such as input accumulation and fish sales. Section D aimed to collect information on the disruption of supply chain and value chain activities during the pandemic period. Section E represented the questions regarding the challenges faced by the fish farmers, fishers, and traders due to COVID-19 and the strategies followed in handling the market force disruption.

The interview schedule was pre-tested by interviewing ten respondents for validation and for necessary modification of the questions. The data were collected following the direct interviewing method. The survey covered the period of April to May, 2021, when the impact of COVID-19 was severe in Bangladesh in the terms of infection and death rates. Besides, we conducted a six key informant interviews (KIIs) and five focus group discussions (FGDs) to acquire a better understanding of the impacts of COVID-19 and related policies on the fisheries and aquaculture sectors.

2.3. Data analysis

Quantitative data are scrutinized using descriptive statistics in the form of frequencies and percentages. Besides, the Problem Confrontation Index (PCI), a mathematically problem ranking index employed to rank the problems associated with inputs supply and fish sale of the fish farmers, fishers, and fish traders. The fish farmers were asked about five specific input supply and fish selling problems identified through FGDs. Besides, four selected input supply and fish sale problems were given to respond for fishers. In addition, the traders were instructed to respond to

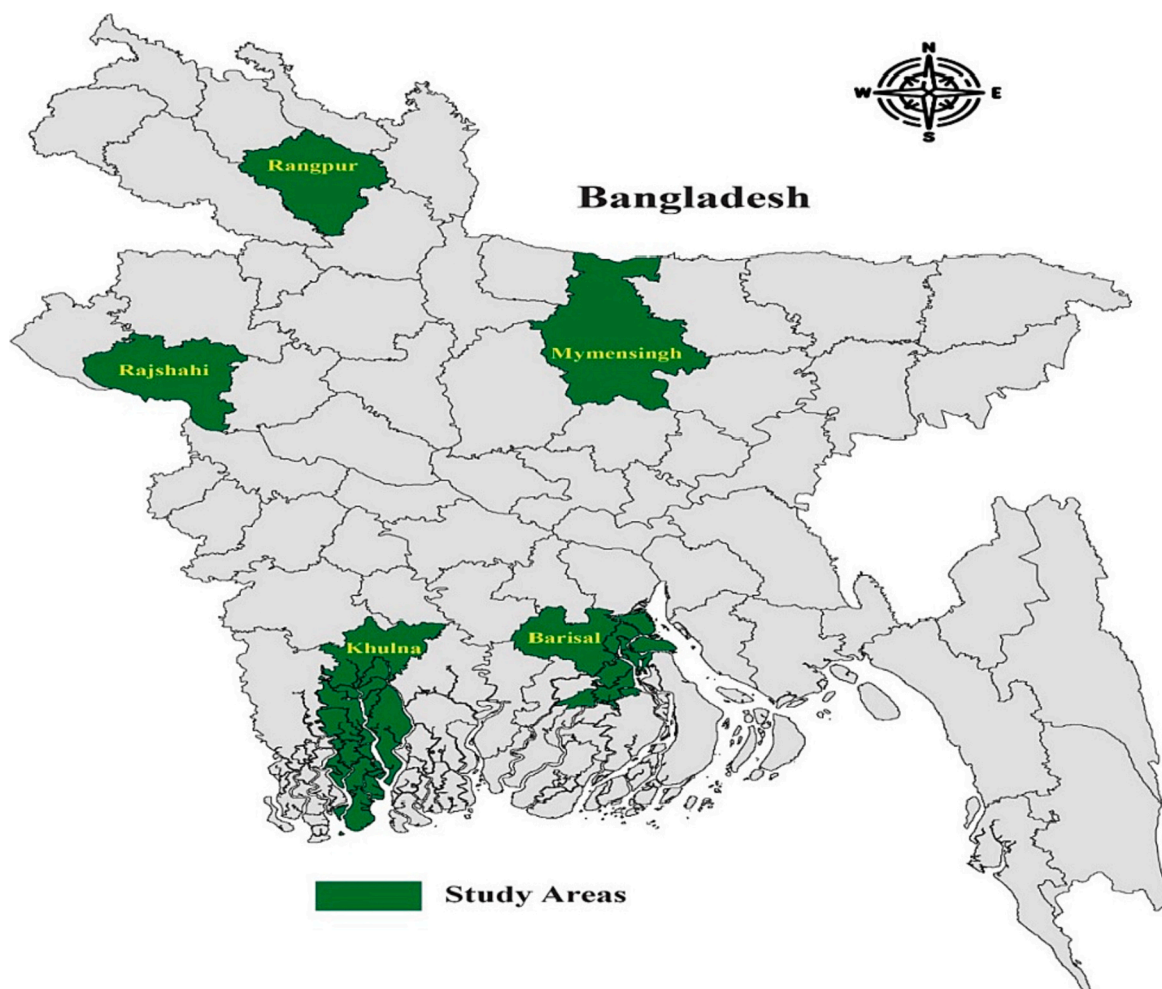


Fig. 1. Map showing the study areas.

four specific input supply and seven fish sale problems. The problem score of a respondent was calculated using a three-point rating scale. Each respondent was asked to rate the difficulty of each problem by checking one of three options: 'High', 'Medium', and 'Low,' with weights of 3, 2, and 1 assigned to each option, respectively. Thus, the problem confrontation score is calculated for each actor of the chain, i. e., fish farmers, fishers, and traders, by multiplying the weights of the problem responses. The problems are ranked based on corresponding PCI scores. The PCI is computed by using the following formula:

$$PCI = (Ph \times 3) + (Pm \times 2) + (Pl \times 1) \quad (1)$$

where Ph = Total number of respondents expressed problem as high; Pm = Total respondents of farmers expressed problem as medium; Pl = Total number of respondents expressed problem as low.

3. Results and discussion

3.1. Effects on income, employment, and farm operations

This research gives a socio-demographic summary of selected respondents before going deeper into the impact of COVID-19 on Bangladesh's aquaculture and fisheries sector. Table 1 illustrates the demographic characteristics of the selected respondents. As shown, more than half of the sampled fish farmers were completed their secondary education, while only 5.5% of them were turned out to be illiterate and 30.1% achieved a higher degree than secondary. In contrast, more than half of the fishers respondent completed their primary

Table 1
Demographic features of the surveyed respondents.

Particulars	Level	Fish farmers	Fishers	Fish traders
		Value (%)	Value (%)	Value (%)
Education	Illiterate	5.5	7.9	20.15
	Up to primary	11.15	51.55	23.35
	Up to secondary	53.25	35.85	53.75
	Beyond secondary	30.1	4.7	2.75
Age (years) ^a	18–36	21.25	34.35	32.75
	37–51	45	53	11.75
	Above 51	33.75	12.65	55.5
Family size	≤4 members	25.5	15.5	22.75
	5–7 members	45.75	65.25	50.5
	≥7 members	28.75	19.25	26.75
Experience (years)	Up to 10	16	22.5	27.5
	11 to 15	28	38.75	15.8
	16 to 20	16	19.55	12.5
	Above 20	40	19.2	44.2
Fish farming/fishing/trading as a primary occupation		88.5	81.75	92.5

^a Age is categorized as Young = 18–36 years, Middle-aged = 37–51 years, and Old-aged = >51 years according to the National Youth Policy of Bangladesh (2017).

education, while 53.75% of sampled fish traders had an education level up to primary school. Regarding the age of respondents, while most of the fish farmers and fishers were in the middle age, more than half of the fish traders were belong to the old age category. In terms of family size, the preponderance of the participants across all three types i.e., fish farmers, fisher, fish traders falls into the category of 5 to 7 members in a family that is medium size family. Alongside, fish farmers seemed to obtain a great deal of experience in farming as 40% of the participants reported holding a farming experience beyond 20 years. Similarly, approximately 45% of the sampled fish traders reported holding more the 20 years of involvement in fish trading business. However, approximately 4 out of 10 sampled fishers hold 11–15 years of fishing experience. While being interrogated about the fish farming or fishing or fish trading as a primary occupation, 88.5% of fish farmers claimed fish farming as their main occupation while it was 81.75% for fishers and 92.5% for fish traders.

