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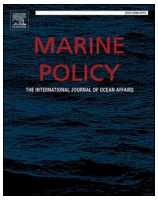

Impact of novel coronavirus pandemic on aquaculture and fisheries in developing countries and sustainable recovery plans: Case of Bangladesh

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ABSTRACT

Like most sectors, the aquaculture and fisheries sector especially in developing countries like Bangladesh is believed to have been severely affected by this unique coronavirus (COVID-19) pandemic. To overcome the adverse impacts of COVID-19, the aquaculture and fisheries economy needs urgent recovery plans which this study focusses on using a mixed-method including online questionnaire surveys, face-to-face and telephonic interviews and focus group discussions during June – November 2020. This study reveals some positive impacts on ecosystem and fish stock (e.g., increase in fish stock) due to less disturbance of fishing activities, but that are not able to bring societal benefits as all the fisheries sub-sectors are affected differently by the pandemic. There are disrupted transportation systems and increased transportation costs (around 20 – 60% higher than normal), more input and maintenance costs and less demand for/and decreased market price of fish. There are also shortages of labourers and reduced patrolling to implement fishery regulations. Cancellation of orders by foreign buyers has seriously affected the shrimp and crab sub-sectors. The fisheries-dependent people's capital assets and activities have been mostly negatively affected resulting in a worsened livelihood. This study has suggested a set of immediate and long-term changes to policy and action plans to recover this sector and sub-sectors from the pandemic considering economic, social and environmental sustainability. The findings of this study may have important implications not only for Bangladesh but also for other fisheries dependent developing countries with similar impacts by the virus like in South Asia.

1. Introduction

Bangladesh is among the top thirty-five countries in the world in terms of the number of people diagnosed with COVID-19 (coronavirus disease 2019) [1]. Till April 12, 2021, there have been 691,957 confirmed COVID-19 positive cases with 9,822 total death toll reported in this country [2]. After identifying the first COVID-19 case on the 8th March 2020, there has been a full shut down of the economy and strict restriction on people's movement from March 26th, with most of the people locked out of their homes continuously for more than two months. After that, the economy reopened to some extent despite the continuous increase of COVID-19 cases and deaths. There were restrictions on people's movement, activities and businesses had to oblige with COVID-19 related health guidelines and social distancing. The economy and livelihoods of the people seemed to have been affected a lot due to these circumstances. A preliminary study in the context of Bangladesh shows that about 95% of people reported a decrease in income due to these impacts where there was a 76% reduction of average household income during April and May, with an alarming 62% of complete loss of job in low-income and daily wage populations [3]. Sadly, women-headed households are facing more crises in managing living expenses than male head households [3]. Among all occupations, transport workers, wage earners and house helpers have the highest impact where there has been around 80% reduction of income to the agricultural wage earners [3].

In Bangladesh, the aquaculture and fisheries sector is considered as one of the most dynamic and productive sectors contributing significantly to the economy which is believed to be amongst the most affected by the coronavirus pandemic – the sector is already vulnerable to different factors including pollution and climate change [4–9]. In this country, this sector supports livelihoods of 18 million people directly and indirectly, produces 4.38 million metric tons of fish, and contributes 3.50% to GDP, 60% to animal protein intake and 501 million USD in export earnings [10]. However, the sudden outbreak of the novel

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coronavirus is believed to have changed the scenario greatly. Restriction in movement, activities and business at the early stage of COVID-19 outbreak has impacted the livelihood of the fishers and related stakeholders. Harvesting of fish during that period by maintaining social distance was almost impossible and has been predicted to impact on the overall fish production. Besides, transportation restriction in the early stage (February-March) and later increased transportation cost after lockdown period (after June 2020) have potentially impacted the economic capital of fishers and fish farmers as they had difficulty in transporting fish which will ultimately affect the livelihood of fisher's households [11]. More importantly, marketing of fish has been reported to be impacted in various national newspapers along with a sharp rise in the price of feed and feed ingredients. In regard to educational institutions, it is predicted to critically impact the marginalised community due to their incapability and lack of access to technology [12]. Violence and gender discrimination are expected to increase due to the lockdown situation [13].

The impact of COVID-19 to fishers and fish farmers is believed to be different in different geographical regions of Bangladesh due to, for example, the variation of dependency on this sector. Food and Agricultural Organization of the United Nations (FAO) has initiated a preliminary session of question and answer regarding the overall impact of COVID-19 pandemic on fisheries and aquaculture sectors which states that the supply chain of fish and shellfish on international trade is being affected due to the closure of foodservice sectors around the world [14]. FAO later published reports on the COVID-19 impacts and how it is affecting the fisheries and aquaculture sector and the food system [15,16]. Focus on the impact of COVID-19 in small-scale fisheries, coastal fishing communities and inland fisheries has also been observed in some editorials and short reports [17,18]. As the seafood sector is being affected worldwide by transportation restrictions, this sector has got special attention [19–22]. Studies have also reviewed the socio-economic impact of novel coronavirus on shrimp aquaculture in India and South-east Asia [23,24]. Economic consequences of coronavirus on fisheries in the Eastern Mediterranean have been observed in one study [11]. There are some reviews and studies that tried to evaluate the impacts of coronavirus in the fisheries sector, small-scale fisheries, and aquaculture sectors in Ghana, India, Indonesia, Kenya, Malaysia, Thailand, Turkey, and USA [19,25–32].

In order to get a general overview of the impact of the coronavirus pandemic in aquaculture and fisheries sectors as well as the livelihoods of the dependent stakeholders, it is important to assess the impacts of this virus in different sub-sectors of fisheries as well as the people who depend their livelihoods on these. The influence of the pandemic is believed to not easily fade away even after the arrival of a vaccine. Therefore, the objective of this study is to identify the impacts of the novel coronavirus on aquaculture and fisheries sector in Bangladesh emphasising on the impact on livelihoods of small-scale fishers and fish farmers. This study also suggests short- and long-term policies and plans for this sector to recover from the current pandemic as well as from similar future disasters.

2. Aquatic habitats, aquaculture and fisheries in Bangladesh

Unlike many countries, Bangladesh has vast inland freshwater resources including floodplains, ponds, rivers, oxbow lakes, large depressions (locally known as haor and beel) and estuaries. It also has a large coastal area with a sea. These support inland closed water culture fisheries (aquaculture), inland open water capture fisheries, and marine capture fisheries (Table 1). Globally, Bangladesh is placed 5th in aquaculture and 3rd in inland open water capture fish production [33].

2.1. Inland aquaculture

The aquaculture in Bangladesh provides 56.76% of total fish production with a total fish production of 2,488,601 metric ton (MT) in 821,923 hectors (ha) water area (Table 1) [10]. This production is from ponds, seasonal cultured water body, shrimp and prawn farms, pen culture and cage culture. Among eight divisions in the country, Khulna (South-Western region of Bangladesh, mainly coastal districts) (Fig. 1) has the highest production in aquaculture (total aquaculture area 308, 817 ha) followed by Chattogram (Eastern Hill region) and Mymensingh divisions (North Central region) [10]. However, fish production from ponds is the highest in Mymensingh division (mainly finfish aquaculture), whereas shrimps/prawn production is the highest in Khulna division. Aquaculture in freshwater ponds is involved in semi-intensive polyculture methods of major carps, common carps, tilapias, catfishes, prawns, etc. which are practiced all over the country. Using an extensive method, the coastal aquaculture farms cultivate mainly shrimps and prawns often with finfish and crabs.

Table 1
Area of aquaculture and fisheries and fish production in Bangladesh [34].

