Marine Policy 129 (2021) 104523

Contents lists available at ScienceDirect

Marine Policy

journal homepage: http://www.elsevier.com/locate/marpol

Full length article

COVID-19 impacts and adaptations in Asia and Africa's aquatic food value chains

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ARTICLE INFO

Keywords:
COVID-19
Value chains
Fisheries and aquaculture
Food and nutrition security
Livelihoods
Adaptation

ABSTRACT

The COVID-19 pandemic is a shock affecting all areas of the global food system. We tracked the impacts of COVID-19 and associated policy responses on the availability and price of aquatic foods and production inputs during 2020, using a high frequency longitudinal survey of 768 respondents in Bangladesh, Egypt, India, Myanmar, Nigeria. We found the following: (1) Aquatic food value chains were severely disrupted but most effects on the availability and accessibility of aquatic foods and production inputs were short-lived. (2) Impacts on demand for aquatic foods, production inputs, and labor have been longer lasting than impacts on their supply. (3) Retail prices of aquatic foods spiked briefly during March-May 2020 but trended down thereafter, whereas prices of production inputs rose. These trends suggest a deepening 'squeeze' on the financial viability of producers and other value chain actors. (4) Survey respondents adapted to the challenges of COVID-19 by reducing production costs, sourcing alternative inputs, diversifying business activities, leveraging social capital, borrowing, seeking alternative employment, and reducing food consumption. Many of these coping strategies are likely to undermine well-being and longer-term resilience, but we also find some evidence of proactive strategies with potential to strengthen business performance. Global production of aquatic food likely contracted significantly in 2020. The importance of aquatic food value chains in supporting livelihoods and food and nutrition security in Asia and Africa makes their revitalization essential in the context of COVID-19 recovery efforts. We outline immediate and longer-term policies and interventions to support this goal.

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https://doi.org/10.1016/j.marpol.2021.104523
Received 15 January 2021; Received in revised form 26 February 2021; Accepted 2 April 2021
Available online 25 April 2021

1. Introduction

Capture fisheries and aquaculture are a vital source of employment, income, and nutritious food for millions of people in Africa and Asia. COVID-19 and policy measures to contain its spread have seriously disrupted food value chains due to disturbances in transportation, trade, labor mobility, logistics, and temporary closures of institutions (e.g. schools) and places of business (e.g. markets, restaurants) [1–5].

Though important for protecting public health, emergency containment measures have contributed to a severe global recession that has depressed consumer spending power. Between 90 million and 150 million people are predicted to fall into extreme poverty as a result [6]. Most of these poverty increases will be in sub-Saharan Africa and South Asia [7]. This trend has already had dire consequences for food and nutrition security. The number of people experiencing extreme food insecurity increased by an estimated 45 million from February to June 2020 alone [8]. Low-income consumers spend a large share of their earnings on food and are likely to substitute relatively cheap staple foods such as rice or maize for more costly nutritious non-staples such as meat, eggs and aquatic foods (e.g. fish, crustaceans) when incomes decline [9]. These trends are rapidly undermining decades of progress on key human development indicators, including the Sustainable Development Goals [10].

The COVID-19 pandemic is a systemic shock that affects all areas of the global food system. A growing range of impacts on aquatic food[1] producers, value chain actors, and consumers is evident. This includes disruptions to international trade in aquatic foods, reconfiguration of domestic food value chains, and exposure of fishers and seafood processing workers to COVID-19 infection [11], immobilization of migrant fishers and fishworkers [12], delays in accessing critical production inputs for aquaculture such as broodstock and seed [13,14], changes in levels of fishing pressure [15], fluctuating consumer and producer prices, changing product preferences, and reduced levels of production [11, 16,17].

Taking into account these emerging patterns, we hypothesized the following:

1. COVID-19 and associated containment measures will disrupt aquatic food value chains, affecting the supply of production inputs, labor, and transport/logistics.
2. COVID-19 and associated containment measures will inhibit the mobility of workers and consumers and reduce employment and incomes. This will lead to lower demand for aquatic foods and lower derived demand for aquatic food production inputs, such as feed and fish seed.
3. Combined supply and demand side shocks will affect availability and prices of aquatic foods and inputs for aquatic food production. Depending on the circumstances, these effects may be short-term (e.g. due to hoarding by consumers) or longer-term (e.g. due to delayed stocking of ponds by farmers). They might also drive prices up (e.g. due to inability to access production inputs), or down (e.g. due to sluggish consumer demand for aquatic foods).
4. The confluence of points 1–3 will drive adaptations in the behavior of actors in aquatic food value chains, and reconfiguration of the structure of these chains (e.g. such as through the accelerated diffusion of e-commerce [18]).
5. Effects will be spatially and temporally uneven. They will be shaped by place specific contexts that include COVID-19 infection rates, stringency of policy responses, and seasonality of production. Effects will also be socially uneven, shaped by factors including gender, economic status, type and scale of business operations, and degree of political influence.

Over the course of 2020, we tracked the impacts of the COVID-19 pandemic and associated policy responses on the availability and price of aquatic foods and production inputs across the entire aquatic food value chain in three Asian and two African countries (Bangladesh, India, Myanmar, Egypt, Nigeria), over the course of 2020. To gain further insight into how the effects of the pandemic were experienced and how those affected adapted, we conducted semi-structured phone interviews with 63 respondents in Bangladesh, and online interviews with 100 aquatic food value chain actors and key informants from 17 sub-Saharan African countries.

The results provide insight into the pathways by which aquatic food value chain actors have been affected by the crisis to date. These results give rise to policy recommendations aimed at mitigating impacts in the present, assisting recovery, and building a more resilient aquatic food system in future. Public health interventions continue to play an important role in saving lives, but the deepening economic crisis demands a renewed emphasis on protecting livelihoods and human nutritional status. We contend that the revitalization of aquatic food value chains can contribute to these goals.

The remainder of the paper is organized as follows: First, we present the survey methodologies. Second, we summarize information on rates of COVID-19 infection and the stringency of COVID-19 policy responses in each of the five countries included in the high frequency survey. Third, we present quantitative findings on supply side and demand side shocks, prices and availability of aquatic foods and production inputs, and qualitative findings on actor responses. We conclude with immediate and longer-term policy recommendations to support a fast and equitable process of recovery in which aquatic foods and aquatic food value chains play a central role in supporting livelihoods and food and nutrition security in Asia and Africa.

2. Methodology

2.1. Survey

We conducted a multi-country survey of aquatic food value chain actors (n = 778 in eight value chain nodes), covering the period from February to October 2020, in three Asian countries[2] (Bangladesh, India, and Myanmar) and two African countries (Egypt and Nigeria). These countries were selected because of high levels of aquatic food production and consumption, and the presence of WorldFish offices. In India, we conducted three separate surveys, covering the states of Andhra Pradesh, Assam and Odisha.

Health precautions and movement restrictions made it impossible to visit the field to select survey respondents. Respondents were therefore identified from existing contacts of WorldFish country offices, with additional snowball sampling where necessary. Care was taken to include actors operating at a range of scales, drawn from major aquatic food producing and consuming areas in each survey location, and to include a mix of women and men respondents. The sampling technique means that survey results can be considered indicative of broad temporal trends but are not nationally or sub-nationally representative.

Survey implementation took place in two stages. The first round was implemented in May and covered the months of February, March, and April. Recall data for February was collected to provide a pre-pandemic "benchmark" for assessing subsequent months. From May to June and onward, data was collected from the same set of respondents on a fortnightly or monthly basis, with each interview covering the period of

[1] The term 'aquatic foods' refers to all foods captured or farmed in water. For the countries and value chain actors studied in this paper, aquatic foods are comprised predominantly of finfish and crustaceans.

[2] We also conducted regular interviews with 22 respondents in Timor Leste, but these are excluded from the results presented here due to the small sample size.

the preceding calendar fortnight or month, respectively. Extra questions were added to the survey instrument at the beginning of this second phase, but the questionnaire remained unchanged afterward. To incentivize continuous participation in the survey, respondents were provided with mobile phone top up credit, worth approximately USD 2 following each completed interview. Where respondent attrition occurred, efforts were made to find replacement respondents with similar characteristics.

