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Early impact of COVID-19 pandemic on the molluscan shellfish supply chain in China

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A B S T R A C T

A farm-level survey and a market survey were conducted in China to study the impact of the COVID-19 on the shellfish supply chain in the early stage of the pandemic in 2020. 114 farms of 36 cities participated in an online survey from mid-July to late August, and 23 markets in five cities were investigated from June to November. The series results are expected to provide an insight for the fisheries and aquaculture sector to mitigate the impact of the pandemic on participants in the shellfish supply chain and to improve the ability of the government to respond to such events in the future. Shellfish farmers and sellers have experienced a sharp drop in profits, largely due to shrinking demand. Relying on local employees and suppliers, shellfish farming activities have rapidly resumed since the gradual reopening from February. Nevertheless, demand has been slow to recover due to public concern about contamination of seafood with the virus. Additionally, we analyzed the ability and attitude of farms of different size to cope with the pandemic and the plight of shellfish sellers, and discussed government supports for different size farms and improvements in seafood distribution channels.

1. Introduction

The COVID-19 pandemic has triggered a huge and unpredictable impact throughout the molluscan shellfish (hereafter the shellfish) supply chain in China, the largest producer and consumer of shellfish in the world (FAO, 2020a, 2020b; Peng et al., 2019; Peng et al., 2021), due to the various effects of widespread virus containment measures on demand, logistics, prices, business operations and planning (FAO, 2020c; Xu et al., 2021). The closure of foodservices in February 2020 and restrictions on restaurants seating capacity after reopening have led to a significant reduction in demand for fresh and alive shellfish (FAO, 2020c). Although the prevention efforts have weakened with the decrease in the number of confirmed cases (IMF, 2020), the demand was sluggish to recover. The first COVID-19 cases were officially linked to a seafood market in Wuhan (<u>Djekic et al., 2021</u>); Jalava, 2020), and re-emergent outbreaks in Beijing, Dalian and Qingdao were also linked to a seafood market, a seafood processing plant and imported frozen seafood, respectively (Han et al., 2020). Although COVID-19 does not infect aquatic species (Godoy et al., 2021), the virus has been detected on packaging materials and storage environments (Han et al., 2020), and isolated from imported frozen seafood package surface. These events that were broadcasted across the country, has raised public concerns about the safety of seafood, including shellfish, which may have exacerbated the plight of supply chain participants during the pandemic (<u>Perillo et al., 2021</u>; Xinhua, 2020a).

China contributed 75.9% to global shellfish production and 75.7% to consumption in 2018, with aquaculture accounting for 95.8% of its production (FAO, 2020a, 2020b). And China is the major contributor to production growth, as its shellfish production increased from 86,900 tons in 1950 to 15,081,753 tons in 2018, contributing 80.0% of the global production growth (FAO, 2020a). Unlike other counties (FAO, 2020c; Pedroza-Gutiérrez et al., 2021; Teng, 2020; White et al., 2020), China is nearly self-sufficient in shellfish. In 2018, China’s shellfish import and export only accounted for 0.8% of the domestic consumption and 1.5% for the domestic production, respectively (FAO, 2020a), and most shellfish was delivered to individual consumers though wholesale markets and wet markets. Even though, a considerable part of export was contributed by processing trade (GACC, 2020), that is, by importing and processing raw shellfish for re-export (Feenstra & Hanson, 2005).

The huge domestic production and consumption implies that it’s...
unlikely for China to fill in the gap between supply and demand by import from the international market, not to mention its market independence. Meanwhile, in view of the global pandemic and shrinking commodity trade (WTO, 2020; Xu et al., 2021), it is obviously not a feasible option to alleviate any shocks created by declining domestic demand through increasing export. China has to figure out and implement its mitigation strategies to cope with sharply reduced demand, price shock and an uncertain outlook facing its shellfish industry (FAO, 2020c).

The effects of COVID-19 pandemic on shellfish industry may depend on the supply chain activities, species, and the size of farms, so do participants’ ability to respond to lockdown and severe demand shocks (<u>Menhat et al., 2021</u>; Milanés et al., 2021). If farms rely on local algae/feed and seeds, the short-term, for example, a month, lockdown may have marginal impact on shellfish supply capacity, while shrinking demand will reduce sales and revenue of retailers and wholesalers, and the effect can be transmitted upstream along the supply chain (Lee et al., 1997). For farms involved in downstream stages (e.g., processing), they may suffer from the demand shock earlier and more severely than those just engaged in upstream activities (e.g., breeding and cultivation of bait organisms). In view of aquaculture production cycle, it may last for a few months or multiple years in duration depending on species farmed (FAO, 2020c) and farmers can change production schedule, such as to delay harvesting if the harvest time is flexible. Nevertheless, the shellfish that remains in the growing phase will eventually be harvested, thus going into the market in the late 2020 or 2021. In addition, large farms may prepare themselves well in terms of cash flow and financial opportunity to address market uncertainties. Small and medium farms, however, may not be so lucky, often feeling helpless when facing difficult market situations (Bennett et al., 2020; FAO, 2020c).

In this study, an online farm-level survey and a field market survey were conducted for the purpose of providing suggestions to mitigate the impact of the pandemic on participants in the shellfish supply chain and to improve the ability of the government to respond to such events in the future. First, from mid-July to late August 2020, 114 shellfish farms in 36 cities of mainland China were invited to finish an online questionnaire. We discussed the differentiated situation faced by shellfish farms in the early stage of the pandemic, as well as response strategies and desired government supports. Then, 23 markets in five cities were visited from June to November 2020. We investigated the business situation of shellfish sellers and discussed market renovation.

2. Material and methods

2.1. Farm-level survey

2.1.1. Survey process

An online survey of shellfish farms located in China’s coastal regions and the Yangtze River Basin was conducted from mid-July to late August 2020. We are quite familiar with 16 operators of shellfish farms in Shandong province, of which 5 were selected to be interviewed by phone in early July, prior to the formal investigation, for the purpose of refining the questionnaire we designed. The questions and options of the questionnaire were then adjusted according to insights derived from the pre-survey.