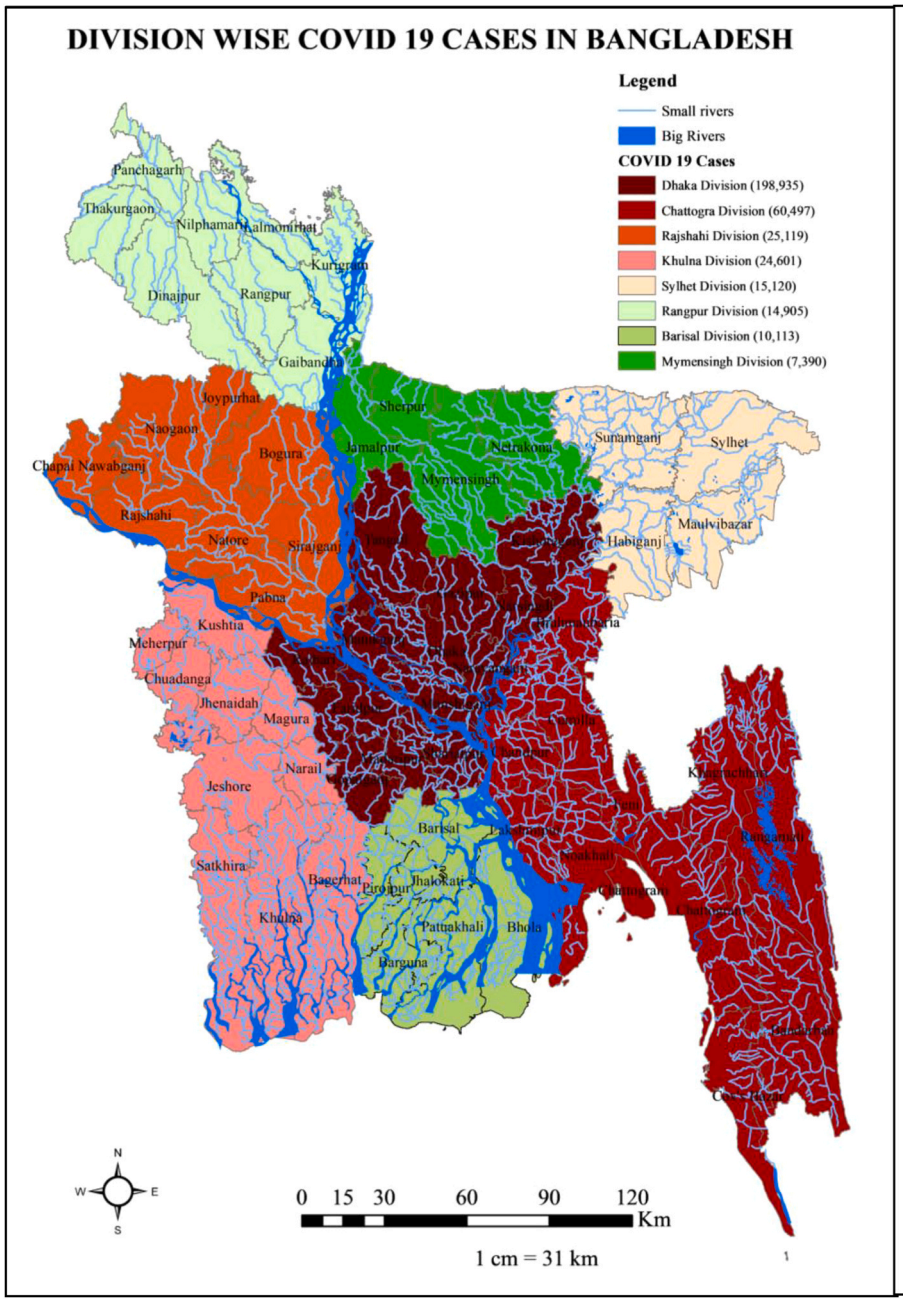
Sub-sector of aquaculture and fisheries	Water area (Hector)	Production (Metric Ton)
Aquaculture	**821,923**	**2,488,601**
Pond	397,775	1,974,632
Seasonal cultured waterbody	144,217	217,340
Oxbow lake (Baor)	5671	10,343
Shrimp/Prawn farm	258,553	258,039
Pen culture	6330	12,361
Cage culture	176,213 m^3	3802
Inland open water capture fisheries	**3,890,282**	**1,235,709**
River and estuary	853,863	325,478
Sundarbans	177,700	18,282
Large depressions (Beel)	114,161	99,890
Kaptai lake	68,800	10,578
Floodplain	2,675,758	781,481
Marine Fisheries	**118,813 km^2**	**659,911**
Industrial		107,236
Artisanal		552,675

2.2. Inland open water capture fisheries

Inland open water fisheries contributes to 28.19% (1,235,709 MT) of the total fish production in approximately 3,890,282 ha [10] containing river and estuary, floodplains, large depressions, the Sundarbans and Kaptai lake. Considering the production trend of 2018–19 [10], Chattogram division has the highest capture fisheries production which mainly comes from rivers, Kaptai lake, floodplains and large depressions. However, Barishal division (South-central and Coastal regions) has the highest fish catch of 168,081 MT from rivers in 2018–19, though the contribution of floodplains is the highest in Chattogram division (159,230 MT). The open freshwater body of Bangladesh inhabits 260 fish species, 12 exotic fish species and 24 prawn species [35] with hilsa shad (*Tenualosa ilisha*) constitutes the largest single-species fishery. Around 0.8 million of registered fishers are engaged in inland openwater capture fisheries sector [34].

2.3. Marine fisheries

Bangladesh has 118,813 km^2 of exclusive economic zone (EEZ) in the Bay of Bengal with 475 finfish species and 25 shrimp species in coastal and marine areas [36]. The current production of marine fisheries is 659,911 MT (15.05% of total fisheries production) which includes both artisanal and industrial fisheries engaging about 0.516 million marine fishers [34]. Industrial fishing trawlers fish in the deep-sea (40–100 m) and catch approximately 107,236 MT fish; but the highest marine fisheries production mainly comes from artisanal fisheries with a total catch of 552,675 MT in the near-shore area using mainly non-mechanised wooden boats and mechanised trawlers [10].



Coronavirus Control Measures in Bangladesh in 2020 - 2021

January 22, 2020: Dhaka airport authorities put alerts on the airport by screening travellers from China.

March 15, 2020: With the first COVID-19 positive cases identified on 8th March, from 15th March the country banned all flights coming from Europe except the United Kingdom, despite some exceptions.

March 26, 2020: People are locked at home, offices closed and transportation halted except for emergency services, strict health guidelines are asked to follow. Total confirmed covid-19 cases were 44 with 5 deaths.

June 1, 2020: Easing restrictions despite increase of covid-19 cases and deaths. Offices, shops and transportations opened at a limited scale but strict health guidelines to follow.

June 15, 2020: The country extended the closure of educational institutions till August 6.

July 21, 2020: To limit the transmission, government ordered to wear face mask whenever they go out from home.

October 25, 2020: "No mask no service" policy implemented in government and private offices.

November 13, 2020: Extension of closure of educational institutions till December 19. This closure later extended till 14 Feb 2021.

April 5, 2021: Seven days controlled movement imposed all over the country to control the second wave of the coronavirus outbreak.

April 14, 2021: Strict lockdown imposed until 21 April closing all the government and non-government organizations, except the emergency services.

Fig. 1. Map of Bangladesh showing the number of COVID-19 confirmed cases in 8 divisions of Bangladesh (Developed by the Authors using ArcGIS 10.3). The box in the right is showing major measures taken to control the pandemic.
(data source: [2]).

3. Materials and methods

3.1. Data collection

This study has mainly used primary data collected through in-depth face-to-face interviews, key informant interviews, focus group discussions and questionnaire survey. Proper ethical guidelines for research with human participation were followed throughout the data collection, storage and sharing stages. This study focusses on the aquaculture and fisheries of entire Bangladesh as all the 64 districts (in 8 divisions) of the country are being affected by the pandemic (Fig. 1).