Surveyed actors included hatcheries (78), feed mills (27), feed sellers (98), fishers (125), farmers (244), processors, comprised mainly of fish driers or smokers (42), traders (77), and retailers (79).[3] The combination of value chain segments and total number of respondents interviewed varied slightly between survey locations, reflecting the types and numbers of actors present. In each location, enumerators conducted the survey by telephone and recorded responses using the KoBoToolbox digital data collection platform. Where relevant, the questionnaire was translated into the local language. The questionnaire structure was standardized across the countries to facilitate direct comparability of results, but response options were country-specific, such as species of fish and types of feed.

The survey instrument was divided into two parts: a general section, and an actor-specific section. In the general section, respondents were asked a common set of questions about employing workers, and access to inputs, transportation, and buyers. The second section was comprised of questions specific to the type of business the respondent operated. These included number of days operated and reasons for any suspension of operations, as well as the quantity and value of inputs procured and/or products produced or sold, which varied by type of value chain actor. Data was first cleaned, and then analyzed using the Microsoft Power BI platform, allowing results to be presented online in an interactive format for public use. The complete survey results can be accessed from the WorldFish COVID-19 webpage [19].

2.2. Qualitative interviews

We implemented a qualitative phone survey of aquatic food value chain actors in Bangladesh to capture more nuanced details on the context in which observed trends from the multi-country structured survey were embedded. A semi-structured interview guide consisting of 10 groups of open-ended questions was designed to capture information of how COVID-19 had impacted participants' occupations, businesses or livelihoods, and their adaptations to these changes, impacts on their food consumption, and the nature of any assistance or support received.

Telephone interviews were conducted in two rounds, in May and September 2020. A list of potential participants was generated based on the prior contacts of the research team and then recruited by phone. During the first round, 44 participants (39 men, 5 women) were selected purposively to capture a diversity of actor types, sizes of business operation, and geographical locations.[4] During the second round, all respondents from the first round were re-interviewed, and an additional 18 women and one man were recruited and interviewed, totaling 63 participants.

2.3. Online survey and key informant interviews

Simultaneously, we conducted a survey with 100 respondents working in aquaculture across 17 sub-Saharan African countries. During May invitations to participate in the survey were posted on social media platforms including the Sustainable Aquaculture Research Networks in Sub Saharan Africa Facebook page [20]. Respondents self-selected themselves as survey participants. Twenty interviews were conducted online or by phone. However, this approach proved difficult due to connectivity and language issues, so a short online survey form was fielded, and answered by 80 respondents from mid-June to mid-July. Survey design was coordinated to include questions covering topics similar to those in the two surveys described above.

3. COVID-19 pandemic impacts and policy responses in surveyed countries

The COVID-19 pandemic spread rapidly throughout the world after it was first recognized in China in December 2019. COVID-19 was first recorded in India in January 2020, in Egypt and Nigeria in February, and in Myanmar and Bangladesh in March (Fig. 1). Reported cases initially increased fastest in Bangladesh, Egypt, and India. Case numbers gradually stabilized from July in Bangladesh, Egypt, and Nigeria, but continued to rise fast in India. Infection rates were initially low in Myanmar but increased sharply from August. By October, India had by far the highest rate of reported infections among the five countries (7078 per 100,000 inhabitants) and Nigeria had the lowest (304 per 100,000). Bangladesh, Egypt, and Myanmar had intermediate levels (approximately 1000–3000 per 100,000).

Governments instituted a variety of containment policies and economic interventions intended to mitigate the impacts incurred by the pandemic and associated restrictions. Containment policies included a mix of phased full and partial "lockdowns" implemented at national (e.g. in India) or sub-national (e.g. in Myanmar) scales. To slow the rate of transmission, restrictions were placed on the movement of people, such as air transport and inter-state or intra-state movements by road. Operation of businesses and institutions such as markets and schools were severely curtailed, as were social gatherings like weddings, funerals, and religious or sports events.

The stringency of the application of these measures varied between countries and over time, as measured by a "response stringency index" (100 = most stringent). The index peaked in April and declined at different rates afterward in most countries (though it remained high in Myanmar where cases increased rapidly from August onward). This reflects policy choices made based on infection rates and economic and political considerations (Fig. 2).

Economic policies introduced to mitigate impacts incurred by the pandemic and the moves to contain it mainly took the form of: (1) economic stimulus policies targeting sectors of the economy such as exporters; (2) financial relief for businesses in the form of loans, debt relief or restructuring, and reduced fees and taxes; and (3) forms of social protection such as cash transfers to vulnerable households [23,24]. However, our results presented below suggest that the reach of such programs in the countries surveyed has been patchy, and the amounts of money disbursed often small.

4. Results

The results are structured in alignment with the hypotheses set out in the introduction. We compare selected results across surveyed countries and value chain nodes to identify common patterns and divergence. First, we evaluate general disruptions to aquatic food value chains, in terms of access to production inputs, buyers, transport, and employment. Second, we assess the impacts of these disruptions on prices and traded quantities of aquatic foods and inputs for aquatic food production. Third, we examine evidence of adaptive behaviors by actors in aquatic food value chains and how these are shaped by actors' social and economic status, drawing on the qualitative survey findings.

[3] The number of individual actors in listed here sums to 770 (two more than the 768 respondents noted in Section 2.1) because two actors changed business operations during the survey.

[4] The sample was not gender balanced, in part because many businesses in aquatic food value chains in Bangladesh are run by men, and in part because the team implementing the survey found it difficult to recruit women respondents willing to be interviewed at length by phone. Attempts were made to ensure a more gender balanced sample in the second round of the survey.

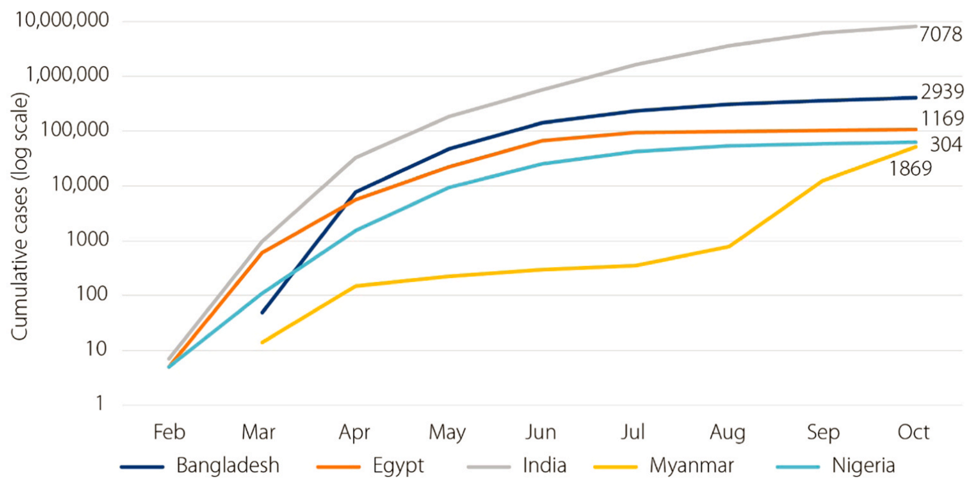

Fig. 1. Cumulative Covid-19 cases by country, February–October 2020, and cases per 1,000,000 inhabitants [21].[51]

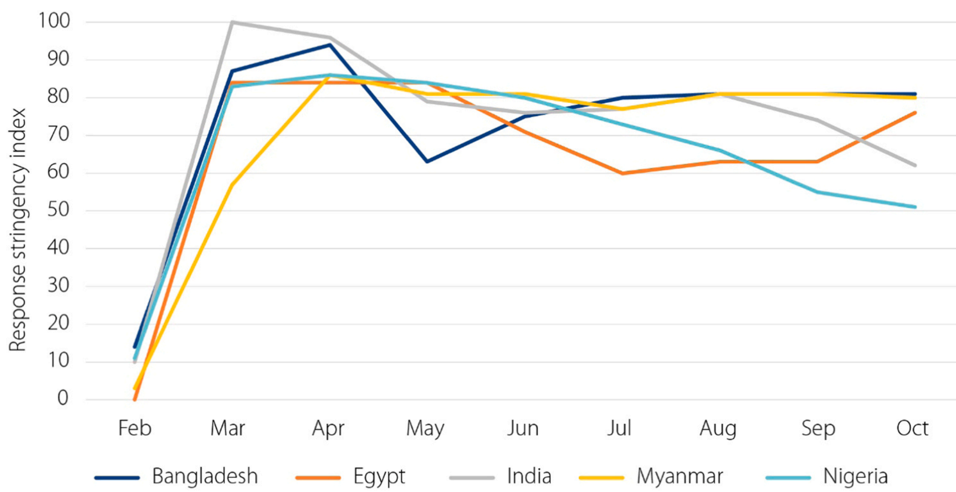

Fig. 2. COVID-19 response stringency index rating by country, February–October 2020 [22].[61]

4.1. Disruptions to aquatic food value chains

4.1.1. Purchasing and sales behavior

Bangladesh, India, and Nigeria experienced a "V shaped" supply side shock during early part of the pandemic. Our first indicator of value chain disruption is the share of respondents reporting whether they attempted to purchase inputs or sell products in each month (Fig. 3A,B). The largest impacts occurred in March and April during the height of lockdown restrictions. Nigeria and India were most severely affected; the share of respondents attempting to purchase inputs fell by 65% and 35% points, respectively, as compared to February. In both countries, this share did not reach or exceed pre-pandemic levels until August. Bangladesh recorded a similar though less pronounced trend, with a smaller initial drop in business activity and quicker recovery.