People who work in the fisheries and aquaculture sector depend primarily on income from it to support their families. However, the COVID-19 greatly impacted their earning; it is observed that fish farmers' and traders' income from fisheries fell by nearly half, while fisher's income dropped by 32.80% on average (Table 2). When social distancing restrictions first came into effect, the operations of many farms and enterprises were forced to close completely. Even social distancing measures have prevented many small-scale fishers from going fishing because of dealing in close contact at local marketplaces (Sunny et al., 2021). Consequently, the income of fish farmers, fishers, traders is seriously impacted due to COVID-19 protective measures. Kumaran et al. (2021) came to similar conclusions for the Indian shrimp sector, emphasizing the relevance of employment and income loss due to the COVID-19 pandemic.

The findings of fishers' dropping income of this study align even with the study of Alaska's Salmon (Salmon State, 2020), which indicated that approximately 45% of survey fishers stated that their income has dropped by >20% during the pandemic. However, fish farming and fisheries-related operations in developing countries are labor-intensive, relying on hired labor largely along with self-employment (Hossain et al., 2022a, 2022b). Fish farmers, fishers, and traders in Bangladesh reduced the number of workers employed, notably around the time of the COVID-19 outbreak, due to constrained production and enterprise-related activities. Comparing fish farmers and fishers, results revealed that fish traders cut the most employees, with labor hiring dropped by 60.55% (Table 2). Similar findings were observed by van Senten et al. (2020), unveiling that 84% of aquaculture enterprises in the United States lost sales, resulting in substantial revenue reductions and job losses. Since the beginning of the crisis, self-employment in aquaculture and fisheries enterprise reduced by more than half for fishers, while the fish traders were most severely affected (Table 2). Results revealed that the self-employment of fish traders was reduced by almost 80% since

Table 2

COVID-19 effects on income, employment, and trading activities of fish farmers, fishers, and traders.

Particulars	Change (%)		
	Fish farmers	Fishers	Traders
Income from fisheries	-42.75	-32.80	-49.75
Self-employment	+28.5	-55.75	-78.25
Hired labor	-35.69	-55.90	-60.55
Household fish consumption	-15.55	-22.66	-27.78
Frequency of transport use	-30.35	-39.40	-70.55
Market demand (no. of customers/traders)	-42.75	-58.00	-72.54
Average amount of fish trade (buy and sell)	-63.55	-33.60	-70.30
Amount of unsold fish	+40.00 ^a	+19.50 ^b	+12.00

Note: "+" sign indicates positive change (increase), while "-" sign denotes negative change (decrease).

^a change in the amount of unsold mature fish,

^b change in unsold catch fish.

there were less fish trading activities with fewer buyers and sellers to deal with due to lockdown and other movement restrictions.

On the other hand, fish farmers raised their self-involvement with the farms by 28.5% because they have a minimum job outside of the farms and spend more time at home. As a result, they devoted most of their time to the fish farms, which they invested in other activities during normal times. Since revenue and employment have plummeted, all actors in the aquaculture and fisheries sectors have lowered their fish consumption, with traders' households being the hardest hit (27.78%), followed by fishers (22.66%). Similar findings reported in Hossain et al. (2022a, 2022b) that the financial loss forced to restrict the fish consumption of fishers. In the long run, this could result in widespread malnutrition, particularly among women and children (Fiorella et al., 2021) particularly in developing countries like Bangladesh.

However, low-income consumers, for whom fish serve as an indispensable source of micronutrients, also suffered from diminished intakes of this vital nutritious food due to depressed income (Mandal et al., 2021). Consequently, market demand for fish plummeted by 42.75%, 58%, and 72.54% for fish farmers, fishers, and traders, respectively (Table 2). Lower market demand not only reduced the amount of fish sold but also lowered the amount of transportation used. Nevertheless, lower demand also restricted the fish trading activities, and it fostered the amount of unsold fish in the market since there are fewer numbers of buyers of fish.

During the pandemic, fish producers in Bangladesh like other countries have to stocked mature fish in their ponds for a longer period, expecting to sell them at a higher price once the market demand returned to normal (FAO, 2021). Fishers and traders, on the other hand, used ice to keep unsold fish frozen until they could be sold later. Results revealed that approximately seven out of ten selected farmers could not sell fish and hence, stocked mature fish in their pond (Table 3). Sunny et al. (2021) found similar findings; more than half of fish farmers could not sell mature fish due to transportation challenges and poor market demand. Furthermore, farmers were also unable to begin a new farming cycle due to the unsold mature fish. In contrast, 17.60% of surveyed fishers and 14.64% of traders utilized ice to keep fish fresh until they were sold.

Farmers held mature fish in their ponds for an average of 118 days, whereas fishers retained 3 days and traders stored fish for 14 days using ice (Table 3). Fish farmers can reduce costs by feeding at maintenance rates rather than growth rates, but some feed is still required to keep the fish alive. Fish producers, fishers, and traders had to pay more for extra feed and ice in order to stock and preserve fish for a longer time. It was observed that fish farmers applied 29.80% of more feed than usual, while the fishers and traders used 5.5% and 7.95% of more ice, respectively (Table 3). For fish farmers, the total cost of per kg fish

Table 3

Information of mature fish stocking in pond during COVID-19.

Particulars	Fish farmers	Fishers	Traders
Mature fish stocking in pond or icing of fish after harvest during COVID-19 (% of respondents)	68.44	17.60	14.64
Mature fish stocking in pond or icing of fish after harvest during COVID-19 (no. of days)	118	3	14
Quantity of feed/ice application increased for further stocking of mature fish or icing of fish after harvest (%)	29.80	5.5	7.95
Feed/ice cost increased for further stocking/icing of mature fish (%)	21.62	6.05	7.55
Change in others cost* (%)	11.01	1.65	3.35
Cost increase per kg of fish production/sell for further stocking/icing (%)	32.63	7.70	10.9

Note: Mature fish stocking strategy used by fish farmers while the fishers and traders used ice for preserving the fish.

* Other cost includes inputs those are required for farm operation except feed/ice.

production increased by 32.63%, in which feed costs increased by nearly two-thirds. However, the change in cost was lower for fishers (7.70%) and traders (10.9%) compared to the fish farmers. This is because they were prompted to sell fish immediately rather than preserving it for a long time, since preserving fish for a long time might degrade the quality of the fish, resulting in a lower price.

3.2. Effects on input and output price

Major findings regarding availability to various farm inputs, as well as variations in input and output prices over the pandemic era, are highlighted in this section. To investigate the change in inputs price, we focused on the major inputs for an aquaculture and fisheries enterprise and asked respondents how much inputs price was changed compared to the usual situation. We focus on the farmed price of fish to investigate the output price change.

3.2.1. Access to different farm inputs

Due to the lockdown and economic slowdown, the fisheries and aquaculture sector may have struggled to maintain its activity or planned production cycles (van Senten et al., 2020), as it was not only unable to find adequate markets for fish but also access to various inputs (e.g., fingerlings, feeds, labor, boat, fishing gear, etc.) were also halted or significantly reduced (Zhang, 2020). Besides, fish farming and fishing were becoming more difficult due to sanitary measures (physical distance, wearing facial masks, etc.) and a lack of necessary inputs, which could halt operations. Under this circumstance, this study also investigated whether fish farmers, fishers, and traders had adequate access to various farm operation inputs (Fig. 2).