3.1.1. In-depth face-to-face interviews

Conducting face-to-face interviews, especially during the early months of the pandemic period was both troublesome and hazardous due to transportation restrictions and rapid coronavirus spread. But we wanted to at least collect some representative samples from different sub-sectors of fisheries, i.e. aquaculture, river and floodplain capture fisheries, estuarine fisheries and marine fisheries. So in-depth face-to-face interviews were carried out in Mehendiganj and Hizla sub-district (Upazila) of Barishal district (flood vulnerable estuarine and on-shore fisheries area in the south-central region), Gosairhat sub-district of Shariatpur district (River fisheries and aquaculture in the south-central region), Kalapara sub-district of Patuakhali district (Off-shore marine fisheries area in the southern coastal region) and Naldanga sub-district of Natore district (Floodplain fisheries and aquaculture area in the western region) of Bangladesh. In total, 28 in-depth face-to-face interviews (15 interviews were conducted at the early stage of the COVID-19 in June-July 2020 and 13 interviews were conducted at the developmental stage of COVID-19 in November 2020) were carried out with the fishers, fish farmers, hatchery owners and fish auctioneers to understand the impacts of the pandemic on aquaculture and fisheries sector and their livelihoods. During the interviews, strict health guidelines and social distancing were maintained due to the pandemic (Fig. 2a).

The Sustainable Livelihood Approach (SLA) has been used in this study as a conceptual frame to understand mainly the impacts of the pandemic on fisheries-based livelihoods' assets, strategies and outcomes (Fig. 3). The SLA, an asset-based conceptual framework, was originally developed by Chambers and Conway [37] and later modified and improved by Scoones [38], DFID [39] and many others. It has evolved as a way of reforming poor peoples' lives after experiencing shocks from uncertain events like COVID-19. It also helps to sort out the exact perspective of a fisher's and fish farmer's livelihood capital assets, strategies and outcomes, which enables the identification of the impacts of the pandemic at the household level. In the original SLA framework, there are 5 livelihood capital such as natural, human, physical, social and financial. However, many scholars (e.g., Stanford et al. [40]) adopted institutional capital with the aforementioned livelihood capitals and revised the earlier framework (Fig. 3). This framework has also helped us to suggest solutions and recovery plans from the pandemic to some extent.

3.1.2. Key informant interviews

A total of 50 telephonic key informant interviews (KIIs) were conducted using semi-structured questionnaires with government fisheries officers, Bangladesh Fisheries Research Institute (BFRI) and Bangladesh Fisheries Development Corporation (BFDC) officers, NGO workers, researchers, fish processors, fish feed factory personnel, hatchery owners, fish auctioneers, money-lenders, fish exporters and leaders of fishers association to know the overall impacts of the pandemic and their suggestions for solutions at different time scales. The telephonic interviews were carried out, both at the early (June-July 2020) and developmental stages (November 2020), in each region of the country – north, south, east, west and central – as it was not possible to conduct face-to-face interviews with some stakeholders due to the adverse circumstance of COVID-19. The telephonic interviews were continued until no new information and suggestions came from the respondents.

3.1.3. Focus group discussion

A total of seven focus group discussions (FGDs) were conducted to triangulate the data of the in- interviews as well as to explore the detailed impacts of the pandemic and recovery options in the sector. Few topics which seemed debatable during face-to-face interviews were also discussed with the FGDs participants. FGDs were conducted in similar areas like the ones for face-to-face interviews (Barishal, Shariatpur, Patuakhali and Natore) with both homogenous and heterogeneous groups of participants following the health guidelines and maintaining social distance due to COVID-19 (Fig. 2b). In each FGD, 7–8 people participated containing fishers, fish farmers, commissioned agents, fisheries union members, etc. Each session continued for about two hours and thirty minutes.

3.1.4. Online questionnaire survey

The individual questionnaire survey was conducted online using Google forms in June 2020 and spread through various social and online media e.g. Facebook, WhatsApp, e-mail, etc. The questionnaire was designed with 5 multiple choice questions and two tables containing questions related to impacts and solutions of coronavirus in culture and capture fisheries. A total of 118 people responded to the survey comprised of government fisheries officers, fisheries-related academicians or researchers, non-government fisheries-related officers, fish farmers, fisheries graduate or diploma holders, fisheries undergrad students and other occupational individuals of 20–60 years of ages. As the number of fishers and fish farmers participated in this questionnaire survey was very low due to lack of technology, internet access, social media or others (if any), this study predominantly relied on the in-depth face-to-face interviews, key informant interviews and focus group discussions to identify the impacts and recovery options.

Fig. 2. Data collection a) in-depth face-to-face interview at Naldanga, Natore b) Focus group discussion at Mehendiganj, Barishal, Bangladesh amid the COVID-19 pandemic.

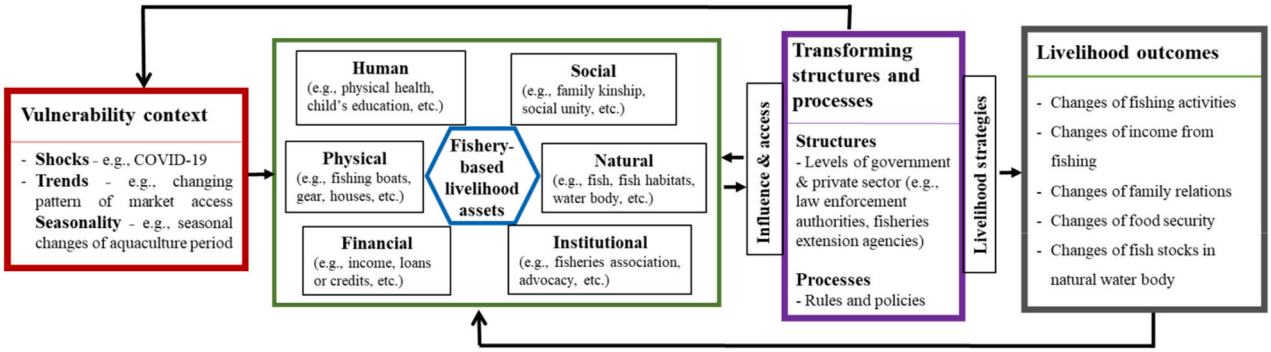


Fig. 3. Conceptual framework of Sustainable Livelihood Approach for fishers' and fish farmers' livelihoods (modified from Chambers and Conway [37]).

3.2. Data analysis

The data in-depth face-to-face interviews, KIIs and FGDs were audio-recorded, transcribed and analysed by content analysis using coding. Inductive content analysis was conducted at three stages: (a) shortened raw data (audio recording and written textual data of the interviews) into summary format; (b) created strong links between the objectives of this study and the summary findings derived from the raw data; and (c) developed a framework of the summary findings derived from this study. For analysing the quantitative data collected from the questionnaire survey, MS Excel (version 2016) was used. First, the occupational varieties of the respondents of the questionnaire survey were evaluated along with their gender. Then the frequency and percentage of the impact variety on the sub-sectors of the aquaculture and fisheries sector were calculated by using MS Excel. The frequency and percentage of priority on loan scheme among the stakeholders were also calculated accordingly. However, due to the incompetency of not being able to collect ample online questionnaire response from small-scale fishers and fish farmers (due to lack of internet access in remote areas), the inferences were mostly based on the qualitative data collected through in-depth face-to-face interviews, KIIs and FGDs.

4. Results and discussion

4.1. Impact of coronavirus on freshwater pond aquaculture

The pandemic has created mostly negative impacts on the freshwater pond aquaculture sub-sector. From face-to-face interviews, KIIs and FGDs, this study identified that the negative impacts are mainly due to an increase in inputs and transport costs and reduction of demand for/and price of fish. Due to the restrictions on transport and less availability of manpower as well as difficulty in production operation, the fish feed companies have incorporated approximately 10–12% increased feed price reported by the key informants. Similar observations were also found in another study conducted by the Southeast Asian Fisheries Development Center [41]. All the fish farmers reported during face-to-face interviews that the price of the cultured fish has decreased due to low demand in the markets. This is because of decreasing most of the consumers' income due to the loss of jobs [2] and in some cases disruption of cash flow since the start of the pandemic [30]. Decline in the average price of fish was also found in Indonesia with a sharp decline in the number of active fishers and fish traders [30]. Difficulty in storage and marketing of fish have severely affected the livelihood of fishing community worldwide [25]. More production cost due to increase in feed price, more transport cost due to unavailability of the usual transport vehicle and less selling price of fish, have induced the fish farmers not to catch the fish rather keep them in the ponds for a longer period in the hope that the situation will be better and the price of the fish will increase. The fish farmers and hatchery owners reported during face-to-face interviews that rearing fish in ponds for a long period ultimately incurred more cost for foods and maintenance. For example, culturing relatively larger fish of a particular species for a longer period required more feed than smaller fish. In addition, there has a shortage of ready feed and feed ingredients in the market. These shortages and higher price of feeds have induced the farmers to apply lesser feeds in the ponds which has ultimately led to slower growth of fish.