Impacts in Myanmar were initially rather limited, but the share of businesses attempting to make sales trended gradually downward until June, to around 20 percentage points below February's level, before recovering in August. Egypt followed the opposite pattern, with the share of businesses attempting to purchase inputs rising 25 percentage points between February and June. This trend reflects the relatively low incidence of COVID-19 infections in Egypt relative to other countries, and the highly seasonal nature of farmed fish production there, with production increasing from March onward as temperatures rise. In all five countries, the share of businesses attempting to sell products followed a similar temporal pattern to those attempting to buy inputs.

4.1.2. Access to buyers

Demand for aquatic foods and production inputs exhibited a "U-shaped" recovery in all countries except Myanmar. The ability to find customers is essential for businesses to continue their operations. We use the share of respondents able to find buyers for all the products they expected to sell as an indicator of access to customers. Businesses' access to customers can be mediated by mobility and access to transport for both buyers and sellers, and by the level of demand from customers. This dynamic is reflected in Fig. 3D.

The ability to find buyers follows a similar temporal pattern to the ability to access transport, but access to buyers is more deeply impacted and somewhat slower to recover than access to transport. By September, the share of businesses able to find buyers whenever anticipated had returned to February levels in only Egypt and Bangladesh, and fell again in Bangladesh during October. This suggests that lagged effects on demand persisted for several months after the most stringent rules imposed in response to COVID-19 were relaxed, and/or that new effects set in over time.

4.1.3. Employment

Demand for labor in aquatic food value chains followed a similar "U-shaped" pattern to demand for food and inputs. Enterprises in aquatic food value chains are important sources of employment and wage income for large numbers of people wherever clusters of these businesses exist, and hired labor is an important input for many enterprises in

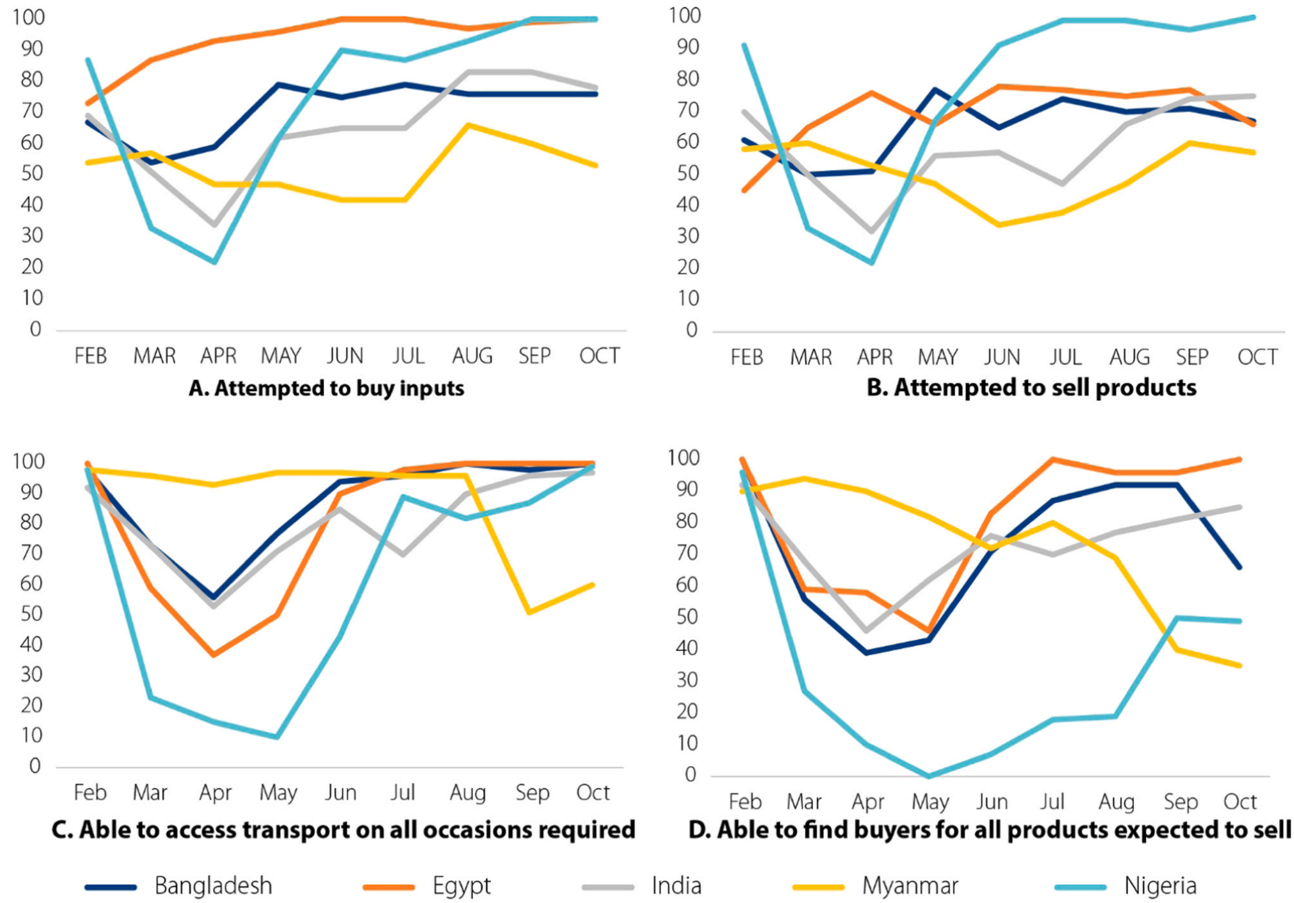

Fig. 3. Purchasing and sales behavior among respondents, February–October 2020 (% of respondents). N = 768.

aquatic food value chains [25]. The share of respondents employing casual workers fell below "baseline" February levels in most months in every country except Egypt, where the share of businesses employing workers increased over the course of the fish farming season, which runs from March to November.

On average across the five surveyed countries, the share of businesses employing male casual workers shrunk from 51% in February to 34% in April, and then climbed gradually again to reach 45% in October. Twelve percent of surveyed businesses reported hiring female casual workers in February. This share shrank to 5% in May and remained static before climbing to 10% in October (Fig. 4).

These figures suggest that COVID-19 had gender-differentiated impacts on men's and women's ability to access paid work in aquatic food value chains, with women's employment more severely impacted than men's. Further research is needed to understand and address the reasons for this trend. One possible explanation relates to the greater burden of unpaid care work falling on women during the pandemic, especially in the form of care for children removed from school as part of containment responses [26,27].

We asked respondents whether they had any difficulties hiring labor, in the expectation that health precautions and movement restrictions could reduce worker availability. About 15–18% of respondents experienced difficulties finding workers when needed between March and May, falling to 8% by October (similar to February levels), indicating that this was a temporary issue. This suggests that lower than usual rates of employment after May are mainly the effect of reduced demand for labor from businesses as they experienced reduced turnover or attempted to cut costs, with implications for the vulnerability of workers in these value chains.

Average nominal daily wages paid to workers climbed to a peak in July (15% higher than February levels for men, and 43% higher for women). Wages then declined to around February levels in October, when they stood at USD 5.05 and USD 3.73[7] daily, for men and women respectively – a large gender wage gap of 35%. Interestingly, reported daily wages for women workers converged with men's in July, possibly reflecting the retention of more skilled women workers and the shedding of less skilled positions. However, wage ratesdiverged again when employment rose.