Results revealed that approximately one-fourth of surveyed fishers did not have adequate access to fishing boats, whereas only 8% reported the ejection of fishing gear during the pandemic. Moreover, roughly four out of ten farmers did not have adequate access to fish feed because feed companies and dealers did not provide adequate feed due to transport movement restrictions. In addition, feed manufacturers lacked feed ingredients and manpower, which impeded their production. Labor unavailability also increased as 61% of respondents reported it. In the short term, it could be due to confinement measures; in the medium to long term, it could be due to financial or cash flow issues faced by farmers or travel barriers for seasonal or migrant workers during the pandemic

(Belton et al., 2021). The lack of input supplies (e.g., fingerling, ice, gear, and boats) during COVID-19 happened due to suppliers closing or being unable to offer inputs on a credit basis. Another issue was financial access, with 88% of respondents claiming that they did not have enough credit throughout the pandemic although Bangladesh's government has devised a BDT 5000 crore refinancing program to enhance farmers' financial inclusion during COVID-19 (Fig. 2). This could be due to both supply and demand-side issues: on the credit supply side, credit providers were hesitant to extend credit because aquaculture and fisheries clients are hit by the crisis and may be unable to pay on time (FAO, 2021). Clients are also cautious about taking credit because of the additional costs incurred due to the absence of earnings during the pandemic, and they are concerned about how they will repay the credit. Furthermore, due to a variety of circumstances such as bureaucratic complexity, failure to submit required documentation, and limited engagement of local representatives, all farmers may not have access to the government special scheme. However, during the pandemic, it was stated that 83% of responders did not receive any extension support. Due to the government's stay-at-home order, all extension services provided by the government, non-government organizations, and feed companies were completely shut down or reduced substantially.

3.2.2. Change in inputs price during COVID-19

Feed, fingerling, labor, ice, fishing gear, fertilizer, medicine, etc., are among the most prevalent farm inputs. However, the pandemic has a considerable impact on the price of these inputs, causing some to rise and others to fall in price (Fig. 3). Results revealed that commercial pelleted feed price increased by one-fourth of than regular price. Commercial pelleted feeds are made from a range of raw materials by feed mills, and most of the raw materials are imported from other countries. Feed mills were unable to acquire these raw supplies due to the closure of the border during the lockdown, resulting in an upsurge in feed price. According to Belton et al. (2021), feed prices climbed by 20% from February to August 2020. This price change might also be reflected from the higher transportation cost due to the movement restriction order imposed by the government. The survey respondents noted that the transportation cost increased by 32.95% compared to business as usual. This inference is backed up by the study of Belton et al. (2021), who pointed out that transportation expenses in Bangladesh jumped by 30% during the lockdown, even it remained 10% higher compared to 2019

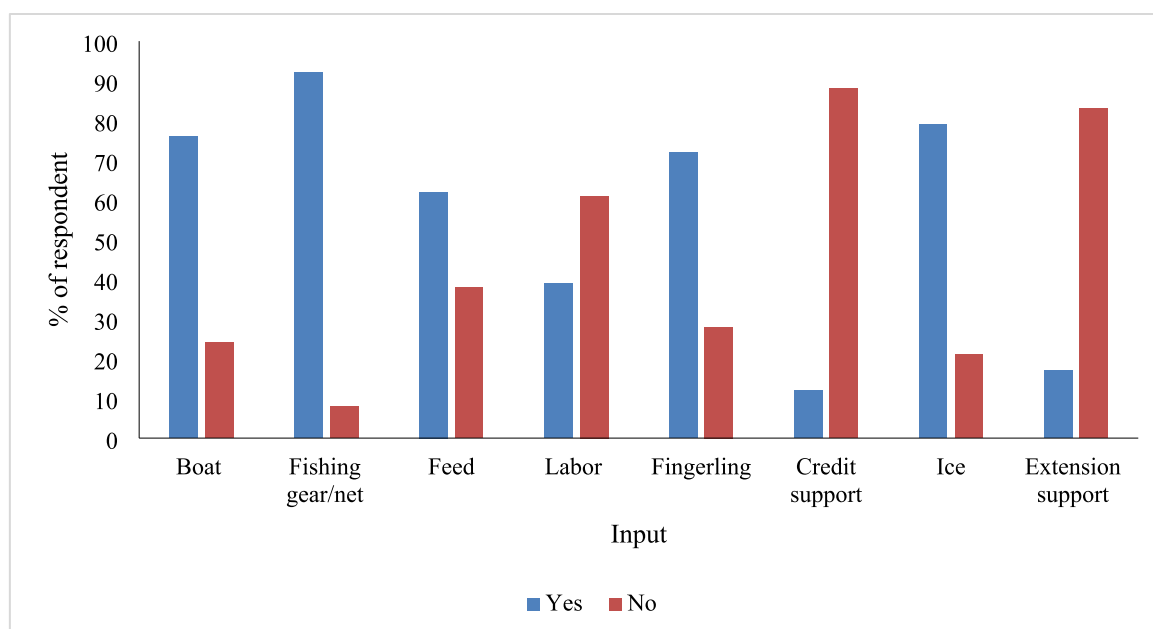


Fig. 2. Percentage of respondents having adequate access to different farm inputs during COVID-19.

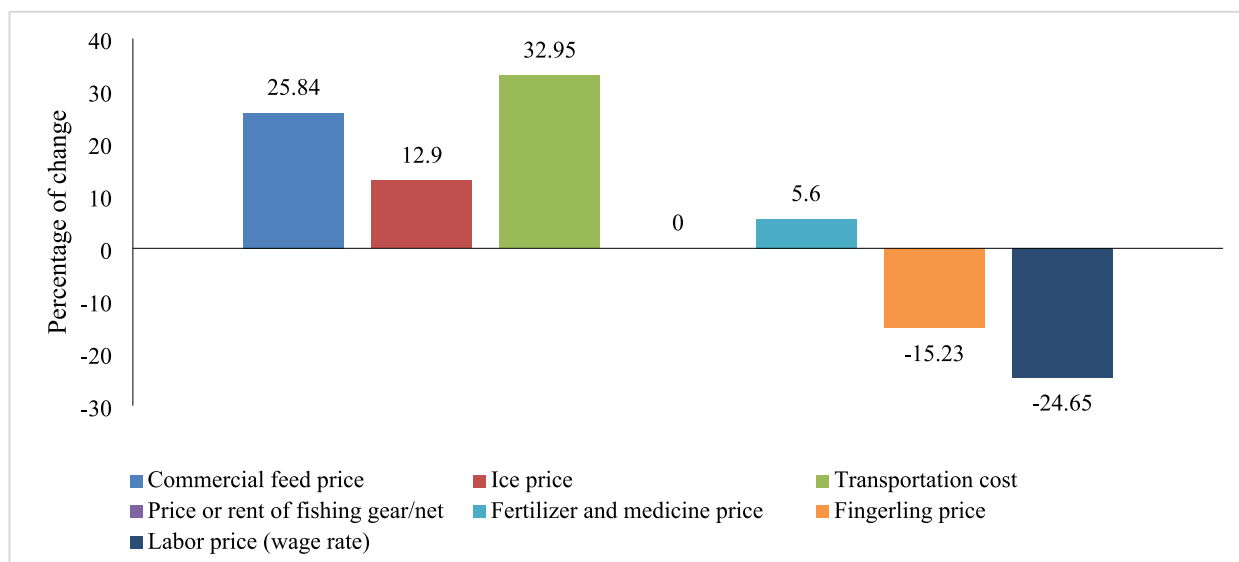


Fig. 3. Changes in inputs price during COVID-19. Note: Positive value indicates the higher price, while negative value denotes lower price during COVID-19.