The pandemic has also induced a reduced rate of stocking of fish fry/fingerling. In Bangladesh, usually by the middle of March to early April, fish farmers catch a considerable number of fish as this is the end of the season with an insufficient amount of water in the ponds. From early May, they start stocking new fish fry/fingerling as rainwater fills the ponds during this time. However, it was found from in-depth qualitative and key informants' interviews that this year (2020), fish farmers are buying and releasing lesser fry in the pond on time as they could not sell the previous batch of fish because of the pandemic. In the Philippines, mobility restriction has negatively affected aquaculture production by limiting the supply of fry and fingerlings [42].

According to 38% of the online questionnaire survey respondents, the impact of coronavirus in freshwater pond aquaculture sector is slightly negative; whereas 25% reported it moderately negative, 9% delineated it highly negative and 6% said severely negative (Table 2). Though about 18% of respondents have reported that novel coronavirus has neither positive nor negative impact on freshwater pond aquaculture, but 4% of respondents have reported a positive impact on this sector (Table 2).

4.2. Impact on brackish water shrimp aquaculture

The export-oriented shrimp aquaculture in Southwest Bangladesh has been impacted negatively mainly because of disruption of transportation, sudden reduction of demand in markets, and reduction of price. About 85% of respondents of the questionnaire survey perceived that impact of coronavirus on shrimp aquaculture as negative. Export-oriented shrimp processing plants used to buy almost all the shrimps. But according to the respondent of a processing plant representative, after a few days of the start of the pandemic, many of them stopped or reduced buying the shrimps due to fear of not being able to export. Their fear became true at the later stages of the pandemic (see Section 4.6 for details). Labour shortage, harvesting delay, insufficient shrimp supply and quarantine rules and regulations imposed by the importing countries have affected the shrimp industry of Southeast Asia [23]. In this study, the key informants reported a 20–35% reduction of shrimp's price depending on the size. The price of high valued larger shrimps reduced more (10–15%) than the smaller ones. The cost of shrimp feeds increased a little bit, although it does not have a major impact on the cost of shrimp production as most shrimp farmers do not apply any feeds to their farms (extensive method of shrimp farming are practised relying mainly on natural foods). Unlike freshwater fish culture, the cost of wild shrimp seed (PL - post-larvae) was increased, whereas, the price of hatchery PL remained unchanged or decreased to some extent during

this pandemic period. However, it has been reported during the interviews that the transportation of PL was temporarily closed because of restricting transportations and public movements from one place to another which have indirectly affected the shrimp farms.

Natural disasters along with coronavirus pandemic can severely affect the life and livelihood of vulnerable fishers community [43,44]. Recently, Amphan – a super cyclone – has stroked these shrimp farming areas on 16th May 2020 leaving huge damage to the shrimp farms amidst the pandemic [45]. A government official reported that out of 11,000 shrimp farms 7,000 were washed away by surge water of Amphan in Shyamnagar sub-district of Satkhira district. In addition, due to this cyclone, a number of people died, road damaged, a lot of trees uprooted, and huge crop damaged.

4.3. Impact on river and floodplain capture fisheries

There are overall positive impacts on river and floodplain ecosystem and fish capture due to the timely onset of rain and less disturbance by humans because of the pandemic as said by the key informants. Around 41% of respondents from the questionnaire survey perceived that there have been some positive impacts on fish habitats due to the pandemic situation as there is less disturbance by fishers in the open water body which helped in recovering and rebuilding the resources and habitats [29,41]. But fishers have reported during face-to-face interviews that they have faced troubles in catching fish as a group in rivers because it is not possible to maintain social distance in the boat. Scarcity and higher price of fuel due to transportation restrictions have also limited the fishing operations in some countries [30,44]. Unlike fish farmers, the fishers have reported that the demand for the natural fish has increased and the price shot up to some extent during the early stage of the pandemic in the northern region of the country. The demand has increased because of returning of many city dwellers and expatriates to village homes during the pandemic who prefer naturally grown fish over culture fish as the former are tastier, more nutritious and have cultural significance. However, the participants of two FGDs have reported that the demand for naturally grown fish to the consumers has also reduced gradually as the duration of the pandemic is prolonged. This is because people are staying at home for a long period without any income source and they relied only on their savings which restrict them to spend more for family maintenance.

However, the pandemic has negatively affected fish market with disruption of the supply chain and ultimately resulted in reduced income from fishing. The FGDs participants reported that during the lockdown period, the price of the fish has decreased as they could not transport fish from one place to another. One fisher in Hizla, Barishal reported that usually, they used to transport fish via launch from Hizla to Barishal or Dhaka. But during the early period of the pandemic (April-May), launches were halted for two months which restricted them to transport the fish. Some local fishers in Mehendiganj, Barishal had reported that they used trawlers to transport the fish with a very high cost (up to double) than usual. In addition, due to shortening the local market hours, fishers could not able to sell their catch like usual. Philippines' fishers were also affected due to shortened market hours and other COVID associated rules [42]. One fisher of Mehendiganj, Barishal said, "*Yields from fishing have reduced because of shortening marketing hours (10am – 4pm). As we could not sell all of our catch within a short period, so we have to sell them at a lower price because we could not preserve the catch for a long time. Before the pandemic, we could earn enough profits in one day. But it takes 3 or 4 days now to earn the same profits*".

4.4. Impact on estuarine and on-shore fisheries

The pandemic has slight positive impacts on the fish stock in most estuarine and on-shore areas of Bangladesh. However, the fishers have reported during face-to-face interviews that shortening the duration of the marketing hours and halting the usual transportation system have affected them. Aggravated fishing pressure in reefs, intertidal zones and mangrove areas by inexperienced fishers has been reported in Vanuatu despite a decline in total catch because of restricted market access and lack of fuel [44]. In India, lockdown in landing centres and harbours have impacted the costal fishers of that country [25].

Hilsa – the largest single-species fishery and the national fish of Bangladesh – which is mainly caught from the estuarine and nearshore areas has also been affected by the pandemic. In five hilsa fish sanctuaries, rivers and estuarine areas, there was a fishing ban during the early months (March – April) of the pandemic. In marine areas, the bans are from 20th May – 23rd July. The respondents of face-to-face and key informant interviews have revealed mixed opinions on whether the hilsa fish production has positively or negatively impacted. Those who were on the positive side argued that due to the pandemic there was lesser illegal fishing or overfishing of juvenile hilsa (locally called jatka) which will ultimately result in higher hilsa yield. However, those who are on

Table 2
Perceived impact of the novel coronavirus in different sub-sectors of aquaculture and fisheries in Bangladesh based on an online questionnaire survey (n = 118).