4.2. Impacts on the availability and price of aquatic foods and production inputs

In this section, we summarize key results on quantities and prices of aquatic foods and production inputs traded in the five countries, from February to September 2000. For comparability, we normalized all values by creating indices in which February represents the base month for each country, with a value of 100. Deviations above or below this

[6] The COVID-19 response stringency index is created by the Oxford COVID-19 Government Response Tracker, which systematically collects information on 18 indicators based of common policy responses by governments to the pandemic, such as school closures and travel restrictions.

[6] The COVID-19 response stringency index is created by the Oxford COVID-19 Government Response Tracker, which systematically collects information on 18 indicators based of common policy responses by governments to the pandemic, such as school closures and travel restrictions.

[7] Calculated using a fixed April 2020 exchange rates, to control for exchange rate fluctuations.

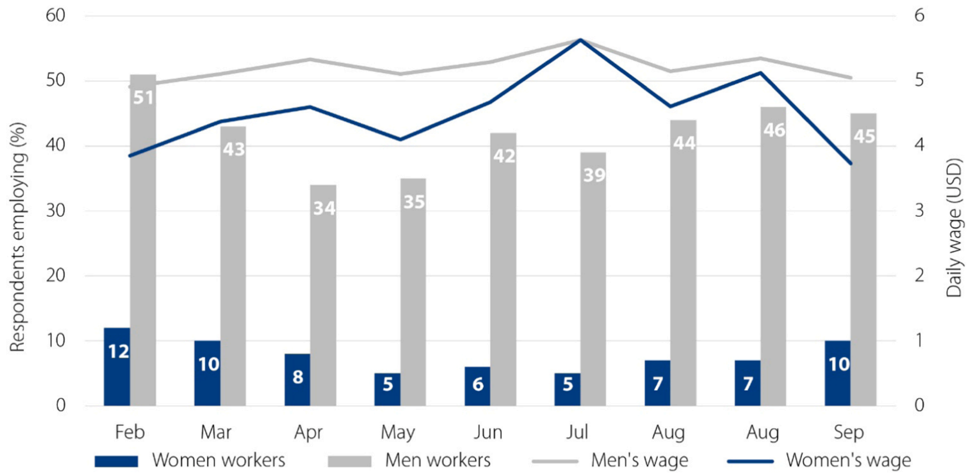

Fig. 4. Respondents hiring male and female casual workers (%) and average daily wage paid (USD), February-September 2020. N = 768.

value in subsequent months can be interpreted as percentage changes relative to the value in the base month.

In keeping with our value chain approach we first analyze, by country, prices and sales volumes of farmed fish in three value chain segments: upstream (farms); midstream (traders); and downstream (retailers),. We focus on farmed fish because it accounted for the bulk of fish produced and traded by respondents in the sample, making cross-country comparisons possible. We then analyze aggregate trends in the quantity, value, and price of selected inputs and products procured, produced, or sold by value chain actors including fishers, fish processors, hatcheries, feed mills, and farms.

4.2.1. Fish prices

Retail farmed fish prices peaked during the initial lockdown, but subsequently slumped due to low demand. Prices received by farms and traders have been depressed since the onset of the COVID-19 crisis. The following observations stand out.

First, in most countries, prices received by fish farmers and traders in most months were lower than before the onset of the COVID-19 crisis (Fig. 5A,B). Minor exceptions are Bangladesh and India, where farmgate prices exceeded those in February in 4 and 3 months, respectively, but by less than 20% in all but one case. In Nigeria and Myanmar, prices that traders received exceeded those in February by a small margin in 3 and 2 months, respectively. For all other countries and months, farms received between 5% and 35% less for fish sold than they had done in February. Across all countries and months, farmgate prices averaged 10% less than in February, with prices in India and Myanmar affected most strongly. A similar pattern is apparent for fish traders. Indian trader prices were affected particularly severely, averaging about half of February levels in most months. Across all countries, traders' sales prices averaged around 15% less than in February. This pattern is likely an effect of the slow demand evident in Fig. 3D, transmitted upstream from consumers, through marketing intermediaries, to producers.

Second, retail prices spiked during the first months of the pandemic but fell from June onwards (Fig. 5C). Retail prices rose by around 15% in most countries, and as much as 45% in Nigeria during the peak lockdown months from March to May. Divergence between producer and retailer prices during these months likely reflects increasing transport costs, paralleling difficulties in accessing transport (shown in Fig. 3C), as well as restrictions on wet market operations and consumers' tendency to stay home, heightening the chance of fish remaining unsold and becoming spoiled [1]. These costs and risks were likely passed on to consumers, some of whom may have been more willing accept them due to the reduced set of retail options available. However, in most months from June onwards, in most countries except Bangladesh, retail prices fell below February levels. This indicates that demand remained depressed after restrictions on transport and business operations eased, which is consistent with Fig. 3D. Egypt is a partial exception, with retail prices in June, July and August unchanged relative to February.

4.2.2. Fish sales

The quantity of fish sold by farms followed a seasonal trend but was lower than in a typical year. Fish sales by traders and retailers were depressed from March onward in most countries. We observe the following specific patterns: First, the trend in volumes of sales that fish farms made reflects the interplay of seasonality with the impacts of COVID-19 and related containment policies. The seasonal effect is most evident in Egypt, where only 8% of farms sold any fish in the 'base' month of February, before the onset of the COVID-19 crisis. Subsequent large increases in the farm sales index for Egypt reflect this low base, the ramping up of production and sales as temperatures rise in March, as well as the relatively moderate human health impacts of the pandemic the country during this period. In Myanmar, fish sales by farms followed a similar, though less pronounced, pattern of high sales relative to February, but contracted in August and September with the emergence of a 'second wave' of COVID-19 infections. Relative to February, volumes of fish sold by farms in India and Nigeria contracted in March-May. This likely reflects the severity of lockdown measures such as restricted interstate movement and market closures in both countries during those months. In most subsequent months however, sales volumes exceeded February levels, especially in Nigeria (Fig. 5D).

Second, the trader and retailer sales index for farmed fish fell in most countries and months, supporting the inference that consumer demand remained sluggish. In all countries except Myanmar, trader and retailer sales in March and April were lower than in February. This finding likely reflects the stringency of lockdown measures and incidence of COVID-19 infections, which were higher in Bangladesh, India, Egypt, and Nigeria during these months than in Myanmar (Figs. 1 and 2). The trader and retailer sales indexes remained above February levels in Myanmar in most subsequent months. In Nigeria, the trader sales index increased up to 10 times between May and September, compared to February. But for all other countries in most months, trader and retailer sales remained below or close to February levels. India's trader and retailer sales were particularly heavily impacted. On average, Indian traders reported selling about 75% less farmed fish in each month than in February, while retailers sold 45% less, suggesting that a dramatic reduction in fish consumption took place.

4.3. Production, procurement, and prices

Fig. 6A–C further illustrates the relationships between seasonality of supply and demand and COVID-19 impacts for fishers, processors,