following the easing of movement regulations. However, only minor price variations were reported for ice, and fertilizer, and medicine, and no price changes were observed for fishing gear or nets (Fig. 3). A substantial price reduction was observed for fingerling (15.23%) and labor (24.65%). Demand for fingerling has dropped considerably as a result of farmers' uncertainty and incapacity to empty their ponds. Further, some hatcheries lack separate nursing and grow-out ponds and are unable to store seed for a longer time, necessitating constant sales. Since hatcheries and nurseries are experiencing a liquidity issue due to a lack of sales, systems for delivering fry and fingerling on credit to farmers are no longer possible; thus, the price of fingerlings has dropped dramatically. Higher input prices coupled with falling earnings would have increasingly squeezed the fishing and fish farming production activities (Sunny et al., 2021; Belton et al., 2021). Reductions in farming and fishing operations also lowered worker demand, resulting in a lower wage rate.

3.2.3. Changes in fish price during COVID-19

As previously stated, market demand for fish has plummeted as a result of the pandemic; therefore, it affected the price of fish because demand and price are inextricably related (Belton et al., 2021). The closure of hotels and restaurants, as well as the restriction of public meetings and large gatherings such as wedding ceremonies, aggravated by the closing of tourist borders, resulted in lower demand for farmed fish and consequently a price drop.

In this study, we compared two scenarios, i.e., pandemic and regular situation, to explore how farm-gate fish prices changed. The sources of fish were divided into two categories, i.e., culture and capture. Low-value cultured fish species, such as pangas, mrigal, common carp, grass carp, tilapia, and silver carp, saw the most substantial price decline among cultured species (Table 4). The surveyed fish farmers stated that the price of pangas fish was cut by 40% during the pandemic period which is significant at 1% level. The price of tilapia was reduced by one-fourth than the regular situation which was significant at 10% level. Low-valued fish species, especially pangasius and tilapia, are largely consumed by poor inhabitants from rural and urban areas. At the start of the crisis, millions of workers returned to their hometowns from the big cities, resulting in a decline in demand. Outside of major cities, demand for these fish has fallen as a result of squeezed income, reduced hours of operation in wet markets, and limited customer movement due to lockdown restrictions; subsequently, fish prices have decreased (FAO, 2020). Similarly, low-value captured fish species had a greater price

Table 4

Changes in fish price during COVID-19 (USD/kg).

Fish species	Fish price (pre-COVID)	Fish price (During COVID)	Mean change (%)	t-value
Culture				
Rui (<i>Labeo rohita</i>)	2.71	2.29	-15.56	0.84
Catla (<i>Catla catla</i>)	2.23	1.81	-18.92	1.01
Silver Carp (<i>Hypophthalmichthys molitrix</i>)	1.81	1.33	-26.67	1.98 ^c
Common Carp (<i>Cyprinus carpio</i>)	1.81	1.20	-33.33	2.11 ^b
Mrigal (<i>Cirrhinus cirrhosis</i>)	1.69	1.20	-28.57	1.97 ^c
Tilapia (<i>Oreochromis mossambicus</i>)	1.45	1.08	-25.00	1.84 ^c
Pangas (<i>Pangasius hypophthalmus</i>)	1.51	0.90	-40.00	2.61 ^a
Grass Carp (<i>Ctenopharyngodon idella</i>)	1.81	1.20	-33.33	2.12 ^b
Prawn/ Golda (<i>Macrobrachium rosenbergii</i>)	8.43	7.23	-14.29	0.72
Capture				
Hilsha (<i>Tenualosa ilisha</i>)	9.04	8.13	-10.00	0.66
Shrimp/Bagda (<i>Penaeus monodon</i>)	6.02	5.42	-10.00	0.65
Tengra (<i>Batasio batasio</i>)	1.45	0.84	-41.67	2.64 ^a
Rida (<i>Rita rita</i>)	3.61	3.61	-0.00	0.02
Mola punti (<i>Puntius guganio</i>)	1.45	0.96	-33.33	2.11 ^b
Baila (<i>Awaous guamensis</i>)	4.82	3.61	-25.00	1.82 ^c
Shol (<i>Channa striata</i>)	4.82	3.01	-37.50	2.09 ^b
Taki (<i>Channa punctate</i>)	1.45	0.96	-33.33	1.97 ^c
Ayre (<i>Bagarius bagarius</i>)	7.23	6.02	-16.67	0.92
Bata (<i>Labeo bata</i>)	1.20	0.96	-20.00	1.23
Boal (<i>Wallago attu</i>)	3.61	3.01	-16.67	0.91

Notes: "-" sing indicates negative change (reduction) of fish price during the pandemic period. ^a, ^b and ^c indicates the significance at 1%, 5% and 10% level, respectively.

decline. Tengra, mola punti, shol, baila and taki experienced the significant price drops among the capture species, whereas high-value captured species like hilsha and shrimp had the lowest price drops

(Table 4). Normally, high-value fish species are purchased by higher-income consumers, however during the pandemic, their income may be reduced, but their consumption habits may not change significantly. As a result, these species' price reductions were lower. However, changes in fish prices would have an impact on overall fishing and fish farming livelihoods (Fiorella et al., 2021), as it is their primary source of income.

3.3. Change in the fish supply chain due to COVID-19

Fishing, aquaculture production, inputs accumulation, retail marketing, processing, and export distribution are all important operations in a fisheries or aquaculture supply chain. Each of these operations is equally important to make an effective supply chain. Each stage of the supply chain is susceptible to being disrupted by impacts of COVID-19 and related protective measures. Fig. 4 depicts the fish supply chain prior to and during the COVID-19 pandemic. The figure shows how the pandemic impacted the fish supply chain, which eventually became shorter due to limited market intermediary engagement.

The backward linkage actors (input suppliers) play a crucial role in stimulating fish production and fishing in the country. In backward linkage, fish farmers are linked with feed and medicine suppliers, credit providers, fingerling and fry providers, whereas fishers get support from fishing equipment such as boats, gear, rope, machines, ice providers. The main intermediaries in the forward linkage were *bepari* (buy from farmers and sell commission agents, export agents, and retailer), commission agents (act as wholesalers in big or wholesale markets with permanent staffs and establishments), processors (who process fish and

sell to exporters), exporters (who usually sell fish to overseas markets), and retail (sell directly to the consumers). Since commission agents handled the majority of the transactions, they are the most important market actors in the fish supply chain.

Due to movement restrictions during the COVID-19 pandemic, traders (*bepari* and others) were unable to access production locations and *arat* (local auction place). On the other hand, most of the *arats* were closed or having limited operation with defined time bound during the pandemic. Due to the lockdown, only a small number of local *beparies* were available to local markets but were unable to transport fish to distant urban and overseas markets through export agents. In addition, processing plants and exporters found themselves in a difficult situation when it came to processing and exporting fish. As a result, fish farmers and fishermen have been obliged to sell their fish directly to consumers or through retailers in local marketplaces. Thus, the supply chain became shorter than it was in regular situation. Sometimes, small fish farmers and fishers took orders over mobile phones from consumers and delivered fish to consumers at their doorstep. On the bright side of the pandemic, new distribution channels, such as e-commerce and home delivery, have been explored, likely to benefit customers. Alam and Khatun (2021) found a similar level of disruption in the vegetable supply chain of Bangladesh.