Sub-sectors	Positive impact (%)	Neither positive nor negative (%)	Slightly negative impact (%)	Moderately negative impact (%)	Highly negatively impact (%)	Severely negative impact (%)
Pond aquaculture	4	18	38	25	9	6
Shrimp aquaculture	5	10	16	22	28	19
Crab aquaculture	3	14	19	19	22	23
Haor fisheries	13	21	28	24	8	6
River and floodplain fisheries	20	23	25	20	9	3
Estuarine and coastal fisheries	20	20	21	26	9	4
Marine off-shore fisheries	13	20	19	18	22	8
Shrimp/Prawn processing plant	2	10	20	10	25	33
Fish drying business	4	15	20	22	22	17
Fish feed factories	3	16	19	25	21	16
Fish hatcheries	5	15	22	16	27	15
Shrimp/Prawn hatcheries	3	13	18	19	28	19
Auctioneer *(Aratdar)*	5	10	29	18	26	12
Fishers	3	12	25	22	25	13
Fish farmers	3	11	24	25	18	19
Fish traders	5	11	28	22	17	17
Fish consumers	6	20	31	20	15	8
Fish habitats	41	25	12	7	7	8

the negative side observed that the pandemic left less patrolling and surveillance by law enforcers resulting in an increased level of illegal fishing during these ban periods. Unlike the city dwellers, some fishers are relatively less bothered of the pandemic and continue to fishing both during (to some extent) and after the ban period. One fisher in Hizla, Barishal said, *"The patrol police usually arrest the fishers who catch fish illegally. But during the pandemic, the patrol police are keeping a distance from the fishers and they do not arrest the fishers rather they sometimes confiscate the fishing gears*". This reluctance in patrolling and surveillance may lead to both growth and recruitment overfishing and ultimately leave less total yield afterwards.

Like other fishery, the transportation and marketing of hilsa fish were affected by the pandemic. During the early months (March-April) of the halt of transportation due to the pandemic, the fishers struggled to market the fish. The transport restriction was eased later for fisheries alongside some other products. These, however, were not able to guarantee a better selling price for them as there was less demand for fish, especially in the city markets – their biggest consumer of fish. Usually, the first day of the Bengali calendar 'Pohela Boishakh' (14th April) marks a huge surge of the sale of hilsa fish due to its cultural significance among the Bangalees. But in 2020, this programme was postponed by the government due to the pandemic leaving no demand for this fish. One of the FGD participants in Gosairhat, Shariatpur said, *"Each year, we used to sell a huge amount of hilsa for the celebration of Bengali New Year and gain a lot of profits. But this year, the demand was dramatically decreased as the programme was postponed due to coronavirus. This pandemic results in severe loss of profit from hilsa fishing"*.

4.5. Impact on off-shore marine fisheries

The pandemic may have resulted in slightly positive impacts on the off-shore marine fish stock. The participants of KIIs and FGDs have revealed that the positive impacts are because of fewer disturbances by humans due to lockdown and labour shortage. Other countries, for example, India is also experiencing a possible benefit and break in the marine ecosystem which positively impacted the overall stock of fish [46] but with a negative impact on fishers and other workers due to wage reduction, unemployment and loan cycle [28]. However, like estuarine and on-shore fisheries, the fishers along with the investors suffered from a loss due to similar reasons like transport restrictions, reduction of demand and price, and lack of storage facilities of fish, etc. An increased level of illegal, unreported and unregulated fishing was also observed around the world [17]. As each fishing trip in off-shore fisheries requires 25–35 crew members in a typical boat which increases the likeliness of COVID-19 infection [20]. An outbreak on a fishing vessel out at sea for a long period (about two weeks) could bring serious consequences where there is no immediate treatment of COVID-19 [47].

4.6. Impact on fisheries-related industries

4.6.1. Impact on feed industry

The pandemic has considerably impacted the fish feed industries due to the crisis of raw materials and labours, lesser sale of feed, increased transportation cost (20–60%), and more operating cost to maintain health guidelines and social distancing, which have in turn forced the factories to increase the feed price. About 25% of survey respondents reported that the impacts of the pandemic in fish feed industries are moderately negative. Besides, KIIs have revealed that the pandemic has forced to shut down the factories temporarily leaving an economic crisis to the workers. Once reopened, maintaining health guidelines and social distancing inside the factory is somehow difficult which has hindered the production process. Difficulty in the transportation of the feed in the market has increased the unit price of the feed. One finfish hatchery manager in Kalapara, Patuakhali said, *"Commercial feed price has increased because of coronavirus impacts. Now we have to pay more money for the same amount of feed that we bought before the coronavirus outbreaks"*.

4.6.2. Impact on hatcheries

The fish and shellfish hatcheries are affected by the pandemic due to the decrease in the sale price of fry and shortages of labours, increase in transportation cost and increase in the cost of maintenance to follow health guidelines and social distancing. One of the hatchery owners has reported that the demand for new fry/fingerling has decreased drastically as much of the farmer's previous season's fish are left in their culture ponds unsold. One government official from the district of Bhola said, *"The demand for fish seed has reduced by nearly 50% this year [2020] during the start of fish culture period"*. Most of the survey respondents have identified that the impact of the novel coronavirus in fish and selfish hatcheries are highly negative. Like other sectors, the transportation of fry throughout the country has been disrupted seriously due to this pandemic. The hatchery managers have reported that unavailability of the regular labours has brought a crisis to the hatcheries and forcing them to hire temporary labour daily. Labour cost has increased as sometimes the hatcheries are paying whole days' payment just for the work of two to three hours. These situations may worsen over time unless some recovery actions are taken.

4.6.3. Impact on shellfish processing plants and export

The shellfish (mainly shrimps and some prawns and crabs) processing plants are export-oriented and are impacted by the pandemic mainly due to cancellation of orders by the buyers and increased operating cost. The buyers are continuously cancelling their orders due to safety issues. According to the KIIs, in Khulna region alone between March and June 2020, 41 out of 70 shrimp processing plants have stopped production and another 29 are operating on a very limited scale. During the same period, the export reduced significantly with a 47% reduction of shrimp only in May-June 2020 [48]. Sixty-five percentage of reduction of export trade has also been observed in Turkey [26]. In this study, one crab export industry has mentioned about the cancellation of six orders from April-June 2020. Crabs and other shellfish factories were forced to decrease their production amount as they were not able to sell most of their products to the foreign buyers, very little demand in the local market and decrease of the product prices (see Section 4.2). There has been a 50% decrease in the price of prawn in the Philippines due to export reduction [42]. The import of live, fresh and chilled seafood in the US has declined by 37% due to a drop in consumer demand [22]. Export markets in US, India and other export-oriented countries have also reported a disrupted trade of seafood resulting in a price decline [21,49]. The seafood system instabilities and travel restrictions significantly impacted the migrant fish workers of industrial fisheries in Thailand, Taiwan [50] and many Southeast Asian countries leading to a shortage of manpower [21,41]. Thirty-three percent of the survey respondents in this study predicted a severe negative impact on shrimp/prawn processing plants due to novel coronavirus outbreak. The industries are ensuring the social distancing of the workers, providing masks, gloves, and soap/hand wash/hand sanitisers and are being more careful regarding safety issue than the usual time which is increasing the operating cost to some extent. However, the industries have no long-term plans to recover the impact. The export industry of other countries such as Turkey was also immediately hit by the novel

Fig. 4. Impacts of coronavirus in the aquaculture and fisheries sector of Bangladesh (summarised from Sections 4.1–4.6).

Table 3
Impacts of Coronavirus on various fishery and aquaculture dependent stakeholders of Bangladesh (source: in-depth face-to-face interviews, key informant interviews and focus group discussions).