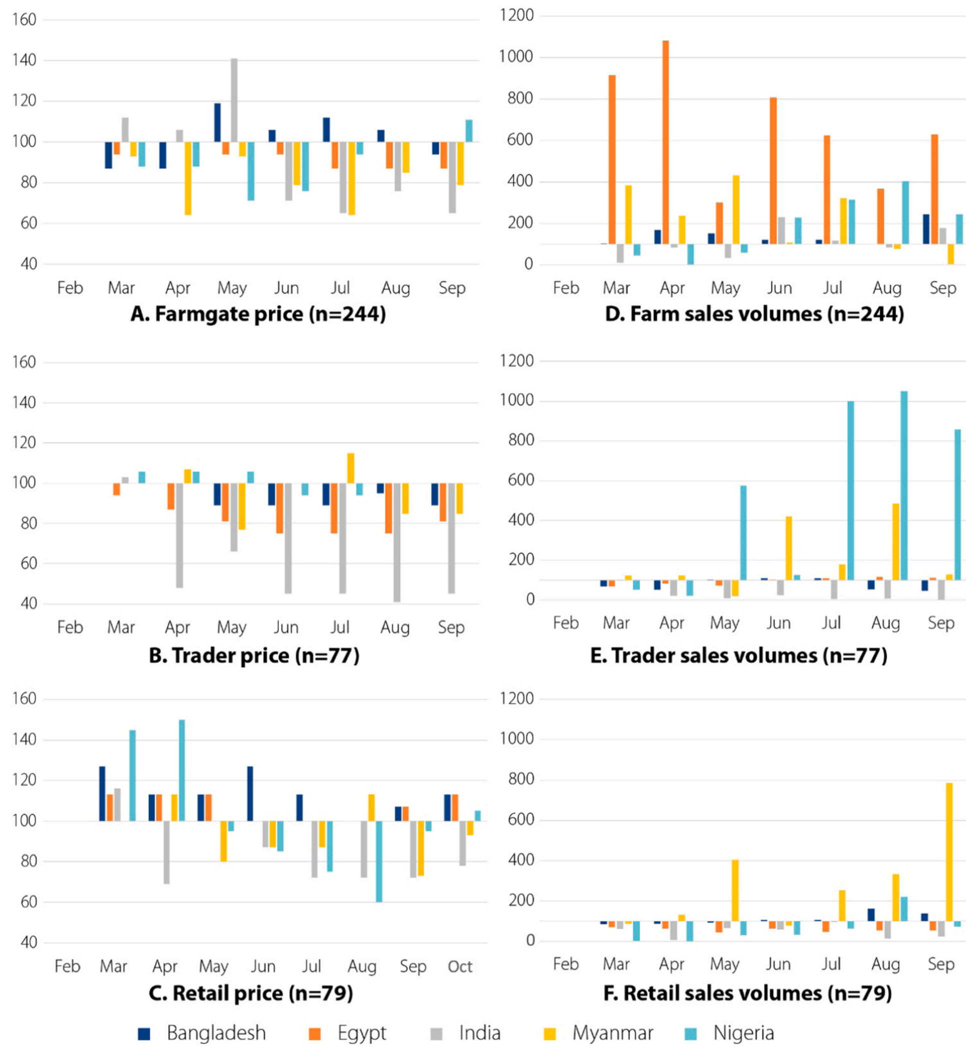

Fig. 5. Monthly farmed fish price indexes and monthly farmed fish sales indexes, February–September 2020 (Note: author's calculations using own survey data. The base month for all indexes is February, with a base value of 100).

hatcheries, and farms. Fig. 6D–F presents price trends for key feed mill and farm inputs.

4.3.1. Production and procurement

Capture fisheries landings are highly seasonal. Stormy weather during the monsoon season often precludes fishing in small-scale marine fisheries. Myanmar, Bangladesh, and states on the east coast of India enact fishing bans during April-June[8] to protect spawning fish stocks. In these locations, "peak" fishing season runs from approximately October to April. Fish processing (meaning fish drying in the case of most survey respondents) is highly dependent on supplies of fish from capture fisheries, requires dry weather, and follows a similar temporal pattern.

The low value of the index for capture fish landings and quantity of fish processed from May to July reflect seasonal tendencies, but the low values in March and April (usually months of high activity) are mainly attributable to COVID-19 impacts (Fig. 6A). Respondents from both types of businesses cited temporary business closures due to COVID-19, restrictions on travel, and difficulties hiring transport among the major reasons for pausing operations in March and April. This is in contrast to the closure of the fishing season and bad weather as the reasons commonly reported from May to August.

Hatchery seed sales undergo two seasonal peaks, especially for hatcheries specializing in carp seed production; in March and April when hatchlings (newly hatched fish) are sold to nurseries, and in July, when fingerlings (larger juvenile fish) are sold to farms. The timing of these peaks in activity is related to the timing of annual production cycles that are linked to seasonal variations in rainfall and temperature. Although these peaks in activity occurred at the usual time, reports from the field in Bangladesh and India indicated that they were low compared to previous years, causing some hatcheries to destroy large quantities of seed that they were unable to sell due to transport restrictions [28,29]. The hatchery sales index remained close to February levels during subsequent months, indicating low levels of business activity as February is low season for hatcheries most countries surveyed (Fig. 6B).

Feed procurement by farms reflects as similar mix of seasonal and COVID-19 effects. Low temperatures reduce fish metabolism, making February a quiet month for feed procurement in Egypt, India, and Bangladesh. The feed procurement index remained at relatively low levels during the peak lockdown months of March and April, even as temperatures rose. The procurement index for non-pelleted feeds, such as rice bran and oilcake, reached its highest level during April and May. This might indicate that they were substituted for more expensive pelleted feeds to reduce costs, an adaptation that farmers reported in our qualitative study in Bangladesh. The overall feed purchase index was about four times higher in May to July than in other months (Fig. 6C).

[8] Exact timings vary by country.

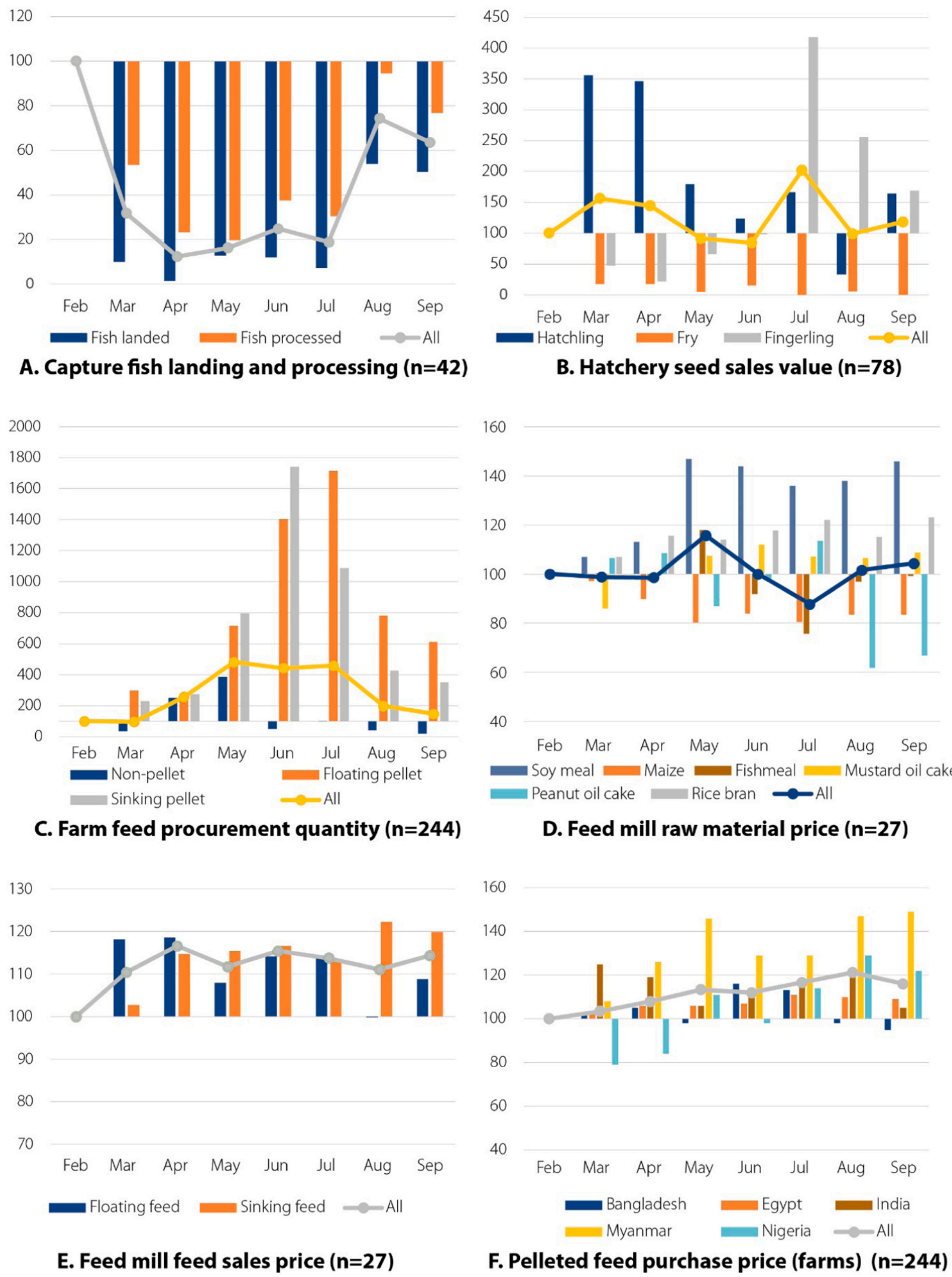

Fig. 6. Monthly all-country indexes, February–September 2020. (Note: author's calculations using own survey data. The base month for all indexes is February, with a base value of 100).