3.4. Disruption of value chain activities

Researchers' field visits, discussions with various value chain shareholders, and data provided by different secondary sources such as news,

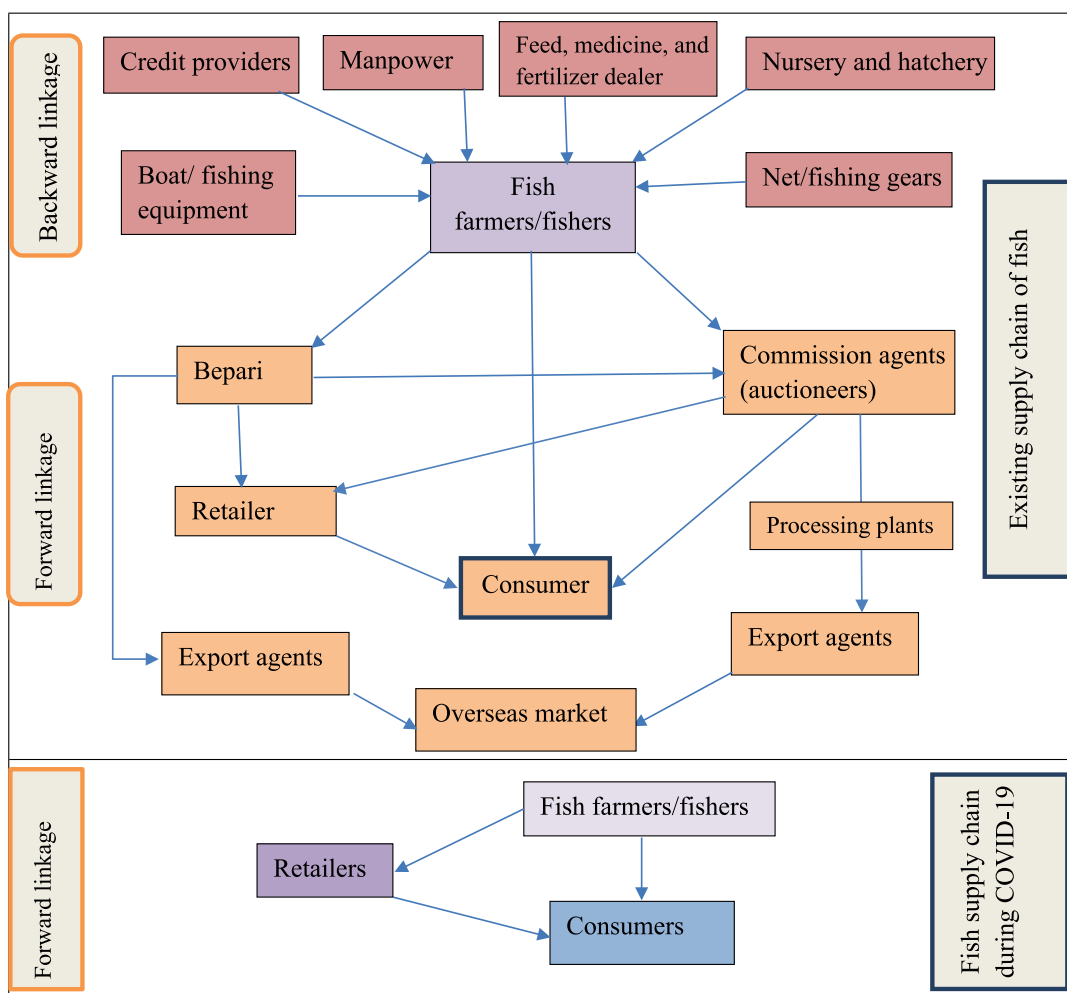


Fig. 4. Disruption of fish supply chain due to COVID-19.

reports of government and development partners present an emerging picture of fish value chain disruptions in Bangladesh due to COVID-19 (Fig. 5). These disruptions had a wide range of effects from the producers' to the consumers stage. In several circumstances, multiple stages of a value chain were disrupted at the same time. During the pandemic, labor and skilled manpower scarcity substantially hampered fish production activities, resulting in lower productivity and economic loss for value chain stakeholders. Due to low income and capital shortage, many fish processing plants were temporarily or permanently shuttered. Besides, workers' demands for better health and safety conditions may also cause processing activities to be disrupted. Numerous fish processing plants in many countries similar to Bangladesh have closed or reduced their operations owing to COVID-19 infection among workers (Xuemin, 2020). As a result, processing capacity and production are reduced, putting processors' economic well-being and food security at risk. Some proactive fish processors, on the other hand, have reacted by implementing tight safeguards, such as physical separation of workers and temperature checks.

COVID-19 induced mobility restrictions to have an impact on the transportation logistics of fisheries and the aquaculture value chain. Several factors disrupted import and export transportation logistics, including travel bans, border controls, and stringent import and export activity. Owing to lockdown measures, several transportation enterprises related to the fisheries and aquaculture sector have curtailed, stopped, or totally shut down operations, potentially adding to food insecurity and obesity. This interruption has a significant impact on the worldwide free movement of fish items and food security issues. Therefore, FAO, WTO, and WHO have recommended the avoidance of disruptive border restriction measures on food trade to ensure that global trade flows remain as unfettered as possible (WTO, 2020). However, COVID-19 protective norms also disrupted the domestic and global market of fish by reducing the number of customers and lowering market demand; hence the disruption occurred at the retail level to sell fish.

The COVID-19 is expected to cause roughly 13% of Bangladeshi

people to lose their jobs as a result of the pandemic (The Financial Express, 2021a), and the unemployment rate is expected to rise by 1.1% to 5.3% in 2020, owing primarily to the pandemic (The Financial Express, 2021b). A decrease in household income means a decrease in purchasing power (Stanciu and Mihăilescu, 2014). Because of the pause in income and change in consumer purchasing patterns, the implementation of MCO might have serious implications on domestic demand for fish and value chain operations (Waiho et al., 2020). Due to consumers' lower purchasing power, fish may not be deemed a cheaper protein alternative. Thus, it affects the working ability of production activities and eventually reduces productivity and income well-being. The findings align with the study of Hivrvonen et al. (2020), who found that the public health interventions in low-income countries, reduced household earnings, which, might lead to malnutrition and reduced productivity because of lower expenditures on nutrient-dense foods.

3.5. Major problems of input supply and fish sale during COVID-19

Fishing and fish farming businesses are complex and face multiple issues related to COVID-19 restrictions. The studied fish farmers, fishers, and traders digested immense shocks in availing proper input supply (Table 5). Due to the international shipping ban and transportation barriers, the fish farmers found it the most troublesome to get an adequate feed supply, which doubled their sufferings for its high price due to inadequate supply. Bangladesh relies heavily on foreign input supply of feed ingredients; thus, it ensued a dire consequence due to import restriction during the pandemic. Besides, it is time-consuming and costly for fish farmers to purchase feed ingredients individually from local markets due to limited market hours and transportation choices. The closure of many hatchery businesses caused a huge shortage of quality fingerlings and fry among the fish farmers. It is worrisome that farmers had to pay their lease rent (76.5% of total sampled farmers were involved in some form of land leasing for fish farming) despite incurring losses, preponderance of the fish, which multiplied their worries. Nonetheless, labor shortage comes at the fourth