Livelihood capital	Identified impacts of COVID-19 on fisheries and aquaculture	Impacts of covid-19 on stakeholders			
		Fishers	Fish farmers	Fish traders	Fish auctioneers
Natural	Reduced fishing disturbance temporarily in natural water body in early months of the pandemic	√	×	×	×
	Increased fish culture period	×	√(85)	×	×
	Reduced fish stocking in aqua-farms	×	√(45)	×	×
	Aquaculture continued but at a reduced level	×	√	×	×
	Reduced fish supply in the market/auction centre	√	√	√	√
Human	Children's education hampered severely as schools were closed for long time	√(95)	√(90)	√(90)	√(50)
	Reduced food intake (three meals to two meals per day, mostly for the female household members)	√(70)	√(35)	×	×
	Dramatically reduced nutritious food intake	√(60)	√	×	×
	Increased level of non-COVID-19 diseases	√	√	√	√
	Inadequate medical supports for household members	√	√	×	×
	Insufficient foods and treatment for adolescences and pregnant women	√	√	√	×
	Increased level of mental stress for household members	√	√	√	√
	Lack of labour	×	×	×	√(35)
Physical	Selling of some physical assets to run the household	√(25)	√(15)	×	×
	Hardship in buying COVID-19 safety materials such as hand sanitiser, face masks, etc. due to financial crisis	√	√	√	×
	Had to provide increased amount of fish feed due to longer aquaculture period	×	√(80)	×	×
	Halt of transport during early months of the pandemic	×	×	√(65)	√(65)
Financial	Reduced income from fish selling	√(100)	√(100)	√(60)	√(50)
	Reduced income from non-fisheries related activities	√	×	√	×
	Debt increased and fell under debt cycle	√(35)	×	×	×
	Extra money required for maintaining health guidelines and buying soap, hand sanitiser, masks and gloves	√	√	√	√
	Extra cost required to cultivate the unsold fish in ponds	×	√(80)	×	×
	Increased cost for fish transportation	×	×	√(55)	×
	Reduced income due to shortening of marketing hours	√	×	√(50)	×
	Commission decreased due to less supply of fish	×	×	×	√(20)
Social	Domestic violence on females increased to some extent	√(30)	√(30)	×	×
	More family quarrel	√(45)	×	×	×
	More competition in fishing at later stage of COVID-19 due to return of factory workers to villages	√(35)	×	×	×
	Less options for family entertainment	√	×	×	×
	Not able to meet extended family members and friends during the pandemic period	√	√	√	√
	Very hard to maintain physical distance on boat while fishing	√	×	×	×
	Reduced political activities	×	×	√	√
Institutional	More illegal fishing due to less patrolling	√(30)	×	×	×
	Disruption of normal activities of fisheries association	√	√	√	√
	Reduced connection with government offices	×	×	√	√

*'√' means impacts have been reported; '×' means impacts are not found; and percent responses of stakeholders in parenthesis.

coronavirus crisis with a decrease in 7.89% of quantity and 7.43% of custom values of aquatic products (e.g. sea bass, sea beam, bluefin tuna and carp) [51]. However, with unbound restrictions all over the world, some processing plants are resuming their activities but there has been a decrease in production and workforce compared to the pre-coronavirus period [52].

4.6.4. Impact on fish drying industries

According to KIIs and FGDs, the dry fish processors mainly suffer from increased transportation cost, less availability of labours, less consumer demand and reduction of the markets price. The fish drying business in Bangladesh is having some troubles as the completion of the drying process requires human involvement due to the open sun drying method. The respondents of the questionnaire survey indicated that this sector has negatively affected to some extent due to coronavirus.

4.7. Impact on stakeholders and their livelihoods

Overall impacts of coronavirus on stakeholders of the aquaculture and fisheries sector are mostly negative (Fig. 4). The stakeholders include fish farmers, fishers, fish auctioneers (locally known as Aratdar who are also often known as investors) and fish traders. According to the survey respondents, these effects are negative (slightly to severely negative) on about 86% of fish farmers, 85% of fishers, 85% of fish auctioneers and 84% of fish traders (Table 2). Surprisingly about 74% of the survey participants mentioned the impacts of this pandemic are negative on fish consumers, despite the reduction of price. This may be because of the decrease in the purchasing capacity of the consumers due to the pandemic. In Turkey, the pandemic mostly affected the exporters with 65% decrease in trade quantity (kg) followed by wholesalers (35%) and retailers (fishing product 17% and aquaculture product 14%) [26]. In Indonesia, there was a 90% decrease in the number of active fishers and traders due to this pandemic [30].

This study has found that all of the stakeholders' livelihood capital has been affected due to the impacts of COVID-19 to some extent. The fishers and small-scale fish farmers – most of whom are poor – are amongst the worst affected by the pandemic. Similar observations were also found in Thailand and Kenya [29,43]. The income and livelihood of fishermen in Cyprus have been negatively affected by the pandemic though the wider economy was not significantly affected [11]. The participants of face-to-face interviews and FGDs have revealed that all the fishers', fish farmers', auctioneers' and fish traders' livelihood capitals, activities and strategies, and the outcome are affected negatively because of the pandemic (Table 3). Based on the findings, this

Table 4
Priority level of different sub-sectors of aquaculture and fisheries sector for government loan scheme recommended by questionnaire survey respondents (n = 118).

Loan category	1st priority to give loan (%)	2nd priority to give loan (%)	3rd priority to give loan (%)	No loan to be given (%)
Fishers	57	29	11	3
Small-scale fish farmer	73	19	6	2
Large-scale fish farmer	43	38	14	5
Shrimp farmer	76	20	3	1
Crab farmer	53	34	11	2
Aratdar	9	27	39	25
Wooden boat and net owner	18	40	30	12
Industrial fishing vessel	20	33	27	20
Shrimp/prawn processing plant	31	34	21	14
Fish feed factories	26	35	25	14
Fish hatcheries	48	35	14	3
Shrimp/prawn hatcheries	52	32	13	3
Fish drying businessmen	21	43	26	10
Fish traders	25	39	29	7

study shows that all of the stakeholders financial capitals (e.g., reduced income, disruption of financial activities, etc.) are highly affected by the adverse impacts of COVID-19 followed by human (e.g., disturbance of child education, reduction of food consumption, etc.), social (e.g., weakening of family relationship, gender impacts, etc.), physical (e.g., hardship to buy safety equipment, sale of productive physical assets, etc.), institutional (e.g., hampering normal activities of fisheries association, etc.) and natural capitals (e.g., reduced fishing disturbance in natural water system, prolonged aquaculture period, etc.).

Most of the stakeholders reported that their income has reduced due to the impacts of COVID-19. Because of reducing income due to shortening of marketing hours, increasing cost for fish feed and transportation, and extra cost for buying soap, hand sanitiser, masks and gloves, all stakeholders are affected miserably. About 35% of the fishers reported that their debt has increased as they could not repay the loan instalment. Fish traders and auctioneers' income has reduced comparatively less than the fishers and fish farmers. The fish auctioneers are mainly affected by the 50% decrease in fish supply in the auction centres and 35% decrease in labours supply. A typical fish auctioneer often provides advanced money (locally known as dadon) to boat owners, fishers and fish farmers under the condition of supplying a certain amount of fish which need to be sold only in the respective auctioneer's auction centre. One of the auctioneers in Mehendiganj, Barishal has reported during the face-to-face interview that due to the pandemic less fish has been supplied to the auction centres which has resulted in reduced commissions for the catch.

In the case of human capital, most of the stakeholder's children's education is disrupted because of long-term closure of the schools. Though online-based classes are started at the later stage of the pandemic, most of the children could not able to join due to lack of internet access, computer, TV, smartphones, etc. This access is very low in case of poor root level fishers, fish farmers and fish traders (Table 3).

There has a *gender* dimension of the pandemic impacts among the stakeholders. The female members of the fisheries-dependent households are more affected by the pandemic than the males. For example, 70% of fishers' and 35% of fish farmers' female household members reduced food intake from three meals to two meals per day to overcome the adverse situation of the pandemic periods (Table 3). Adolescences and pregnant women are suffered due to a lack of nutritious foods and proper treatment. Other studies also reported that the female members of the households are particularly the worst victim to the pandemic [53]. The pandemic is thus identified as a shock to their livelihoods.