Peaks in the purchase of feed at this time are associated with the peak monsoon farmed fish production season in Asia and Nigeria, when nearly all ponds are stocked with growing fish. High levels of feed purchases during these months may also reflect farms making bulk purchases after transport restrictions eased – a strategy reported by respondents to our Bangladesh qualitative survey.

4.3.2. Input prices

Feed mills use a variety of raw materials for manufacturing pelleted feeds. Raw material prices remained relatively stable throughout the survey period. The price index did not deviate by much more than 20% above or below February levels, for all raw materials except soy. The price index for maize and peanut oil cake trended downward in most months after February. Soy, rice bran and mustard oilcake prices exceeded February levels in most months. The fishmeal price index fluctuated (Fig. 6D). Raw materials are procured from domestic or international markets or both, depending on local availability, price, and quality, meaning that prices are influenced by both international and local conditions. The relative overall stability of raw material prices during this period reflects, in part, the lack of emergency restrictions on international trade during the crisis, which has helped to minimize price volatility for key staple crops such as rice, maize and wheat [30].

Despite relatively stable prices for most raw materials, the mean price of feed that mills sold between April and September was 10–15% higher than in February (Fig. 6E). Farms also reported increases in the price of pelleted feed. The average farm procurement price index for pelleted feed rose about 20% from February to August. Price increases could reflect increased operating costs, including higher wage rates and transport costs. This inference was supported by respondents to our qualitative survey in Bangladesh, who noted that transport costs jumped 30% during lockdown, and remained 10% higher than in 2019 following the relaxation of movement restrictions. Increasing prices of feed may also reflect high rates of inflation in surveyed countries during 2020 (Fig. 6F).[9]

4.4. Impacts and adaptations

In this section, we review the impacts of the trends outlined above, with respect to incomes and employment, food and nutrition security, assistance (i.e. receipt of financial or other material support), and adaptive behaviors.

4.4.1. Incomes and employment

Higher input prices coupled with falling farmgate prices, as noted above, suggest that farm earnings would have become increasingly squeezed over the course of 2020. Reductions in farming and fishing activity also reduced demand for harvesting labor, transport, and other services, with significant negative outcomes for the many workers who depend on these activities. Qualitative interviews in Bangladesh show working hours declined 30–40% and incomes decreased nearly 70% during the lockdown period for drivers employed in transporting fish and production inputs, due to lower fish and shrimp harvests and landings.

Income levels reported by farmers, fishers, businesses, and workers in aquatic food value chains in Bangladesh, typically improved post-lockdown but fell short of 2019 levels. For example, fish harvesting workers worked an average of 25–28 days and earned approximately USD 145–180 per month in May-August 2019. This plummeted to 8–12 days and USD 60 per month in March-April 2020, before recovering partially to 15–20 days and USD 90–95 per month in May-August 2020. Transport workers carrying fish, shrimp, crab, and fish seed reported similar trends.

Many respondents in Bangladesh reported seeking supplemental work to cope. For example, an itinerant fish seed trader (*patilwala*) reported taking up day laboring to support his family due to the negative impact of COVID-19 on demand for fish seed, while a female collector of wild shrimp post-larvae (PL) began working as a laborer on a crab farm to supplement reduced income from PL sales. Other respondents used savings or borrowed to meet their food consumption needs. Poorer respondents, in particular, expressed feelings of anxiety and helplessness in the face of uncertainty, inability to find work, and pressures around paying back loans. This strongly suggests that non-material dimensions of their well-being were also compromised.

4.4.2. Food and nutrition security

COVID-19′s impacts on food and nutrition security varied widely by country. From May onward, we asked respondents whether the quantity of food their family purchased during the past month was the same as, higher, or lower, than under 'usual' circumstances. By this simple measure, food and nutrition insecurity was lowest in Egypt (where no respondent reported purchasing less than usual from July onward), and highest in Nigeria, where 55–85% of respondents gave this answer in each month (Fig. 7). Impacts were significant in Bangladesh and Myanmar, where between approximately one-quarter and half of respondents, respectively, purchased less food than usual each month. Myanmar is notable because this share trended up over time, reflecting the late onset of widespread COVID-19 infections and a second round of containment measures there. These figures suggest that the reduced financial viability of businesses in the aquatic food value chain has been linked to persistent negative impacts on food and nutrition security for many operators.

Qualitative interviews from Bangladesh provide additional insight into food and nutrition security during the pandemic. Effects on consumer behavior differed among lower- and higher-income consumers.

Actors in lower-income groups, including small-scale farmers and fishers, *patilwala*, drivers, and laborers, described decreased dietary diversity and increased food and nutrition insecurity, due largely to loss of work and income. Commonly reported coping strategies included skipping meals, eating less per meal, purchasing fewer food items, consuming fewer animal-source foods and/or eating greater quantities of more affordable staple foods. For example, a fish farmer described how her family had not eaten meat in a single meal in a month during the COVID-19 pandemic, a decline from their usual four times per month prior to this time. One fishing laborer explained that his school-aged children had to start working at the fish landing center to supplement declining household income and cope with increasing food and nutrition insecurity. However, some lower-income respondents reported being able to maintain normal levels of food consumption by producing part of their own food. For example, a dried fish retailer explained that her household was able to continue consuming fresh and dried fish from fishing, as well as vegetables grown on a small area of her own land.

In contrast, respondents with higher incomes, including operators of large hatcheries and feed mills and employees of seafood export companies, reported being able to switch to mobile applications for grocery shopping and delivery. They also described eating more nutritious foods such as fruits rich in vitamin C with the intent of boosting their immune systems. Better-off respondents also reported following food safety and hygiene practices such as soaking vegetables and fruits in saltwater before consumption, which they believed would reduce the risk of COVID-19 infection. No low-income participants reported carrying out these practices, likely reflecting limited access to utilities such as running water, and indicating their heightened vulnerability during the pandemic relative to groups with more resources.

4.4.3. Assistance

Beginning in May, respondents were asked whether they had received any form of assistance, like cash transfers or emergency food rations, from institutions such as government, NGOs, religious institutions or business associations. The share of respondents receiving assistance was very low in Bangladesh, Egypt, and Nigeria. In Myanmar, rates of assistance were low from May–July, but jumped to 32% in August and 39% in September as the government implemented a cash transfer scheme during the country's second lockdown [32]. India had the most consistent rates of delivery, with 12–24% of respondents receiving assistance each month (Fig. 8). Government was the main source of assistance, but trade associations also played a significant role in India, accounting for 15–35% of assistance in all but 1 month. Our online survey of actors in African aquaculture value chains produced similar findings, with only 4% of respondents reported having received any assistance by mid-July.

Most of the assistance received appears to have been in the form of social protection transfers to households or individuals, rather than support targeted at businesses. A Bangladesh qualitative survey respondent opined that in the past, public funds had often been distributed inequitably, stating, "bank loans and benefits have always been for the musclemen of society, with less chance to reach to the real entrepreneurs". Other respondents felt that such funds might be difficult to obtain, or that informal businesses and enterprises without bank accounts could be ineligible to receive them. Low levels of information about and access to government loan programs for businesses are also reported by operators of integrated poultry-fish farms in Myanmar [33].

Many qualitative survey respondents from Bangladesh used informal support mechanisms to sustain their families, leveraging social capital with friends, relatives, and/or wealthier actors in aquatic food value chains to cope with lost income or livelihood activities. For example, a driver explained that a local shopkeeper had allowed him to delay payment for his groceries. Fishing laborers and fish harvesters often took loans from fishers and farmers on condition of working for them in the following year, effectively selling their labor in advance, likely at discounted rates. Some operators of larger businesses reported providing

[9] Nigeria (12.9%), Myanmar (6.1%), Egypt (5.7%), Bangladesh (5.6%), and India (4.9%) [31].