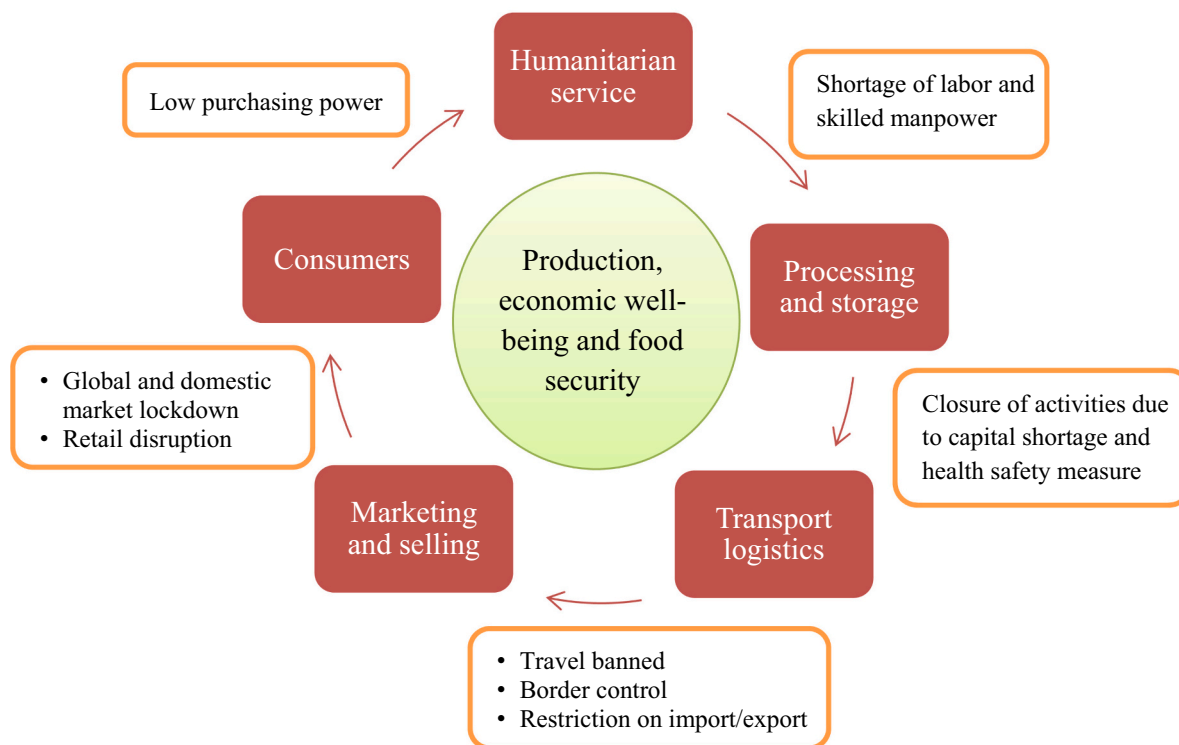


Fig. 5. COVID-19 disruptions and impacts on aquaculture and fisheries value chain activities. Note: This graph is based on a variety of data streams acquired through a survey, although it is not meant to represent a quantitative analysis. In the center of the figure are key outcomes: production, well-being, and food security.

Table 5
Major problems faced by fish farmers, fishers, and traders for input supply.

Problems of inputs accumulation	Extent of problem (%)			Total PCI	Rank
	Low (1)	Medium (2)	High (3)		
Fish farmers					
Raised the feed price due to deficient supply	15 (10)	55 (36.67)	80 (53.33)	365	1
Lack of quality fingerling and fry due to the closure of hatchery business	37 (24.67)	21 (14)	92 (61.33)	355	2
Unable to sell fish but have to pay the lease value of land	32 (21.33)	43 (28.67)	75 (50)	343	3
Inadequate labor supply	39 (26)	44 (29.33)	67 (44.67)	328	4
Price rise of locally made feed ingredients	122 (81.33)	16 (10.67)	12 (8)	190	5
Fishers					
Unable to catch fish due to movement restriction	12 (8)	45 (30)	93 (62)	381	1
Inadequate cocksheets/ container supply	34 (22.67)	55 (36.67)	61 (40.67)	327	2
High rope price	67 (44.67)	46 (30.67)	37 (24.67)	270	3
Difficulties in purchasing fishing nets	97 (64.67)	23 (15.33)	30 (20)	233	4
Fish traders					
Unavailability of transport and high cost	9 (9)	24 (24)	67 (67)	258	1
Lack of capital and credit support	12 (12)	33 (33)	55 (55)	243	2
Labor shortage	33 (33)	29 (29)	38 (38)	205	3
Inadequate ice supply and high price of ice	27 (27)	52 (52)	21 (21)	194	4

Notes: Figure shown in the parenthesis indicates the percentage of respondents in each category.

serious reported problem by the fish farmers, which can be attributed to the fact that due to the early days of lockdown across the nation, human resources could not mobilize to the production areas and thus created an artificial crisis for labor. In addition, after recovering from the lockdown days, many people shifted their occupation and migrated to other places, which could also induce the labor crisis. This same problem ranked third most influential issue in input supply for the fish traders.

Movement restriction also took a heavy blow to the fishers as they could not reach their fishing sites. Furthermore, the travel bans also squeezed the supply of cocksheets and containers; therefore, they were unable to preserve fish in anticipation of a greater price at a later period. Besides, higher rope price was another problem mentioned by the fishers, and it eventually impacted fishing operations since a substantial amount of rope is required to perform fishing operations. Besides, a considerable portion of the fishers faced difficulties in purchasing fishing nets which exacerbated their operation.

The most significant issue that traders experienced was the high transportation cost and unavailability of transportation. Alongside, as their income seemed to reduce, they lacked adequate capital and credit. It should be mentioned that aside from fish traders, other people involved in the agriculture sector also endured a shortage of credit supply during the pandemic (Pan et al., 2020). Ice supply for storing fish was also found scarce with a higher price. All these issues hampered the vital input accumulation activities across fish farmers, fishers, and traders, which eventually increased their production cost and endangered the value chain as a whole.

As the input supply was found to be disrupted, it was not surprising that all the stakeholders received serious constraints in selling fish. The prime issues for fish farmers and fish traders were low fish prices,

followed by the closure of auction places led by *arat*, lack of bargaining power, limited numbers of buyers resulting in lower demand (Table 6). Hence, as the price and demand were low the fish farmers and fishers incurred huge losses and found it difficult to survive. Besides, transportation barriers intensified the sufferings of the fishers. Small-scale fishers' ability to pursue their livelihoods has been further harmed by knock-on economic impacts from market disruptions, which have resulted in a "twin disaster" of diminished demand and price collapse (Bennett et al., 2020). The fish traders, however, faced a more diversified range of issues in the fish sale. Due to transportation restrictions, buyers could not move to the market, which was the most severe problem reported by the traders. Besides, because of lockdown measures, traders found it difficult in opening their *arats*. Even if they manage to open their *arats*, they can conduct their operation for a limited time period. As a result, their market duration was shorter and fewer *bepari* and wholesalers prevailed in the market. Other cited problems included low fish volume, labor shortage, and inadequate transportation facilities. As a result, the lockdown measures have inflicted an unparalleled scar on Bangladesh's whole fish value chain. All of these instances had serious ramifications for all stakeholders, and merely any of them could circumvent the obstacles induced by the COVID-19.

Table 6
Major issues faced by fish farmers, fishers, and traders for fish sale.