Since there were still sporadic new confirmed cases of COVID-19 in China, questionnaires were filled through the online platform Wenjuanxing (<https://www.wjx.cn/app/survey.aspx>), and the link to the questionnaire was sent to the respondents via WeChat with their consent. Farms were contacted in advance to analyze availability for participating in the survey. To ensure a representative sample, shellfish farms in each coastal province of mainland China were invited to participate in this survey, as marine aquaculture contributed 98.66% of China’s shellfish production in 2018 (FAO, 2020a). Besides geographical distribution, the only criterion was that the farms operate in at least one stage of the shellfish production: algae/feed production, seed production, nursery, intermediate cultivation, grow-out and processing. We did not limit shellfish species and the proportion of farms that culture each shellfish species, as farms often raise multiple species.

A total of 114 farms in 36 cities of 12 provinces in mainland China were included in the survey (Fig. 1). In 2018, the total shellfish aquaculture production of these 12 provinces was 14,563,801 tons (including 14,439,302 tons of marine aquaculture production and 124,499 tons of freshwater aquaculture production) (BOF, NFTEC, & CSOF, 2019), accounting for 99.51% of China’s shellfish aquaculture production, 83.17% of global shellfish aquaculture production and 72.39% of global shellfish production (FAO, 2020a). The farm characteristics are presented in Table 1.

2.1.2. Questionnaire used for the survey

A questionnaire has been developed in Chinese language to analyze whether the COVID-19 pandemic has affected farms and stages of the shellfish aquaculture production chain. The questionnaire was designed in four parts.

The first section collected business information related to the farms, including location, years in business, farming species and operating revenue and number of employees in the previous year (2019).

More specific characteristics of farms were analyzed in the second section. Stages involved in, the native place of employees, algae/feed sources, seeds sources and customer distribution were asked to analyze the ability of farms to cope with logistics restrictions. Since logistics restrictions are based on levels of administrative divisions, the options of these multiple-choice questions included ‘within the city’, ‘other cities within the province’, ‘other provinces’ and ‘abroad’.

The third section was dedicated to identifying the pandemic impact on farms and their activities. First, we asked the month they resumed to work and the pandemic impact on farms and production stages, including labor recruitment, algae/feed production or purchase, seed production (hatchery and seed collection) or purchase, nursery, intermediate cultivation, grow-out, harvesting, processing, logistics and sales (Yang et al., 2016), and then the changes in production, the number of employees and per capita labor costs this year compared to previous years. As bivalve growers generally do not need to feed their brood (FAO, 2021), the question about ‘algae/feed production or purchase’ would be skipped, if feeding was not required in their shellfish farms. And if nursery, intermediate cultivation, grow-out or processing was not involved in the farm, the corresponding questions would be skipped as well. The respondents had the option to rate the degree of the pandemic impact on farms and stages according to a five-point Likert scale from 1 ‘very low’, 2 ‘low’, 3 ‘moderate’, 4 ‘high’ to 5 ‘very high’. To ensure that a same score chosen by respondents refers to the same level of shock on their farms, situations corresponding to the scores were added to the description of the question (Table 2).

Finally, the fourth section explored the problems encountered by farms and their concerns for the coming year, responses strategies, and desired government supports.

2.1.3. Working definition of large, medium and small farms

In this study, combining the collected data and China’s regulations on the standards for classification of small and medium-sized enterprises (SMEs) (NBS, 2017), a score method was created to measure farm size according to operating revenue and number of employees. Farms with revenue below 0.5 million yuan, 0.5–1 million yuan, 1–5 million yuan, 5–10 million yuan and 10–200 million yuan were assigned a farm size score of 1–5 points respectively (no farms with revenue greater than 200 million yuan participated in the survey). And farms with 1–5, 6–10, 11–50, 51–100 and more than 100 employees were added 1–5 points to their size scores, respectively. Those with scores between 2 and 4 were small farms, 5–7 were medium farms, and 8–10 were large farms.

Based on this approach, the 114 farms participating in the survey were classified into 30 small farms, 61 medium farms and 23 large farms.
(Fig. 2). Farm attributes by size are shown in Table 1. To explore the differential impact of the pandemic on farms of different sizes, we calculated the Spearman’s rank correlation coefficients (Spearman, 1904) between size and farm characteristics. As correlation coefficient shows the linear relationship between variables (Mukaka, 2012), non-linear relationships, especially the distinctiveness of medium farms were described separately.

It should be noted that China has implemented different level of tax and fees reductions and financial supports for large enterprises and SMEs (MOF & STA, 2020; MOHRSS, MOF, & STA, 2020; PBC, CBIRC, MOF, NDRC, & MIIT,2020; Zhang, 2020). According to classification standards for SMEs in China (NBS, 2017), Fishery SMEs are those with operating revenue bellow 200 million, which means all farms participating in the survey were SMEs.

2.2. Seafood markets survey

In China, seafood trade mainly take place in wholesale markets and wet markets, which are the linkage between farmers and consumers in China (Zhong et al., 2020). In wholesale markets, which are mainly located outside major urban areas, wholesalers sell fresh fruits, vegetables, meat and seafood mainly to retailers, caterers, and some to consumers. Some wholesale markets also serve as distribution centers.

Wet markets, a traditional form of food retail, also known as public markets in China, dominate the retail of fresh food in Chinese cities (Bai et al., 2008; Chen, 2019b; Maruyama et al., 2016; Si et al., 2019; Zhang & Pan, 2013; Zhong et al., 2020). Unlike developed countries (Burch et al., 2013; Wrigley & Lowe, 2002), despite the rapid expansion of modern supermarket chains in urban China, wet markets have maintained their popularity which primarily rests in their competitive advantage with regards to a particular kind of freshness corresponds with consumers’ consumption habits and food culture (Zhong et al., 2020). However, these markets have been blamed in some reports for the virus transmission during the pandemic. Frozen seafood and humid environment were thought to have created the conditions for the virus to lurk and spread in seafood markets (Wang, 2020).