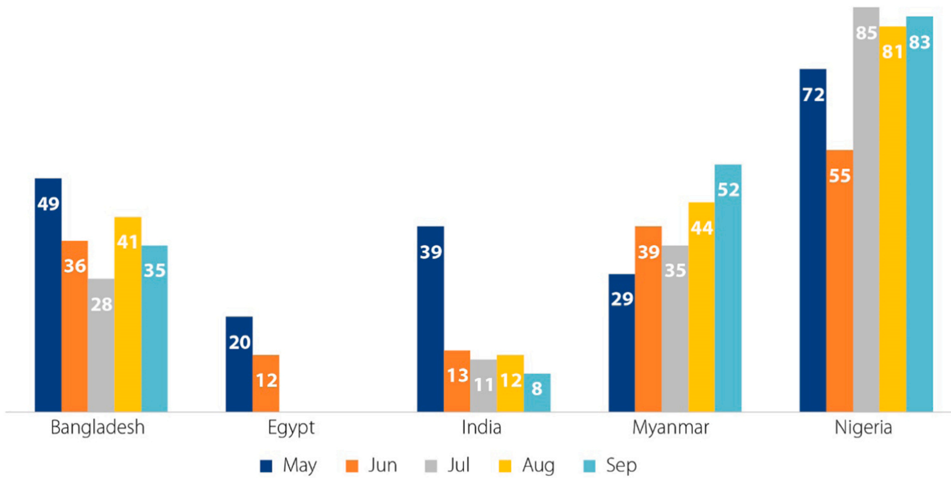

Fig. 7. Respondents consuming less purchased food than usual, by month (%). N = 768.

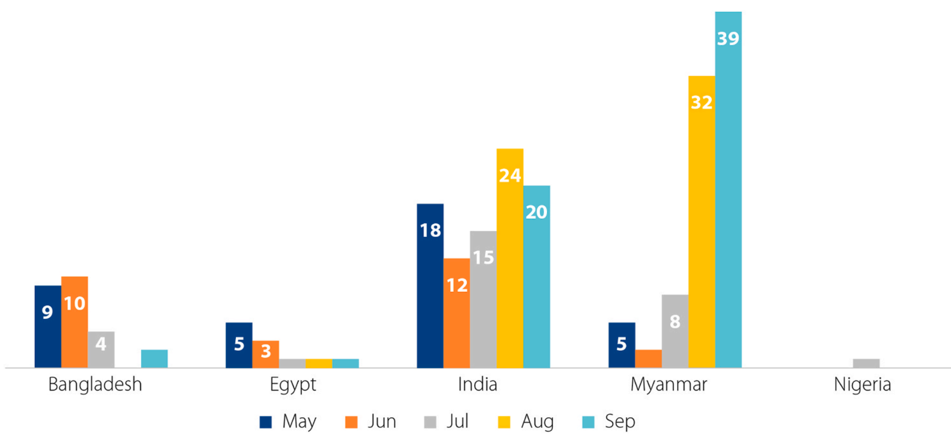

Fig. 8. Respondents reporting receiving any assistance, by month and country (%). N = 768.

food, financial assistance or loans to workers, neighbors, and smaller enterprises, during the lockdown period. These observations hint at the operation of local moral economies, with somewhat ambiguous implications. While they are capable of providing a degree of social protection in the absence of state support, there is potential for exploitative consequences.

4.4.4. Adaptive behaviors

Qualitative interviews from Bangladesh and our online survey in Africa revealed that aquatic food value chain actors took a variety of adaptive measures to facilitate businesses operations. These can be categorized broadly as reactive or proactive.

Reactive adaptations focus on variable cost reduction or input substitution, as a response to low demand for products and/or constrained supply of inputs. The most common reactive adaptations reported by respondents in Africa and Bangladesh include the following: (1) Temporarily pausing or reducing the duration of operations; (2) Minimizing operating costs (e.g. by laying off or hiring fewer workers, paying lower wages, reducing input procurement, reducing harvesting and/or stocking rates, delaying the beginning or end of a production cycle, or using cheaper production inputs); (4) Sourcing alternatives to unavailable inputs; (5) Bulk buying and hoarding inputs; (6) Selling products at discounted rates; (7) Borrowing working capital; (8) Paying bribes to facilitate continued operations.

Reactive adaptations are common, particularly for smaller enterprises with limited resources. Although often necessary for reducing losses, minimizing risks, or overcoming constraints, these strategies tend to lower productivity and incomes. For example, hatcheries in Bangladesh used synthetic hormones after the price of imported carp pituitary gland from India rose several times, resulting in lower ovulation and higher rates of hatchling mortality. Also, feed mills and farms in Africa and Bangladesh used locally sourced raw materials or feeds of inferior quality and/or higher price when imported products were unavailable. In another example, farmers in Bangladesh stocked hatchery produced shrimp PL, perceived to be of inferior quality to wild caught seed. Many actors in Bangladesh, including dried fish processors, hatcheries, *patilwala*, and feed retailers reported offering discounts or selling products at reduced rates to clear stock or generate sales.

During the lockdown in Bangladesh, confusion around the enforcement of movement restrictions, which vehicles transporting fish and shrimp were officially exempted from, often resulted in drivers having to pay bribes, raising transport costs. Similar findings are reported in Nigeria [1]. Selling assets was a drastic but relatively uncommon coping strategy, reported in one instance in Bangladesh where a small feed retailer sold land to cover business losses.

Proactive adaptations are innovations that fundamentally alter business operations, value chain structure, or relations between value chains actors, creating new opportunities or potential to improve performance. Adaptations of this type were most common among, though not exclusive to, larger businesses. Respondents in Africa and Bangladesh cited the following examples: (1) using digital platforms for marketing or procurement; (2) operational diversification, such as farms selling products direct to customers, offering delivery services, or setting up retail operations; (3) institutional innovations, including coordination among shrimp hatcheries in Bangladesh to set a minimum price for PL; (4) providing expanded trade credit to customers to maintain demand.

Other minor proactive adaptations include conducting business activities remotely (meeting online instead of face-to-face), placing orders by phone, and following safety precautions such as social distancing and providing personal protective equipment and hand sanitizers to safeguard the health of workers and customers.

5. Discussion and conclusions

Here we synthesize findings from our multi-country panel survey of aquatic food value chain actors and contextual interviews from Bangladesh and Africa. Six results stand out.

First, consistent with other reports [1,3,11,14,17], COVID-19 and associated containment measures severely disrupted aquatic food value chains across the countries surveyed, particularly via impacts on transport and logistics. Importantly, most effects on the availability and accessibility of aquatic foods and production inputs were relatively short-lived, leading to a “V shaped” recovery in aquatic food and production input supply after the most stringent lockdown measures were eased.

Second, also consistent findings from many Global South countries, lagged effects of lockdown measures and the ongoing COVID-19 health crisis have resulted in persistent reductions in consumer demand [6,7,9,32]. Demand for aquatic foods has yet to recover to pre-pandemic levels in the countries surveyed. As a result, derived demand for production inputs and services, such as seed, feed, transport, and labor also remains low. This resulted in substantially lower incomes for businesses and workers throughout the value chain in 2020, as compared to 2019.

Third, except for a brief spike in retail prices during the lockdown period, aquatic food prices in all segments of the value chain trended downward over the course of the pandemic in the countries surveyed, reflecting depressed demand. Prices of most raw materials used for feed production remained relatively stable, in line with international agricultural commodity prices [7,30], but prices of manufactured feeds rose, reflecting increased costs of doing business and inflation. These trends may result in a deepening “squeeze” on the financial viability of producers and supporting value chain actors if demand does not recover. Based on trends observed in the countries surveyed, it seems likely that global aquatic food production contracted significantly in 2020, for the first time after decades of near continuous growth, as also reported elsewhere [34,35].

Fourth, aquatic food value chain actors reacted to these challenges in multiple ways. These included reducing production costs, using alternative inputs, leveraging social capital through informal networks, borrowing, seeking alternative employment, and reducing food consumption. While born of necessity and essential for enabling businesses and households to survive in the short to medium term, some of these coping strategies seem likely to undermine well-being and longer-term resilience [36]. It remains to be seen to what extent flexible strategies such as lowering input costs, subsistence food production, self-exploitation (e.g. practicing farming or fishing with very low returns) [37], and survival-driven livelihood diversification [38], will enable smaller producers and others to persist in the short run, prior to their ultimate recovery. Larger businesses appear to have greater capacity to adapt proactively. These advantages may deepen as the COVID-19 crisis continues, leading to concentration in some value chain segments [3].