Problems of fish sale	Extent of problem (%)			Total PCI	Rank
	Low (1)	Medium (2)	High (3)		
Fish farmers					
Low fish price	7 (4.67)	24 (16.0)	119 (79.33)	412	1
Closure of <i>arat</i> (auction place)	12 (8)	39 (26)	99 (66)	387	2
Lack of bargaining power	34 (22.67)	55 (36.67)	61 (40.67)	327	3
Limited number of buyers	37 (24.67)	69 (46)	44 (29.33)	307	4
Lower demand	55 (36.67)	59 (39.33)	36 (24)	281	5
Fishers					
Closure of <i>arat</i> (auction place)	9 (6)	17 (11.33)	124 (82.67)	415	1
Low fish price	12 (8)	18 (12)	120 (80)	408	2
Limited number of buyers	27 (18)	23 (15.33)	100 (66.67)	373	3
Transportation problem	77 (51.33)	12 (8)	61 (40.67)	284	4
Fish traders					
Limited number of buyers from distant market	12 (12)	8 (8)	80 (80)	268	1
During a lockdown, the administrative difficulty of <i>arat</i> opening	18 (18)	32 (32)	50 (50)	232	2
Shorter market duration	23 (23)	29 (29)	48 (480)	225	3
Lack of <i>bepari</i> and wholesaler (<i>paikar</i>)	20 (20)	55 (55)	25 (25)	205	4
Unavailability of sufficient labor	56 (56)	22 (22)	22 (22)	166	5
Low volume of fish to sell	44 (44)	49 (49)	7 (7)	163	6
Unavailability of transport	43 (43)	55 (55)	2 (2)	159	7

Notes: Figure shown in the parenthesis indicates the percentage of respondents in each category.

3.6. Adaptation strategies followed to handle the market force disruption due to COVID-19 pandemic

Fisheries and aquaculture-related ventures adopted several strategies to cushion the negative impact of COVID-19. This research uncovered some of the strategies that were fish farmers, fishers, and traders adopted to deal with market disruption during the pandemic. However, each respondent can adopt more than one strategy to survive during the pandemic.

Strategies followed by the fish farmers and fishers to deal with market force disruption are depicted in Fig. 6. Results revealed that approximately half of the respondents followed the direct selling approach to local consumers over the phone. In Bangladesh, many wholesale and retail fish markets are frequently congested and packed, posing infection risks to both traders and consumers. As a result, retail marketplaces have become heavily regulated in order to provide physical distance and other sanitary norms, which prevent consumers from entering the market. Many small-scale fish farmers and fishers have adopted home delivery by taking orders over the phone to combat this situation. In Malaysia, Azra et al. (2021) demonstrated similar findings where 76% of fish producers use digital platforms and/or online markets as an effective solution for combating COVID-19. Results also revealed that roughly 40% of the respondents reduced the number of employees as a adoption strategy. Because of labor layoff and stocked of mature fish in the pond, approximately 35% of respondents did not start their new production cycle. One of the most likely options among the respondents (18.45%) was to reduce culture volume as a result of lower sales and the inability to start a new production cycle. The survey also found that respondents were planning to switch to other supplementary income sources (22%), which are easier to adopt. Such an alternative may be difficult to execute because fish farmers and fishers have specialized skills in fish farming and fishing; hence professional change could not be quickly and easily practicable for them. Some respondents were compelled to acquire financial assistance in the form of loans (12%) to cope with decreasing sales and market demand during the pandemic, while others (15.45%) were looking for new markets to sell their fish. However, farms with multiple income sources were less likely to be adversely impacted by any shock (Lebel et al., 2021); thus, some farms (9%) tried to diversify their investment along with fishing or fish farming.

Similar to the fish farmers and fishers, traders also followed several strategies to cope with the COVID-19 induced market force disruption

(Fig. 7). Results revealed that more than half of the sampled fish traders reduced the number of employees to survive during the pandemic. Employee reductions enable them to save funds in order to counteract declining sales. However, when they could handle buyers from local or distant marketplaces, some traders (34.75%) directly contacted fish farmers for fish harvesting. Often, they took less commission than usual time to attract the buyers. The survey results demonstrated that one-fourth of the selected traders tried to sell fish in other Upazila (sub-administrative areas) or district markets. Due to the closure of *arat* and fish business, many fish traders (22.45%) were seeking alternative means of income; therefore, they were forced to other off-farm income such as shop keeping, driving, migration to cities, etc. To deal with the capital deficit, some traders (16%) take out loans and seek government assistance. Surprisingly, 2% of the survey respondents followed an unorthodox strategy to expand the market during the pandemic by offering more prices to the seller. Despite the fact that it was not feasible for them, several traders did so in order to run their businesses, with the hope that it would benefit them when the situation return to normal.

4. Concluding remarks and policy insights

The COVID-19-induced shock impacted the global fisheries and aquaculture industries, particularly in underdeveloped nations like Bangladesh. However, to the best of the authors' understanding, this study was the very first attempt identifying consequences of the COVID-19 on fisheries and aquaculture sectors with a wide range of respondents across the fish value chain. As the pandemic caused an unprecedented disruption in movement and transportation, the production activities, marketing and distribution of fishes and fishery products were severely hampered because of labor and capital shortage, higher input prices, unavailability of input, and elimination of intermediaries. Besides, the demand for fish products declined, which significantly reduced the fish price by a large margin. In addition, tons of mature fish products were left unsold in the pond, which raised farmers' costs, as they were required to be fed for additional period. Alongside the farmers and fishers, individuals engaged in fish trading also fell victim to the dire circumstances. Indeed, our paper elicits worrisome findings that indicate that fishers and fish traders conceded an enormous loss that severely compressed their income level, made them food-unsecured, and put them on the bait of financial crisis. To mitigate losses and overcome the challenges of the fisheries and aquaculture sectors, there is a dearth of proper strategies taken to rebound by the fish farmers, fishers, and

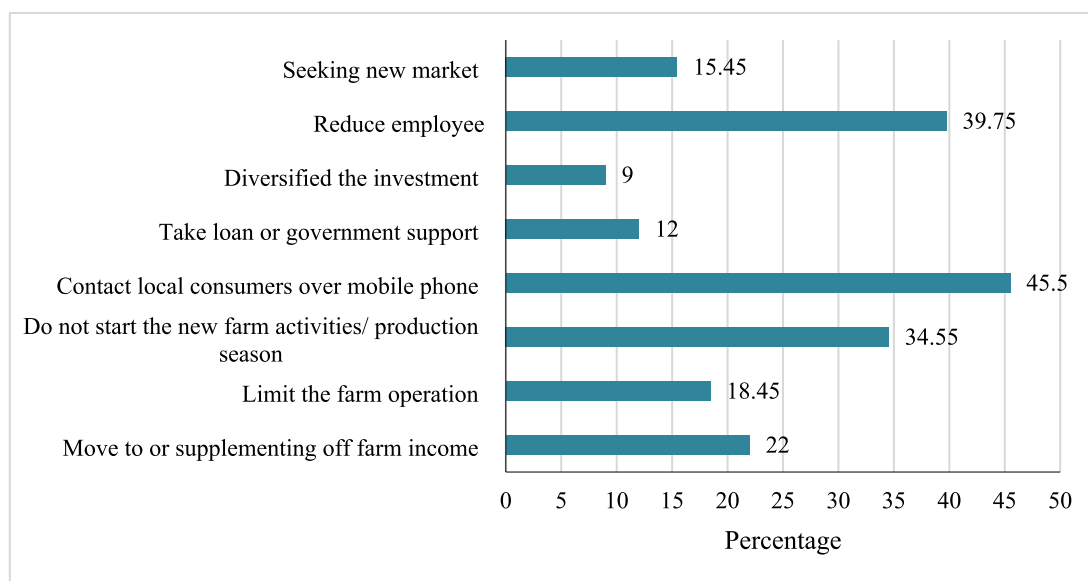


Fig. 6. Strategies followed by the fish farmers and fishers to combat COVID-19. Note: Responses are mutually exclusive.