Before the pandemic, China had been renovating these markets over the past decades to improve market environment. First, trading venues have been transformed from the open-air to the indoor. Second, markets are divided into several sections such as fruits & vegetable, meat & eggs, seafood, deli, and non-agricultural products, where stalls sell the corresponding products. Third, markets are equipped with appropriate infrastructure according to characteristics of products sold in each section. For example, in seafood section, the floor is covered with non-slip tiles, and drainage facilities are superior to other sections. Nevertheless, the outbreaks in Wuhan and Beijing were directly linked to a wet market
Table 1
Farm characteristics.

| Farm characteristics | Overall (n = 114) | Farm Size | Correlation Coefficient |
|----------------------|------------------|-----------|-------------------------|
|                      | (Small n = 30)   | (Medium n = 61) | (Large n = 23)          |
| Years in business    |                  |           |                         |
| 0-2                  | 7 (6.1%)         | 1 (3.3%)  | 5 (8.2%)                | 1 (4.3%) | 0.237*|
| 3-5                  | 11 (9.6%)        | 6 (20.0%) | 5 (8.2%)                | 0        |
| 6-10                 | 28 (24.6%)       | 10 (33.3%)| 14 (23.0%)              | 4        |
| >10                  | 68 (59.6%)       | 13 (43.5%)| 37 (60.0%)              | 18       |
| Operating revenue in 2019 (Million ¥) |                  |           |                         |
| <0.5                 | 16 (14.0%)       | 16 (53.3%)| 0 (0.0%)                | 0        | 0.756**|
| 0.5-1                | 16 (14.0%)       | 9 (30.0%) | 7 (11.5%)               | 0        |
| 1-5                  | 50 (43.9%)       | 5 (16.7%) | 39 (63.9%)              | 6        |
| 5-10                 | 27 (23.7%)       | 0 (0.0%)  | 15 (26.1%)              | 12       |
| 10-200               | 5 (4.4%)         | 0 (0.0%)  | 0 (0.0%)                | 5        | (21.7%)|
| >200                 | 0                | 0         | 0                       | 0        |
| Number of employees in 2019 |                  |           |                         |
| 1-5                  | 21 (18.4%)       | 19 (63.3%)| 2 (3.3%)                | 0        | 0.864**|
| 6-10                 | 20 (17.5%)       | 10 (33.3%)| 10 (16.4%)              | 0        |
| 11-50                | 43 (37.7%)       | 3 (10.0%) | 41 (67.2%)              | 1 (4.3%) |
| 51-100               | 16 (14.0%)       | 8 (31.1%) | 8 (34.8%)               | 0        |
| >100                 | 14 (12.3%)       | 0         | 14 (60.9%)              | 0        |
| Farm species         |                  |           |                         |
| Oysters              | 59 (53.4%)       | 14 (46.7%)| 9 (50.8%)               | 1 (39.1%)| 0.093|
| Scallops             | 39 (35.3%)       | 10 (33.3%)| 19 (31.1%)              | 10 (43.5%)| 0.063|
| Clams, cockles, ark shells | 33 (32.6%)       | 2 (6.7%)  | 23 (37.7%)              | 8        |
| Mussels              | 10 (8.1%)        | 3 (10.0%) | 6 (9.8%)                | 1 (4.3%) | 0.234*|
| Abalone              | 12 (10.5%)       | 1 (3.3%)  | 7 (11.5%)               | 4        |
| Other molluscs       | 40 (34.8%)       | 12 (40.0%)| 19 (31.1%)              | 9        |
| Other q. animals     | 37 (35.7%)       | 6 (20.0%) | 20 (32.8%)              | 11       | 0.200*|

Note: Correlation Coefficient. Spearman’s rank correlation coefficients between farm size (small = 1, medium = 2 and large = 3) and the scores of farm characteristics (see Supplementary Data).

*Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

Table 2
The situations of farms corresponding to the degrees of the pandemic impact.

| Score | Degree of impact |Situation of farms          |
|-------|------------------|----------------------------|
| 1     | Very low         | No apparent impact         |
| 2     | Low              | Problems can be solved by adjusting plans |
| 3     | Moderate         | Plans are disrupted and profits are significantly reduced |
| 4     | High             | Facing certain losses      |
| 5     | Very high        | On the verge of bankruptcy |

mainly selling seafood and a seafood section of a wholesale market, respectively, which has raised public concerns about buying seafood in such markets and led to a decline in demand. And the fact shows the necessity of further improvement of seafood distribution channels.

In seafood market survey, we visited 13 wholesale markets and 10 wet markets in five cities including Qingdao, Dalian, Nanjing, Jinan and Beijing (Fig. 1) from June to November 2020 to verify the feedback from farms about the pandemic impact on shellfish demand and to understand the improvements made by the markets to prevent the virus transmission. The months we visited each city, the markets investigated and the number of stalls interviewed in each market are listed in Appendix. All five cities are capital (Beijing), provincial capitals (Nanjing and Jinan) or sub-provincial cities (Qingdao and Dalian) with a population of more than 5 million (NBS, 2019). And there were seafood-related outbreaks in Beijing, Dalian and Qingdao, while there were none in Nanjing and Jinan. At least one wholesale market and one wet market were investigated in each city. The selected wholesale markets were the local seafood distribution centers, and the selected wet markets were the most popular seafood retail markets. We observed the layout and environment of the market, and interviewed shellfish sellers about their business. If there were more than 10 shellfish stalls in the market, we would stop after interviewing the shellfish sellers of ten stalls. And in some of wholesale markets, managers were interviewed about the rent waiver (SASAC, 2020) and the details of market renovation implemented or planned.

3. Results and discussion

3.1. Farm-level survey

3.1.1. Farm characteristics

The characteristics of the farms that participated in the survey are displayed in Table 1. Farms in business for more than 10 years represented 59.6% of the sample, followed by farms for 6–10 years (24.6%), 3–5 years (9.6%) and 0–2 years (6.1%). Majority of the farms cultured oysters (53.4%), followed by scallops (35.3%), clams cockles, ark shells (32.6%), mussels (8.1%) and abalone (3.3%). And one-third of the farms cultured other shellfish (34.8%) and other aquatic animals (35.7%).

In addition to the indispensable activities of harvesting and logistics, the farms were involved in 2-7 production stages on average (Table 3). Most of farms were involved in grow-out (53.4%), followed by scallops (35.3%), clams cockles, ark shells (32.6%), mussels (8.1%) and abalone (3.3%). And one-third of the farms cultured other shellfish (34.8%) and other aquatic animals (35.7%).