Fifth, there is a high degree of commonality in the impacts and adaptations observed across countries, but with local conditions tempering outcomes. The stringency and timing of COVID-19 containment policy responses and the progress of the pandemic are critical factors, and these interact with seasonality in ways that may heighten or dampen impacts. The underlying robustness of the economy in which containment measures are implemented also appears to play an important role. Actors in Egypt and India seem to have recovered more quickly and fully than in Myanmar and Nigeria, while Bangladesh occupies an intermediate position. As widely observed elsewhere [39,40], findings from Bangladesh show that COVID-19 has exacerbated pre-existing social and economic inequalities. Asset-poor respondents and those in precarious occupations are most vulnerable to financial, food and nutrition insecurity and health risks, with consequences that are highly gendered [41].

Finally, the global COVID-19 pandemic has already reversed years of progress on key human development indicators, including poverty and food and nutrition security, with sub-Saharan Africa and South Asia affected most severely [10]. Aquatic foods play a unique role in diets in countries in both regions, as a leading source of relatively affordable and accessible nutrient-rich animal-source food [42]. Aquatic food value chains also support livelihoods and generate employment and income for millions of women and men across the Global South, offering routes out of poverty for some [25]. Prior to the COVID-19 pandemic, the dynamism of aquatic food value chains and their potential to drive progress toward development goals made them attractive sites for investment and intervention by governments and development agencies. This potential makes renewed investments in aquatic food value chains and the livelihoods they support of even greater importance in the context of post-COVID-19 recovery efforts.

6. Policy recommendations

In this section, drawing on the results presented above, we outline policy recommendations to mitigate and support recovery from the on-going shock of COVID-19. These are divided into supply side and demand side recommendations, and recommendations that are immediate (aimed at mitigating the on-going shock) and longer term (aimed at resilient recovery).

6.1. Immediate, supply side

Immediate supply side recommendations fall into two groups: (1) ensuring the smooth functioning of aquatic food value chains; (2) providing emergency financial support to actors in them.

The first set of recommendations includes the following points:

- Ensure that logistics (transport, storage), physical marketplaces, and “lateral” value chains delivering inputs, are designated essential. They must also be exempt from movement restrictions, and kept open and operating, with social distancing and sanitation provisions such as water and soap for handwashing, and providing personal protective equipment (PPE) to protect public health. This is the most fundamental condition for avoiding supply-side shocks [1,43].
- Designate workers throughout aquatic food value chains as essential workers. Special consideration should be given to mitigating the effects of containment policies on migrant workers, who make up a significant part of the workforce in many aquatic food value chains and can be particularly vulnerable to both lockdown measures and health risks [12].
- Ensure that rules governing containment policies are clearly formulated and publicized widely to maximize compliance and minimize rent seeking opportunities.
- Establish regular processes of consultation between government, fisheries professionals, and relevant business associations at national and sub-national levels to quickly identify emerging problems in aquatic food value chains and agree on and implement remedies.
- Avoid border closures and restrictions on imports or exports to help prices remain stable.

The second set of recommendations is prefaced by the observation that emergency financial support to actors in aquatic food value chains has been very limited to date in the countries surveyed. Where such schemes are implemented, they should take into account the following:

- Accord value chain actors such as traders, transporters, input suppliers, and processors the same priority as producers when allocating resources.
- Focus on small and medium enterprises, farms, and fishers, as these are more labor- intensive (employing many more people) than large enterprises, and they account for the majority of aquatic food produced and traded [3].
- Bailout programs that prioritize allocation of scarce resources to industry could exacerbate inequities rather than reduce them [44]. To maximize impact, aid packages can be scaled progressively. For example, when providing financial aid, payments can be made on a sliding scale weighted in favor of smaller boats or farms, rather than allocating a flat fee per unit of size or area.
- Financial support packages for business should be well-advertised. They must have transparent and simple application criteria and be designed in recognition that most aquatic food value chain enterprises are informal and often unbanked, making it necessary to devise inclusive application and distribution mechanisms.
- Loan timing and duration should account for seasonality, such as by scheduling disbursement around peak stocking season for farms, and repayment dates after final harvest.

6.2. Immediate, demand side

In most of the countries studied, the reach of formal social safety nets appears to have been limited or patchy to date. Keeping value chains working is thus of paramount importance. Nevertheless, where implemented adequately, safety nets play important roles in mitigating the impacts of shocks on the poor and vulnerable [45]. We observe the following:

- Unconditional cash transfers targeted particularly to vulnerable and poor groups, including women of reproductive age, can increase consumption of nutritious aquatic foods and stimulate demand for their production. Disbursement can be timed to coincide with the implementation of any forthcoming waves of lockdown measures, or other periods of particularly acute stress, including cyclones and drought, or fishing ban periods.
- Aquatic foods such as dried fish can be included in food aid packages as nutritious, culturally appropriate, convenient and low-cost foods, and used as an alternative to nutritional supplements that also stimulate demand for production.

6.3. Long term, supply side

Recommendations for the long term are aimed at revitalizing aquatic food value chains, to protect livelihoods and human nutrition, contribute to post-pandemic recovery and promote resilience to other future shocks. These include the following:

- The physiology of widely consumed aquatic organisms means that there is little chance of transferring viral zoonoses to humans [46]. This is strong grounds for promoting aquatic foods as preferred animal-source foods, given the associations between livestock rearing and bushmeat consumption and the emergence of new infectious diseases [47].
- Construct or upgrade critical infrastructure such as roads, electricity, and marketplaces.
- Establish systems for real time monitoring of the quantities and prices of aquatic foods and inputs produced and traded to track changes and support speedy interventions where necessary.
- Provide practical digital literacy training to actors throughout aquatic food value chains to support digitalization in aquaculture and fisheries to facilitate ease of advertising, marketing, input procurement, and delivery of technical advice and payments.
- Invest in human capacity and skills through training programs to support sectoral development in fisheries and aquaculture. This may include promoting production of nutrient-rich aquatic foods for household consumption to reduce food and nutrition insecurity in the face of shocks.
- Capture fisheries can play an important safety valve function during shocks such as COVID-19 but are vulnerable to particularly heavy exploitation during such events [15,48]. Fisheries should be accorded higher priority in development planning processes because of their importance for livelihoods and food and nutrition security.

6.4. Long term, demand side

On the demand side, revitalizing aquatic food value chains through the types of intervention described above will boost employment and income. This will contribute to demand for aquatic foods and other goods and services through production, consumption, and employment linkages [49]. The COVID-19 pandemic has widened existing inequalities and underlined the weakness of existing forms of social protection in many countries [50]. Over the long term, better developed and more comprehensive systems of social protection and public health care will be key to pre-empting rapid, large-scale slides into extreme poverty and food and nutrition insecurity when shocks occur [51].

CRediT authorship contribution statement

Ben Belton: Conceptualization, Formal analysis, Methodology, Supervision, Roles/Writing - original draft. **Leah Rosen:** Data curation, Formal analysis, Roles/Writing - original draft. **Lucinda Middleton**: Data curation, Formal analysis. **Saadiah Ghazali:** Data curation, Formal analysis. **Abdullah-Al Mamun**: Data curation, Formal analysis, Investigation, Supervision, Roles/Writing - original draft. **Jacqueline Shieh**: Data curation, Formal analysis, Roles/Writing - original draft. **Hamia S. Noronha**: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Roles/Writing - original draft. **Goutam Dhar**: Data curation, Formal analysis. **Mohammod Ilyas**: Investigation. **Christopher Price**: Supervision. **Ahmed Nasr-Allah**: Supervision. **Ibrahim Elsira**: Investigation. **Bikram K. Baliarsingh**: Investigation, Supervision. **Arun Padiyar**: Supervision. **Suresh Rajendran**: Supervision. **A.B.C Mohan**: Supervision. **Ravi Babu**: Supervision. **Michael Joseph Akester**: Supervision. **Ei Ei Phyo**: Investigation, Supervision. **Khin Maung Soe**: Investigation, Supervision. **Ajibola Olaniyi**: Investigation. **Sunil N. Siriwardena**: Supervision. **John Bostock**: Methodology, Supervision, Writing - review & editing. **David C. Little**: Methodology, Supervision, Writing - review & editing. **Michael Phillips**: Funding acquisition, Writing - review & editing. **Shakuntala H. Thilsted**: Conceptualization, Writing - review & editing.

Acknowledgments

This work was also undertaken as part of the CGIAR Research Program (CRP) on Fish Agri-Food Systems (FISH), led by WorldFish, and contributes to the WorldFish 2030 Research and Innovation Strategy: Aquatic Foods for Healthy People and Planet, and the CGIAR COVID-19 Hub.

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