4.8. Developments of COVID-19 situation

Since the invasion of the pandemic in March 2020, several months have passed with many people still affected and many valuable lives departed. The government of Bangladesh has imposed many restrictions and guidelines to control or minimise the COVID-19 outbreaks in the country. But as the economy of the country cannot be kept in halt for long, the government opened all the activities by maintaining strict health guidelines. Like other departments, in the early stage of the pandemic, the fisheries activities of the country has been exempt from the restrictions like other countries [21] and the fisheries officers were instructed not to leave the stations until further notice. Avoiding any physical contact or strict social distancing (3 feet distance between two people) must be maintained in providing any extension service to the fishers or fish farmers. On October 25, 2020 'no mask no service' policy has been implemented in all government and private offices and organisations mainly to face the second wave of the pandemic. Upazila (sub-district) fisheries officers have been guided to provide COVID-19 health guidelines before starting any training to the fishers or fish farmers. Key informants reported that fishers and fish farmers have started to take the 4% loan scheme and all the banks of Bangladesh (both government and private) have been instructed to provide the loan. Some fishers are migrating their previous loan to this scheme. However, respondents also reported that in some areas, banks are refusing to provide the 4% loan scheme to the fishers even after showing the testimony certificate from the upazila fisheries office. Government is also planning to provide compensation money to the damaged shrimp/prawn farm owners. Aquaculture production in November 2020 may again back to an increased level in some districts, but farmers are claiming to face 20–40% reduction (species wise) in price because of the change in market condition and loss of connection to the wholesalers due to COVID-19. The second wave of COVID-19 has already hit Bangladesh in March 2021, resulting more daily infected people and more death reported compared to the previous year. The government of Bangladesh has again imposed lockdown measures from 14th April to 21st April by shutting all the government and non-government organisations (except some industrial organisations), financial institutions, all types of public transport leaving only the emergency services like food, medicine, agricultural and other emergency services. Considering the current

coronavirus and future similar situations more short- and long- term recovery plans are needed.

4.9. Recovery policy and plan from the coronavirus pandemic

There need to have a short-term recovery plan to tackle the immediate needs and long-term plan to ensure a more durable recovery. Both quantitative and qualitative impact assessments are imperative in long- and short-term responses and adaptations [44]. Database development and accessibility of fisheries data should advance for supporting fisheries management [29]. Besides, the government's intra-departmental, intra-institutional and community collaboration are also essential in advancing policies regarding fisheries resource management [16,21, 54]. Below are some recovery plans based on in-depth face-to-face interviews, KIIs, FGDs and authors' own assessment:

a) **To tackle the disrupted transportation systems and increased transportation costs,** the government allowed the transport of fishery products from May 2020 and eased the general travel restriction from June 2020 on condition of maintaining health guidelines i.e. wearing mask and sanitising hands from time to time. Uninterrupted transport and logistical support are necessary for an effective supply chain of fish [21] in both national and international markets. The FAO, the World Trade Organization (WTO) and the World Health Organization (WHO) have suggested for a joint effort in securing continuous trade flow by preventing border restriction in food trade [16]. Continual access and cooperation from the port, rail and border officials can also ensure easy access of oversea supply chain [16].

b) **To reduce the higher maintenance costs of farms and industries** due to the pandemic, locally made (handmade) safety materials could be prepared following the standard guidelines by WHO and Government of Bangladesh. It is now been proved that locally made cheaper cloth masks could be almost equally effective as branded ones if used with other safety measures i.e. social distancing, frequent hand washing and disinfecting touched surfaces [55]. If needed a guideline and app/online-based training could be developed which will be applicable to the local contexts. In addition, where applicable, the farms and fishery industries could adapt themselves to more mechanisation to reduce the labour requirement. They could also introduce flexible working time for the labours to get a service at a low cost. The fisheries farms and industries should have long-term plans and policies on how to tackle similar types of impacts in future.

c) **To save the fisheries stakeholders from less demand for and price of fish,** the responses from face-to-face interviews and KIIs have emphasised to include fish in the list of aid that the government is providing to some people. In this case, the fish need to be bought directly from the small-scale fish farmers or fishers, especially who are the worst affected by the pandemic. FAO [16] and Bennett et al. [17] also recommended fish purchase for institutional use and increase local sales by online deliveries, direct marketing and deliveries, community support etc. Other studies in India, Southeast Asia and even the developed countries like the USA also suggested similar recommendations [21,41,49]. Nutritious foods are being highly recommended to tackle the COVID-19 [56] and fish is amongst the most nutritious food consumed. The market chain can be subsidised by officially buying fish and fish product to provide in an emergency food relief programme [30]. According to local media, the online and social media-based fish marketing is progressively getting popularity as the consumers are getting better fish at a reasonable price and without direct interaction with people. However, there are still some barriers and lack of training and transparency and accountability. These barriers need to be removed and the online marketing system needs to scale up especially by involving the private sector and unemployed youths. Besides, the shortened marketing channel of this marketing system can greatly reduce the risk of COVID-19 infection. Strong community collaboration, in this case, might help in selling fish through online marketing system. In addition, the market needs to be kept open for a considerable amount of time preferable like pre-pandemic time. Some of the countries e.g. Thailand, Viet Nam, are easing the lockdown process and reopening the food businesses ascending the demand for fish gradually [47]. Fish traders in this study suggested reducing market commissions during this pandemic period.

d) **To reduce the cost of fish feed,** the feed companies are asking to ease the transportation system and withdraw/reduce VAT on imported ingredients. Use of more local raw materials and ingredients that require less transportation could also be tried.

e) **To reduce the price of fish seed,** the FGD participants suggested reducing VAT on the imported materials used there. In addition, the government could interfere directly by supplying cheaper labour or providing direct incentives. Local fishery office could negotiate with the hatchery owners to ensure the reduced price of the seeds. If it is not possible to reduce the price of fish feed and seed, the fish farmers could reduce the stocking density temporally and resume again when the market price of fish feed and seed becomes reasonable and they could make enough profit from selling their fish.

f) **To enforce the regulations** properly that has been dwindled due to the pandemic, the law enforcers need to be supplied with quality safety materials and flexible working hours. In addition, monitoring systems need to be more technology-based and digitalized. For example, instead of physically visiting in some fish ban areas close circuit camera or censors could be installed. FAO also suggested remote surveillance and non-observer monitoring system containing cameras, log-books, electronic reporting system to increase the control, monitoring and surveillance of fishing activities [16]. Citizen science programme could be scaled up to get data directly from local people. Guarding the hilsa sanctuary by the communities themselves has worked before [57]; this could be scaled up in other areas. The environmental regulation system in freshwater fish biodiversity needs to be maintained and strengthen soon after the economic reinstatement [58].

g) **To get rid of cancellation of orders by foreign shellfish buyers** more efforts need to be given to ease the transportation system and exporting channel. The buyers need to be convinced through bilateral and multilateral talks. Quality needs to be ensured for the export products by following the additional requirements imposed by the buyer given in the pandemic situation. Government interventions are necessary for prioritising the seafood export subsector [22] and working with international supply chain logistics for the smooth movement of export products [21]. Demirci et al. [26] proposed for central Enterprise Resource Planning (ERP) system in Turkey, a process to manage and integrate the business components, which can help in adjusting the problem associated with fisheries industries arisen due to pandemic. In India, Kumaran et al. [24] recommended for a forecasting system of national and international shrimp market demand and price through updated communication portal to

stabilise the processing and marketing channel as an immediate mitigation measure. Meharoof et al. [21] also suggested similar recommendation for Indian seafood industry by making informed decision to reduce uncertainty in international trade through the accurate and timely communication of supply and stock of fish and fisheries-related products. As a medium-term mitigation measure, Kumaran et al. [24] suggested to establish a preservation facility and promote domestic marketing of shrimp.

h) **Urgent guideline needs to develop** for fish hatcheries, feed industries, processing plants and fish farmers. The respondents of face-to-face interviews, KIIs and FGDs have revealed that currently, the stakeholders are clueless about what should be done to save their business and livelihoods. Thus, specific guidelines are needed.

i) **Segregate and separate fish market** from other goods and extend marketing hours, where possible and practical.