Except sales, all production activities of farms were carried out domestically, and most activities occurred within the province where the farms were located. Some companies in China delayed the
Table 3
Production characteristics.

| Production characteristics | Overall (n = 114) | Farm Size | Correlation Coefficient |
|----------------------------|------------------|-----------|-------------------------|
|                            | Small (n = 30)   | Medium (n = 61) | Large (n = 23)          |
| Algae/feed production      |                  |            |                         |
| (29.8%)                   | (13.3%)          | (37.7%)    | (30.4%)                 |
| Seed production            |                  |            |                         |
| (50.9%)                   | (26.7%)          | (60.7%)    | (56.5%)                 |
| Nursery                    |                  |            |                         |
| (50.9%)                   | (14.3%)          | (39.9%)    | (65.2%)                 |
| Intermediate cultivation   |                  |            |                         |
| (48.2%)                   | (36.7%)          | (44.3%)    | (73.9%)                 |
| Grow-out                   |                  |            |                         |
| (91%)                     | (24%)            | (48%)      | (19%)                   |
| Sources of algae/feed     |                  |            |                         |
| No need to feed           |                  |            |                         |
| (57%)                     | (15%)            | (28%)      | (14%)                   |
| Algae/feed production      |                  |            |                         |
| (34%)                     | (5%)             | (23%)      | (7%)                    |
| Purchase inside the city   |                  |            |                         |
| (13.2%)                   | (5%)             | (7%)       | (3%)                    |
| Purchase in other cities   |                  |            |                         |
| (26.3%)                   | (9%)             | (17%)      | (4%)                    |

Notes: Correlation coefficient. Spearman’s rank correlation coefficients between farm size (small = 1, medium = 2 and large = 3) and production characteristics (no = 0, yes = 1).

a The indispensable activities of harvesting and logistics and “other” production stages are not counted in “Num of stages”; and the correlation coefficient is of between farm size and the number of stages.

b Correlation is significant at the 0.05 level (2-tailed).

c Correlation is significant at the 0.01 level (2-tailed).

3.1.2. Pandemic effects on shellfish farming

Based on the Likert scale used (from 1 ‘very low’ to 5 ‘very high’), the pandemic had a moderate impact on shellfish farms (3.1) (Table 4), with the average level of situation could be described as ‘Plans were disrupted and profits were significantly reduced’ (Table 2). 66.67% of the farms reported a decline in production compared to the same period of previous years, and 17.54% of them reduced production by more than 50% (Table 5). 34.21% of the farms did not shutdown during the pandemic, and most of the rest achieved resumption in February–April, with 92.11% of the farms resuming work as of April (Fig. 3a).

By production segment, the impact on the production activities increased from upstream to downstream. As shown in Fig. 3b and Table 4, sales, the stage at the end of shellfish production, was most affected (3.6), followed by processing (3.3) and logistics (2.8), the other two post-harvest stages. In rearing segment, harvesting (2.6), grow-out (2.6) and intermediate cultivation (2.5) were less affected than the stages in the post-harvest segment. In pre-production segment, nursery (2.5), the production or purchase of seed (2.4) and the production or purchase of algae/feed (2.0) were affected to a lesser extent than rearing and post-harvest segments, except for labor recruitment (2.6).

The pandemic had a greater impact on cross-regional activities. Employees of farms in which recruitment was not affected (score = 1) were mainly local inhabitants, while a higher proportion of farms that were more affected (score = 4 or 5), hired workers from other cities within the province and other provinces (Fig. 3c). This phenomenon also occurred in the production or purchase of seed and algae/feed and sales (<u>Fig. 3d-f</u>), i.e., the more affected, the more reliance on cross-regional activities.
changing the number of employees (33.3%), price promotions (24.6%), developing new products (24.6%). It should be noted that a small proportion of farms (9.6%), mainly small farms, were quite negative and planned to quit shellfish aquaculture.

Faced with declining demand, most of farms expected the government to help explore sales channels, dock production and marketing (63.2%), and introduce or extending support measures in credit (44.7%), technology (36.8%), logistics (36.0%), taxation (35.1%), agricultural insurance (24.6%), recruitment (21.9%) and social insurance premiums (20.2%).

### 3.1.4. Differential impact on farms of different sizes

This part focused on the attributes that were significantly correlated (P < 0.05) with farm size. The sample consisted of 30 small farms (26.3%), 61 medium farms (53.5%) and 23 large farms (20.2%). The farm characteristics, effects of the pandemic, problems, concerns, strategies and desired government supports for each farm size and the Spearman’s rank correlation coefficients between these attributes and farm sizes are displayed in Tables 1 and 3.

### Table 4

| The changes compared to previous years | Overall (n = 114) | Farm Size | Correlation Coefficient |
|---------------------------------------|------------------|-----------|-------------------------|
|                                        | Small (n = 30)   | Medium (n = 61) | Large (n = 23) |
| **Production**                        |                  |           |                         |
| Decrease                               |                  |           |                         |
| >50%                                   | (15.8%)          | (16.7%)     | (21.3%)                 | -0.132  |
| Decrease 20%–50%                       | (24.6%)          | (23.3%)     | (19.7%)                 | (39.1%)  |
| Decrease 50%–<20%                      | (24.6%)          | (26.7%)     | (27.9%)                 | (13.0%)  |
| No change                              | 30               | 8          | 15                      | 7       |
| Increase                               | 8 (7.0%)         | 2 (6.7%)    | 4 (6.6%)                | 2 (8.7%) |
| **Number of employees**                |                  |           |                         |
| Decrease                               | 13               | 4          | 6 (9.8%)                | 3       | 0.055  |
| >50%                                   | (11.4%)          | (13.3%)     | (13.0%)                 |         |
| Decrease 20%–50%                       | (27.2%)          | (22.3%)     | (31.2%)                 | (21.7%)  |
| Decrease 50%–<20%                      | (19.3%)          | (18.0%)     | (39.1%)                 |         |
| No change                              | 44               | 14         | 24                      | 6       |
| Increase                               | 4 (3.5%)         | 3          | 1 (1.6%)                | 0       | (10.0%) |
| **Per capita labor costs**             |                  |           |                         |
| Decrease                               | 14               | 3          | 11                      | 0       | 0.013  |
| >50%                                   | (12.3%)          | (10.0%)     | (18.0%)                 |         |
| Decrease 20%–50%                       | (28.1%)          | (33.3%)     | (26.2%)                 | (26.1%)  |
| Decrease 50%–<20%                      | (25.4%)          | (16.7%)     | (26.2%)                 | (34.8%)  |
| No change                              | 32               | 10         | 16                      | 6       |
| Increase                               | 18               | 6          | 7 (11.5%)               | 5       | (15.8%) |
| Increase 10%–20%                       | 21               | 6          | 11                      | 4       |
| Increase >20%                          | 21               | 6          | 11                      | 4       |

**Notes:** Correlation coefficient. Spearman’s rank correlation coefficients for farm size (small = 1, medium = 2 and large = 3) and the score of changes in production, number of employees and per capita labor costs (see Supplementary Data).