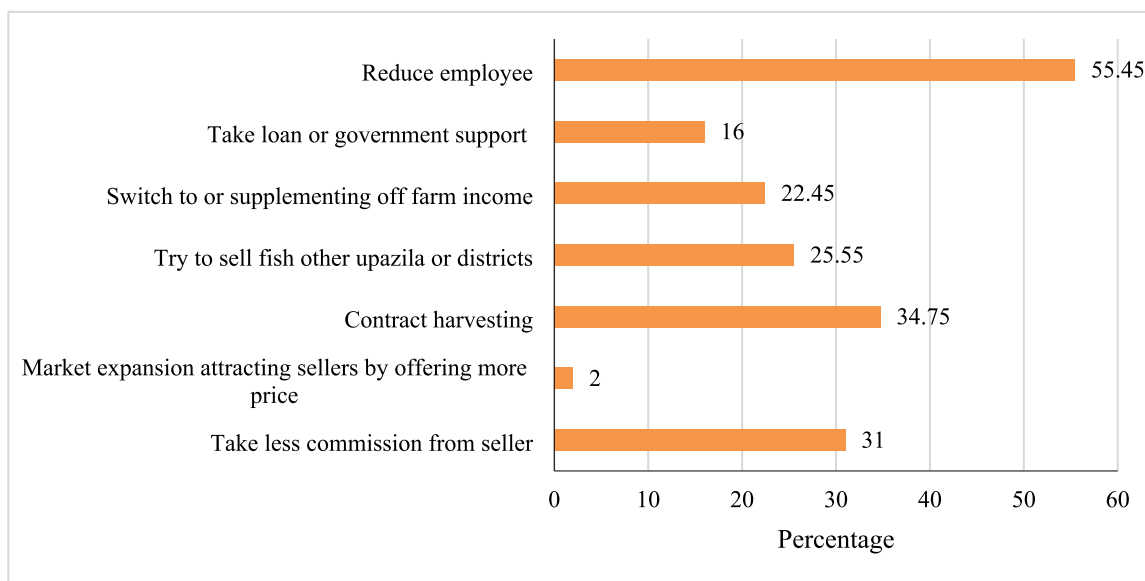


Fig. 7. Strategies followed by the fish traders to handle the disruption of market forces. Note: Responses are mutually exclusive.

traders. After evaluating the empirical findings, this study proposes some policy advice that might assist to recover the shock of Bangladesh's fishing industry and other developing nations.

First, further market studies can be undertaken to determine the actual demand and supply of inputs, which may reveal the intensity of the input shortage across different geographical regions. Accordingly, the shortage can be met by prioritizing the most vulnerable places.

Second, as observed in this study, most of the participants reported a shortage of capital and credit. It is worth mentioning that, without enough credit and ample capital, farmers or traders will not be willing to continue their operations. Hence, as the COVID-19 fell them into the trap of capital crisis accompanied by debt, they might think of shifting to another profession. As a result, in the long run, a significant portion of the fisheries-related people may quit fishing activities. Therefore, the government, accompanied by the assistance of NGOs, should take immediate actions to prevent them from closing their fish farms, catching and fish trading businesses by providing easily accessible and low-cost credit. A BDT 5000 crore revolving refinancing scheme for farmers in the agriculture, dairy, poultry, horticulture, and aquaculture industries has been launched by Bangladesh's government. This fund should be disbursed appropriately and on the basis of priority to overcome the loss induced by the COVID-19 pandemic.

Third, contract farming may be a remedial alternative for fish farmers to palliate their losses not just during the COVID-19 period, even after the end of the pandemic. Since contract farming involves production being carried out on the basis of an agreement between the buyer and producers, it has a significant impact in raising the livelihood standard and income of the farmers and fishers while reducing their losses and struggles in any situation.

Fourth, building cooperative societies among farmers, fishers, and fish traders will also ease the pandemic's burden because cooperatives may help improve input availability, smoothen marketing activities, generate greater credit accessibility, and increase household income (Seneerattanaprayul and Gan, 2021).

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CRediT authorship contribution statement

Md. Akhtaruzzaman Khan: Conceptualization, Formal analysis, Project administration, Funding acquisition, Writing – original draft. **Md. Emran Hossain:** Conceptualization, Data curation, Methodology, Writing – original draft. **Md. Takibur Rahman:** Investigation, Visualization, Writing – review & editing. **Madan Mohan Dey:** Project administration, Funding acquisition, Supervision, Writing – review & editing.

Declaration of Competing Interest

The authors declare no conflicts of interest.

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Appendix A. Appendix

Table A1

Relevant literatures of COVID-19's impact on aquaculture and fisheries around the world.

Author/s (year)	Country	Sub-sector	Key findings
Azra et al. (2021)	Malaysia	Aquaculture	Eight out of ten respondents identified low market demand as a major constraint to their aquaculture activities. While using online markets or digital platforms was the most popular adaptive option.
van Senten et al. (2020)	The United States	Aquaculture	The disruption of traditional marketing channels was the primary impact of COVID-19. The COVID-19 had a cascade of effects, including a loss of revenue, manpower shortage, and difficulty obtaining production inputs.
Kumaran et al. (2021)	India	Shrimp aquaculture	The shrimp aquaculture sector suffered an economic loss of 1.50 billion USD. Due to the pandemic, severe constraints were identified in shrimp seed production and supply i.e., disruption in the supply chain, farming, processing, marketing, and loss of employment and income.
Sunny et al. (2021)	Bangladesh	Small-scale fisheries	Reduced income, difficulties in collecting inputs, labor shortages, transportation abstraction, a weak value chain, low consumer demand, and creditor's pressure were identified as the main affecting factors in Bangladesh's small-scale fisheries.
Smith et al. (2020)	The United States	Fisheries	Almost every participant reported a loss of revenue. Direct sales to consumers, switching species, and supplementing their income with government payments or other sources of revenue were among the adaptation measures mentioned by fishers.
Waiho et al. (2020)	Malaysia	Aquaculture	COVID-19 had the most significant influence on reducing demand, as well as supply chain disruption. The key adaptive measure was government stimulus packages.
Marschke et al. (2021)	Thailand and Taiwan	Fisheries	Fisher's employment is disrupted due to instability in the seafood industry, travel or mobility restrictions, and limited access to services such as health care and social programs.
Bennett et al. (2020)	Worldwide	Fisheries	The impact of COVID-19 included some fisheries were completely shut down as a result of COVID-19, market disruptions, increased health hazards, and a rise in illegal, unreported, and unregulated fishing.
Lebel et al. (2021)	Vietnam Myanmar Thailand Cambodia and Laos	Aquaculture	The COVID-19 pandemic hampered farmer mobility, interrupted input and produce logistics, and decreased consumer demand, which in turn, lowering net income. Large aquaculture farms were more likely to be harmed by increasing input prices and decreased fish market prices.
Islam et al. (2021)	Bangladesh	Aquaculture and Fisheries	COVID-19 increased transportation, input and maintenance costs, and a drop in fish market prices. However, the pandemic has a positive effect, namely, a rise in fish stocks as a result of reduced fishing activity.
Hasan et al. (2021)	Bangladesh	Aquaculture	COVID has caused a profit squeeze for finfish farmers. Farmers have lowered labor costs by reducing the number of employees and their wages.
Hoque et al. (2021)	Bangladesh	Fisheries	COVID-19 resulted in lower fish demand, labor shortages, and transportation challenges. Fisher's fishing time and earnings both were reduced. Owners of boats had a greater income reduction (49%) than fishers (26%).
Rahman et al. (2021)	Bangladesh	Shrimp aquaculture	The cost of shrimp production increased significantly during COVID-19, lowering profitability.

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