j) **Provide subsidy/incentives/loan to the stakeholders** as much as possible. Support from the government to the vulnerable community is necessary to sustain the economic consequences of the novel coronavirus pandemic [59]. Government of Bangladesh has already announced to provide 589,894 USD at 4% interest rate. The beneficiary selection process and the entire loan providing process need to be fair and transparent. The stakeholders are not sure who will get how much and when. They added that there should not have a condition for collateral, bank solvency, and other strict regulations to get the loans. Targeted subsidy packages (e.g. aid, loan) can play a substantial role in supporting fishers and fish farmers living in vulnerable situations [17,22,49]. There are several loan and aid schemes in the USA for the COVID-19 affected communities [49]. The Indonesian government has allocated 69 million USD which is 18% of its 2020 budget in aiding the pandemic affected fisheries stakeholders, poaching surveillance and international fishing industry auditing [30]. India has announced approximately 267 million USD for five year period to facilitate the aquaculture production by strengthening value chain, increasing employment and income, and economic and social security of the fish farmers [24]. The questionnaire survey depicts that the small-scale fish farmers and open water fishers should be given the priority to provide the loan (Table 4). However, there might have some pro-poor households who might need direct cash as a donation. Different donors, international credit organisations, as well as the richer section of the society could be approached as the fishers and fish farmers are amongst the poorest group of people. The fishery-related industries such as hatcheries, feed factories, processing plants are eligible to take loan with relatively low interest from other sources. However, as the overwhelming impacts of the pandemic, they should also be included in the subsidy or very low-interest credit especially to help reduce the input cost for aquaculture. While providing the loan or any support, it needs to ensure that the loan meets the economic, social and environmental sustainability.

k) **The shortage of government staff** may be one of the main barriers to implement the recovery plans and some extra staffs could be employed temporally to help the current staffs. Fisheries students could be used here who are younger and may be less affected by the pandemic while they will gain a practical experience to serve the people during difficult times.

l) **For the long-term solutions to such threats, the government should increase the budget** for the fisheries sector. Currently, it is 0.56% of the national budget combined for fisheries and livestock sectors [60]. Each sub-district of fisheries gets generally only 589.89 USD annual revenue budget, whereas, the agricultural sector gets about 58,989.40 USD annual revenue budget. The budget for fisheries is used to train the fish farmers or fishers. There are some development/extension projects in some sub-districts. But there are a lot of other important things that need to be done to ensure sustainability as well as to tackle foreseeable future shock.

m) **A fishery bank needs to establish** to provide loan only to fishery stakeholders. Although the industries related to fisheries get loans from different banks, small-scale fish farmers and almost all the open water fisheries stakeholders (e.g. fishers, boat owners and auctioneers) usually do not get a loan from any bank. Many of them take micro-credit from NGOs which has a higher interest rate and very inadequate amount with unfavourable terms and conditions. Most money is supplied by local people informally with very high interest [7] due to financial illiteracy, collateral deficiency, geographic barrier and lack of formal identification [61]. Formal financial services which support and strengthen the small-scale local fishers can help in building financial resilience to the vulnerable fishing communities [61]. In Bangladesh currently, there are 60 scheduled banks but none is dedicated for fisheries. A fishery bank establishment is thus utmost important to look into the interest of the aquaculture and fisheries sector.

n) **Extra job pressure by outsiders needs to be managed.** If the pandemic continues for a longer period, the jobless people most of whom are in low-income groups will create more pressure on natural resources as also presumed by Stokes et al. [18]. Thus, more people may engage in fishing from different natural habitats creating overfishing by imposing threats to the sustainable fisheries stock in the open water body and damage to the value chain and market. India is facing a similar problem of intensified pressure on aquatic wildlife due to COVID-19 induced extreme poverty [62]. This extra pressure by the outsiders needs to be managed in the near future to avoid an even bigger disaster.

o) **Making the fisheries and aquaculture sector resilient** by investing, for instance, on transformational livelihood strategies, education and health so that the sector can withstand shocks and can be able to bounce back. Kaewnuratchadasorn et al. [41] also emphasised on enhancing the fisher's capacity by creating alternative livelihoods and alternative marketing system in Southeast Asian regions.

p) **It is important to bring the stakeholders, the industries and the resources under insurance.** Currently, the insurance includes only a few cases for example in the deep-sea fishing industry but the vast majority is outside the coverage. In India, a large number of migrant workers work in fisheries were immediately impacted in COVID-19 pandemic. Kumaran et al. [24] suggested for minimum wage, health coverage, life insurance and gratuity for the migrant workers in the fisheries sector. FAO [16] also suggested providing payroll and unemployment assistance for small fish farmers and crew members.

q) **Degradation of the aquatic ecosystem due to excessive use of surgical face mask, disinfectants, hand sanitiser and other pharmaceutical chemicals needs special attention**. Surgical mask, a solid waste macro-plastic, ultimately end up as micro-

plastic in the aquatic ecosystem are ingested by fish and aquatic microorganism needs scientific research and awareness programme to reduce the threat [63].

r) **At every step of the recovery process, it needs to be ensured that it does not increase the risk of COVID-19 infection** rather decreases it, by following proper health guidelines and social distancing.

s) **Finally, it is important to ensure that the recovery processes are fair and equitable and environmentally friendly**.

5. Conclusions

This study assesses the impacts of the novel coronavirus in the aquaculture and fisheries sector of Bangladesh from the period March to November 2020 and suggests possible recovery plans. Following a mixed-method approach, this study identified differential impacts on the stakeholders of different sub-sectors of aquaculture and fisheries. The main impacts include increased costs for fish feed ingredients, cultivation, transportation and maintenance; reduced fish seed stocking and aquaculture production; reduced fish demand and price; and cancellation of shrimp and crab orders by foreign buyers. There are slightly positive impacts on aquatic ecosystems and openwater fish stock because of less disturbance of fishing activities due to COVID-19 outbreaks, despite reduced enforcement of fishery regulations. The small-scale fish farmers and fishers most of whom are poor are amongst the worst affected with reduced livelihood capitals and activities resulting in degraded livelihood outcome.

Given the increased level of significant negative impacts of this pandemic with time, the fishery-dependent stakeholders cannot afford to wait till the pandemic is over. Likewise, they have started to recover on their own with little support from outside. A set of plans are needed at different time-scales to help them recover. The short-term recovery plan needs to focus on reducing the input cost of aquaculture and fisheries and facilitating the poor fishers and fish farmers to sell their products at a reasonable price. In the long-term, the sector needs to be made more resilient to shocks by more financial investment and developing human capital, markets and technology. However, any interventions need to consider not only the economy and overall livelihoods development but also to equity, inclusiveness, gender, fairness and environmental sustainability.

This is the first study of its kind in Bangladesh and tries to cover the whole aquaculture and fisheries sector for a given period. Thus, it was beyond the scope of this study to conduct an in-depth analysis of each of the sub-sectors, which the future study should consider to develop a comprehensive recovery plan.

Nonetheless, the findings and suggestions of this study may have important implications to prioritise, plan and implement the actions to recover the aquaculture and fisheries sector of Bangladesh from this pandemic. Many developing countries have similar transport, fish culture, fishing and marketing systems like Bangladesh. Besides, with poor per capita income and higher dependency in natural resources, developing countries are experiencing crux during this pandemic with a considerable amount of population having no jobs, incomes or savings and limited opportunity to practice social distancing and good hygiene. This study may help them as well to identify the problems and recover. Developing countries in West Africa, Brazil, India and Myanmar have already started collecting data using different electronic and online tools. This study can aid their effort and facilitate the journey of sustainable development.

It seems that it will take at least a few years (or will never go away) to eradicate the COVID-19 from developing countries when the vaccine develops. In this case, the whole aquaculture and fisheries system need to adapt to the 'new normal' situation. The sooner the whole world learns to live competing with the impacts of coronavirus the better. Thus, the fishery-related stakeholders would not wait longer for the COVID-19 situation to be fixed to restart the activities rather need to make quick planning using a scenario planning approach, i.e. plans for the scenario when coronavirus is still infecting as is now, plan for the scenario when the virus isn't infecting that much but still, there are some restriction and plans for the scenario when there will be no infection or risk of infection from this virus.

CRediT authorship contribution statement

Md. Monirul Islam: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Supervision; Writing - original draft; Writing - review & editing. **Makidul Islam Khan**: Data curation; Formal analysis; Investigation; Methodology; Validation; Writing - original draft; Writing - review & editing. **Aparna Barman**: Data curation; Formal analysis; Investigation; Methodology; Software; Validation; Writing - original draft; Writing - review & editing.

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Declarations of interest

None.

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