### 3.1.3. Problems, concerns, strategies, and desired government supports

Table 6 Displays farms’ problems (financial pressures and other problems), concerns for the coming year, strategies to cope with the pandemic, and desired government supports.

In terms of financial pressures, majority of farms experienced a decrease in operating revenue (59.6%). Some farms were plagued by operating costs, e.g., rent, materials & infrastructure costs (39.5%), labor costs (19.3%) and loan repayment (18.4%), and it was hard for a few farms to get loans (18.4%). And there were still 18.4% of farms without financial pressures.

Most of farms were suffering from seafood price fluctuations (77.2%), followed by weather disasters (38.6%), fish diseases (34.2%), government calling for shutdown (27.2%), lack of technical support (15.8%), and facilities maintenance, repair and renewal (10.5%).

For the coming year, farmers were most concerned about price (price drop of fluctuation, 70.2%) and demand (drop in shellfish demand due to public concerns for seafood safety, 62.3%), and the effect of shrinking demand transmitted to upstream along the supply chain, 32.5%). Nearly half of farmers worried about the rises in labor costs or recruiting difficulty (44.7%) and logistics cost or transport restrictions (43.9%), followed by rent or materials cost (25.4%), stock level (25.4%), difficulties in facilities maintenance, repair and renewal (15.8%) and regulation tightening (10.5%).

Farmers had generated and implemented COVID-19 mitigation strategies amidst vanishing demand, falling prices and an uncertain outlook (FAO, 2020c). The most popular measure was delaying harvesting or reduce harvest volume (57.0%), followed by changing aquaculture practices (47.4%), exploring sales channels (42.1%), and facilities maintenance, repair and renewal (10.5%).

| Table 5 The changes compared to previous years. |
|-----------------------------------------------|------------------|-----------|-------------------------|
| Impact                                        | Num              | Overall (n = 114) | Farm Size | Correlation Coefficient |
| Month of work resumption                      | 114              | 2.6 ± 2.6 ± 2.6 ± | 2.5 ± 2.5 ± | -0.045  |
| Impact on farm                               | 114              | 3.1 ± 3.2 ± 3.1 ± | 3.0 ± 3.0 ± | -0.096  |
| Impact on production stage                   | Labor            | 3.9 ± 2.4 ± 2.7 ± | 2.8 ± 2.7 ± | 0.110   |
|                                                   | recruitment      | 1.4          | 1.5                    | 1.4      |
|                                                   | Algae/seed       | 57           | 2.0 ± 2.0 ± 2.2 ±      | 1.7 ± 1.7 | -0.027  |
|                                                   | production       | 1.2          | 1.4                    | 1.1      |
|                                                   | Seed             | 114           | 2.4 ± 2.5 ± 2.4 ±      | 2.4 ± 2.4 | -0.036  |
|                                                  | production       | 1.4          | 1.4                    | 1.3      |
|                                                  | or purchase      | 1.4          | 1.3                    | 1.4      |
|                                                  | Nursery          | 50           | 2.8 ± 2.8 ± 2.4 ±      | 2.5 ± 2.5 | -0.022  |
|                                                  | Intermediate     | 55           | 2.5 ± 2.5 ± 2.6 ±      | 2.5 ± 2.5 | 0.015   |
|                                                  | cultivation      | 1.5          | 1.6                    | 1.6      |
|                                                  | Grow-out         | 91           | 2.6 ± 2.6 ± 2.6 ±      | 2.9 ± 2.6 | 0.025   |
|                                                  | Harvesting       | 114           | 2.6 ± 2.6 ± 2.6 ±      | 2.9 ± 2.9 | 0.042   |
|                                                  | Processing       | 23           | 3.3 ± 3.3 ± 2.8 ±      | 4.0 ± 2.4 | 0.244   |
|                                                  | Logistics        | 114           | 2.8 ± 2.9 ± 2.9 ±      | 3.0 ± 3.2 | 0.142   |
|                                                  | Sales            | 114           | 3.6 ± 3.5 ± 3.5 ±      | 3.7 ± 3.7 | 0.039   |

**Notes:** Correlation coefficient. Spearman’s rank correlation coefficients between farm size (small = 1, medium = 2 and large = 3) and scores (see Supplementary Data).

* No Shutdown = 1; No Resumption = 8.

* Farms where feeding was not required are excluded.

* Only farms involved in the stage are included.
Fig. 3. The COVID-19 impact on shellfish farms. (a) Percentage of farms resuming work. (b) The average scores of the impact on farms and stages. (c–f) The native place of employees (c), sources of algae/feed (d) and seed (e), and distribution of customers (f) for farms unaffected (score = 1), less affected (score = 2 or 3), and more affected (score = 4 or 5) in recruitment, production or purchase of algae/feed and seed, and sales. Values in parentheses are the numbers of farms. Local = within the city the farm was located, Provincial = in other cities within the province, Domestic = in other provinces.
Table 6
Problems, concerns, and strategies desired government supports.

| Content                        | Overall (n = 114) | Farm Size (n = 30) | Medium (n = 61) | Large (n = 23) | Correlation Coefficient |
|--------------------------------|-------------------|--------------------|-----------------|---------------|-------------------------|
| **Financial pressures**        |                   |                    |                 |               |                         |
| Labor costs                   | 0.001             |                    |                 |               |                         |
| Rent, materials & infrastructure costs | 0.217             |                    |                 |               |                         |
| Decrease in operating revenue | 0.019             |                    |                 |               |                         |
| Loan repayment                | 0.008             |                    |                 |               |                         |
| Hard to get loans             | 0.014             |                    |                 |               |                         |
| Other financial pressure      | 0.196             |                    |                 |               |                         |
| No financial pressure         | 0.207             |                    |                 |               |                         |
| **Problems**                  |                   |                    |                 |               |                         |
| Government calling for shutdown | 0.025             |                    |                 |               |                         |
| Shortage of epidemic prevention supplies | 0.032             |                    |                 |               |                         |
| Lack of technical support     | 0.249             |                    |                 |               |                         |
| Seafood price fluctuations    | 0.047             |                    |                 |               |                         |
| Facilities maintenance, repair and renewal | 0.198             |                    |                 |               |                         |
| **Fishing**                   |                   |                    |                 |               |                         |
| Diseases                      | 0.041             |                    |                 |               |                         |
| Weather                       | 0.021             |                    |                 |               |                         |
| Other disasters               | 0.015             |                    |                 |               |                         |
| No problems                   | 0.046             |                    |                 |               |                         |
| **Concerns for the coming year** |                   |                    |                 |               |                         |
| Rise in labor costs or recruiting difficulty | 0.031             |                    |                 |               |                         |
| Rise in rent or materials cost | 0.064             |                    |                 |               |                         |
| Rise in logistics cost or transport restrictions | 0.184             |                    |                 |               |                         |
| Facilities maintenance, repair and renewal | 0.264             |                    |                 |               |                         |
| Drop in shellfish demand due to public concerns for seafood safety | 0.009             |                    |                 |               |                         |
| The effect of shrinking demand transmitted to upstream along the supply chain | 0.282             |                    |                 |               |                         |
| Price drop or fluctuation     | 0.009             |                    |                 |               |                         |

Table 6 (continued)

| Content                        | Overall (n = 114) | Farm Size (n = 30) | Medium (n = 61) | Large (n = 23) | Correlation Coefficient |
|--------------------------------|-------------------|--------------------|-----------------|---------------|-------------------------|
| **Response strategies**        |                   |                    |                 |               |                         |
| Changing the scale of production | 0.081             |                    |                 |               |                         |
| Changing the number of employees | 0.232             |                    |                 |               |                         |
| Changing aquaculture practice | 0.062             |                    |                 |               |                         |
| Exploring new sources of algae/ feed and seed | 0.028             |                    |                 |               |                         |
| Expanding to upstream and downstream | 0.187             |                    |                 |               |                         |
| Price promotions               | 0.000             |                    |                 |               |                         |
| Developing new products        | 0.012             |                    |                 |               |                         |
| Broadening distribution channels | 0.234             |                    |                 |               |                         |
| Quitting shellfish aquaculture | 0.039             |                    |                 |               |                         |
| Other measures or plans        | 0.077             |                    |                 |               |                         |
| Desirable government supports  |                   |                    |                 |               |                         |
| Providing epidemic prevention supplies | 0.015             |                    |                 |               |                         |
| Recruitment support            | 0.052             |                    |                 |               |                         |
| Agricultural support subsidies | 0.263             |                    |                 |               |                         |
| Social insurance premiums cut or deferral | 0.203             |                    |                 |               |                         |
| Technical support              | 0.092             |                    |                 |               |                         |
| Logistics support              | 0.255             |                    |                 |               |                         |
| Helping explore sales channels, dock production and marketing | 0.048             |                    |                 |               |                         |
| Credit support                 | 0.071             |                    |                 |               |                         |
| Tax cut or deferral            | 0.032             |                    |                 |               |                         |
| Other supports                 | 0.009             |                    |                 |               |                         |

Notes: Correlation coefficient. Spearman’s rank correlation coefficients for farm size (small = 1, medium = 2 and large = 3) and farm characteristics (no = 0, yes = 1).

• Correlation is significant at the 0.05 level (2-tailed).
customers in other provinces ($p = 0.315$) and abroad ($p = 0.189$), which might explain the interest in logistic supports for larger farms ($p = 0.255$).

Problems and concerns varied by farm size. First, financial situation of large farms was not so critical as that of small farms. Whether the farm was free of financial pressure was correlated to its size ($p = 0.207$). There was no financial pressure for 34.8% of large farms, compared to 16.39% and 10.00% of medium and small farms respectively, probably because larger farms usually had more adequate funding to deal with short-term crises and had easier access to bank financing (Andrieu, Stagljanò, & van der Zwan, 2018; Demirgüç-Kunt et al., 2020). Second, large farms were more concerned about technology and facilities. There were correlations between the size of farms and whether they were lack of technical support, had problems in facilities maintenance, repair and renewal, and concerned about facilities maintenance, repair and renewal for the coming year. Farms with above problems and concern accounted for 34.8%, 21.7% and 21.7% of large farms, while 13.1%, 9.8% and 19.7% of medium, and 6.7%, 3.3% and 3.3% of small, which suggested a higher level of mechanization and more reliance on technology on large farms. Third, larger farms were more concerned about the transmission of the effect of shrinking demand to upstream along the supply chain ($p = 0.282$). A higher percentage of large farms (56.5%) have this concern compared to medium (31.1%) and small farms (16.7%), probably because large farms involved in more production stages had realized the impact of the pandemic on the industry from a broader perspective. In terms of response strategies and desirable government supports, there were positive correlations between farm size and whether the farm changed the number of employees ($p = 0.232$), expand to upstream and downstream ($p = 0.187$), broaden distribution channels ($p = 0.234$) and desire agricultural insurance subsidies ($p = 0.263$), social insurance premiums cut or deferral ($p = 0.203$) and logistics support ($p = 0.255$), while there was a negative correlation between farm size and quitting shellfish aquaculture ($p = -0.279$). In addition to the linear relationships measured by the correlation coefficients, compared to large and small farms, a higher percentage of medium farms were more concerned about getting loan (24.6%), regulation tightening (14.7%), recruitment support (27.9%), and tax cut or deferral (42.6%).

The above results reflect the differentiated attitudes of operators from different size of farms in coping with the impact of the pandemic. Despite an uncertain outlook, large farms were motivated to explore sales channels (42.1%) and expand to upstream and downstream (21.7%). Regarding the desired government supports, large farms with wider customers distribution and more employees than medium and small, were more attracted to logistics support (56.5%) and social insurance premiums cut or deferral (39.1%), as well as agricultural insurance subsidies (39.1%). However, small farms handled the pandemic in a negative manner. On the one hand, small farm had less willingness or capacity to expand their operations. Desperate farmers in a quarter of small farms even intended to quit shellfish aquaculture (23.3%), compared to 6.6% of medium and 0 of large. On the other hand, unlike large farms, small farms desired government supports in sales channels (70.0%) and credit (46.7%), which implied that they were suffering more severe stagnant sales and financial constraints than large farms. In addition, compared to large and small farms, a higher percentage of medium farms were more concerned about getting loan (24.6%), regulation tightening (14.7%), recruitment support (27.9%), and tax cut or deferral (42.6%). The divergence in situations and strategies of different size farms in coping with the pandemic, particularly large and small farms, may lead to an increase in the concentration of shellfish farming in the post-pandemic era in China. Although it will hurt small farms, the increased market share of large farms that have utilized more technology and equipment in shellfish aquaculture will improve the efficiency of the industry.

3.2. Market survey

3.2.1. Shrinking demand

In the markets we visited, shellfish retailers and wholesalers experienced a significant decline in sales due to market closures and a decrease in customers.

At the retail level, according to the statement of shellfish sellers, public markets in the cities we visited were closed during the lockdown from late January to early February 2020, and consumers turned to supermarkets and online channels to purchase food, including seafood. Although these public markets had not been shut down since then due to the pandemic, whenever there were new COVID-19 cases that were linked to seafood, few customers went to the markets for seafood in the ensuing periods.

After the report of COVID-19 infections linked to seafood stalls in Beijing Xinfadi Agricultural Wholesale Market, the largest wholesale food market in China’s capital, on Friday, June 12, over the following weekend “there were almost no customers in the seafood section” in the public markets in all five cities and “the number of people coming to the retail market (non-seafood sections) also dropped by more than half,” retailers said. “While retail sales had recovered to near pre-outbreak levels over the previous weekend.” And after the re-emergent outbreaks in Beijing, we observed that, in seafood sections of public markets in Qingdao, there were almost devoid of customers until Father’s Day on June 21 and the Dragon Boat Festival on June 25. And retailers said that the phenomenon had returned to the markets in the cities we surveyed after the seafood-related outbreaks in Dalian in July and Qingdao in September, but “lasted for a shorter period of time”.

At the wholesale level, markets in Beijing and Dalian were severely impacted by the local outbreak, with most wholesalers reporting a drop in turnover of more than half compared to the same period last year. Following the outbreak in June, the Beijing Xinfadi Agricultural Wholesale Market and Jingshen Seafood Markets were closed until September. During that time, the rest of the wholesale markets in Beijing also suspended frozen seafood trading. And wholesalers dealing in live and fresh seafood relocated to other markets, such as Shenghuahonglin Wholesale Market, or continued their business in temporary open-air trading sites. And none of the wholesalers we interviewed who had moved to other markets had intention of moving back to the two markets. In Dalian, after an outbreak linked to a seafood processing plant of Dalian Kaiyang Seafood Co., Ltd. in late July, the nearby Liaoyu International Aquatic Products Market was closed for a month. Although not closed, the rest of the seafood markets in Dalian experienced a plunge in sales. At the New Changxing Agricultural & Sideline Products Wholesale Market, hours of operation were reduced from 18 to 7 h “Sales had dropped 70 percent in the two months following the outbreak,” shellfish wholesalers at the market said. “Those who used to import seafood have switched to selling domestic seafood.” At the Tiansheng Seafood Comprehensive Wholesale Market, we observed that only a quarter of seafood stalls were in business. A shellfish wholesaler said that before the pandemic they mainly sold shellfish to consumers and barbecue stalls, but at the moment the former hardly come to the market and the latter had halved their purchases.

In Qingdao, where seafood wholesale markets remained open despite the seafood-related outbreak, shellfish sales dropped by half; as retailers and caterers reduced their purchase. As for the seafood markets in Nanjing and Jinan, without seafood-related outbreaks, most wholesaler reported a 30–50 percent decline in sales, mainly due to a drop in catering purchases.

Despite the decline in sales, few wholesalers reduced prices for promotions. The reason explained by wholesalers in these cities was that farmers refused to reduce prices, which was consistent with the results of our farm-level survey, where only 24.6% of farms were willing to conduct prices promotions.
In addition, despite the government promoting rent exemption and reduction (Chinadaily, 2020; SASAC, 2020), majority of wholesalers did not get rent relief. We asked the management of the Jinao Seafood Market about this issue, and they replied:

All stalls in the market have been sold. Wholesalers in the market are the owners or renters of the stalls. We have appealed to lessors to reduce the rent for their renters. However, it is up to the lessors and the renters to negotiate whether and how much to reduce, and we have no authority to require them to adopt a particular option.

Wholesalers at the Tianzhushuang Food Comprehensive Wholesale Market in Dalian experienced a similar situation:

We rent our stall from the market. The market had promised to waive part of the rent, but there was a delay in action. We were told that the waived rent would be paid by the market rather than a government subsidy.

It follows that the availability of rent relief to wholesalers depends largely on the willingness of lessors of stalls. And the lessors had no incentive to waive the rent for the renters in the absence of subsidies.

In addition to not getting rent relief, wholesalers had to bear the cost of regular PCR tests on their employees and products to ensure their seafood were free of the virus. Due to the increase in operating costs and decrease in sales, some wholesalers suspended their business.

3.2.2. Distribution channel improvements

The results of the market survey showed a decline in demand and the plight of sellers during the pandemic. And the farm-level survey indicated that the shrinking demand had a more severe impact on farms compared to the disruption of production caused by the lockdown, and that the farms, especially small ones, desired the government to help explore distribution channels. Therefore, dispelling consumers’ fears to foster demand recovery has been the key to mitigating the impact of the pandemic on shellfish supply chain participants.

To allay consumer concerns about the safety of buying and consuming seafood, a series of measures have been implemented to reduce the risk of virus transmission in the markets we investigated. As frozen seafood and humid environment are thought to have created the conditions for the virus to lurk and spread in the seafood market (Wang, 2020), these measures have focused on the separation of live & fresh from chilled & frozen products in the stage of distribution and the improvement of the market environment.

First, after the outbreak in Beijing Xinfadi Wholesale Market, regular PCR tests were conducted in all the wholesale markets we investigated to ensure the seafood on sale was free of the virus. Second, renovations of the markets, especially the seafood sections, have been implemented or planned.

In terms of wholesale market renovation, Beijing has been a step ahead of other cities. In the past, wholesale markets served wholesalers, retailers, caterers and consumers, with both wholesale and retail functions. Now, wholesale markets in Beijing are no longer available to individual consumers without any record of business transactions. In public markets, if products are found to be defective or tested positive for the virus, it’s hardly possible to accurately trace the unpackaged and unlabeled seafood products that are sold to numerous customers without any record of business transactions. In public markets, customers pay as they buy at each stall, instead of settling all at the exit as in supermarkets, so shopping receipts are not applicable to these markets. Nevertheless, electronic payments have created the conditions for recording these fragmented transactions, and new retail channels, such as community group buying, also offer a path to solving the problems at the retail level. Community group buying, a new type of location-based social e-commerce model, is changing how people engage in food shopping (Chen, 2019q; Weinswig, 2020) and have appeared superior in satisfying the consumer needs and easing the panic buying perception during the pandemic (Hao et al., 2020). The model usually centers on a group of residents who live in the same community.

Consumers place their order through online platforms, mainly launched or supported by China’s internet giants such as Alibaba and Tencent. Products typically from selected suppliers are sent to regional central distribution centers after an order is placed and then delivered to collection points in communities the next day (Weinswig, 2020), which partially replace the role of public markets in retail. And the model can realize the digitalization of retail as commodity information and the process of delivering products from suppliers to consumers are recorded by the platforms, which provides a new solution to achieve the traceability in fresh grocery retail. However, the involvement of e-commerce giants has raised public concerns about consumer privacy, monopoly, and livelihood of vendors in public markets. China government has enhanced regulations of these community group buying platforms (Li, 2020; SAMR, 2020).

4. Conclusions

A farm-level survey and a market survey were conducted in China to study the impact of the COVID-19 on the shellfish supply chain in the early stage of the pandemic, especially the lockdown and the re-emergent outbreaks linked to seafood in 2020. Relying on local employees and suppliers, shellfish farming activities have rapidly resumed since the gradual reopening from February, and some farms even remained in operations during the lockdown. Nevertheless, shellfish farmers have experienced a significant drop in profits, largely due to shrinking demand. Capacity and attitude of farms to cope with the pandemic varied by farm size. Despite an uncertain outlook, large farms were struggling with fewer customers, market closures, and costs for pandemic prevention. Most of them have not received subsidies, including rent waivers. Additionally, to reduce the risk of pandemic transmission in seafood markets, wholesale markets in Beijing have
conducted regular PCR tests, separated retail from wholesale markets, and isolated live & fresh and chilled & frozen seafood. And we recommend further improvements of markets in other cities, especially wet markets.

The farm-level survey ended in August 2020 and the market survey in November 2020, while the ongoing pandemic still have an uncertain impact on China’s shellfish supply chain. As the recurrences of the pandemic and the late harvest continue to hit the market, the government should avoid prematurely withdrawing support policies for farmers. In the post-pandemic era, market renovations should be implemented in more cities to avoid the spread of disease in wholesale and public markets. And government, e-commerce giants and traditional sellers are supposed to work together to explore the capabilities of electronic payments and e-commerce platforms in enabling traceability of seafood. As for farmers, it’s an important proposition to improve flexibility in their supply chains and distribution channels to prepare for another potential crisis. Moreover, the pandemic may also lead to a temporary or permanent transition in shellfish consumption patterns, which was not covered in this study. A series of systematical studies need to be carried out in more countries with different patterns of production, distribution and consumption to fully understand the effects of the pandemic.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ocecoaman.2021.105852.

Appendix

### Market Information

| City    | Market                                                            | Type         | Num of interviewed stalls |
|---------|------------------------------------------------------------------|--------------|---------------------------|
| Qingdao | Chenguang Vegetable & Aquatic Products Wholesale Market          | Wholesale    | 10 + 1                    |
| Status  | Sub-provincial                                                   |              |                           |
| Population | 10.07 M              | Retail       | 10                        |
| Visiting month | Jun-Nov          | Retail       | 10                        |
| Dalian  | Tianhe Seafood Comprehensive Wholesale Market                    | Wholesale    | 10 + 1                    |
| Status  | Sub-provincial                                                   |              |                           |
| Population | 7.45                | Wholesale    | 10                        |
| Visiting month | Sep              | Retail       | 5                         |
| Nanjing | Nanjing Agricultural & Sideline Products Logistics Center        | Wholesale    | 6 + 1                     |
| Status  | Provincial capital                                              |              |                           |
| Population | 7.45 M              | Retail       | 3                         |
| Visiting month | Nov              | Retail       | 3                         |
| Beijing | Yuezhuzhuang Wholesale Market                                    | Wholesale    | 10 + 1                    |
| Status  | Capital                                                          |              |                           |
| Population | 21.89 M             | Wholesale    | 10 + 1                    |
| Visiting month | Nov              | Retail       | 3                         |
| Jinan   | Jinan Seafood Market                                             | Wholesale    | 10 + 1                    |
| Status  | Provincial capital                                              |              |                           |
| Population | 9.20 M              | Wholesale    | 10                        |
| Visiting month | Nov              | Retail       | 4                         |

Note: “+1” in Num of interviewed stalls indicates that the manager of the market was interviewed.

### References

Andrieu, G., Staglianò, R., van der Zwan, P., 2018. Bank debt and trade credit for SMEs in Europe: firm-, industry-, and country-level determinants. Small Bus. Econ. 51 (1), 245–264. https://doi.org/10.1007/s11187-017-9926-v.

Bai, J., Wahl, T.I., McCluskey, J.J., 2008. Consumer choice of retail food store formats in China. J. Int. Food & Agribus. Mark. 20 (2), 89–109. https://doi.org/10.1080/08697440802186217.

Bennett, N.J., Finkbeiner, E.M., Ban, N.C., Belhabib, D., Jupiter, S.D., Kittinger, J.N., Christie, P., 2020. The COVID-19 pandemic, small-scale fisheries and coastal fishing communities. Coast. Manag. 48 (4), 336–347. https://doi.org/10.1080/09275252.2020.1766937.

Bureau of Fisheries (BOF), National Fisheries Technology Extension Center (NFTEC), & China Society of Fisheries (CSOF). (2019). China Fishery Statistical Yearbook 2018. Beijing: China Agriculture Press.

Burch, D., Dixon, J., Lawrence, G., 2013. Introduction to symposium on the changing role of supermarkets in global supply chains: from seedling to supermarket: agri-food supply chains in transition. Agric. Hum. Val. 30 (2), 215–224. https://doi.org/10.1007/s11187-012-9410-x.

Chen, T., 2019a. Community Group Buy - the Next Billion Dollar E-Commerce Industry 2021-1-27 from. https://walkthechat.com/community-group-buy-the-next-billion-dollar-e-commerce-industry/.

Chen, Y., 2019b. Neighborhood form and residents’ walking and biking distance to food markets: evidence from Beijing, China. Transport Pol. 81, 340–349. https://doi.org/10.1016/j.tranpol.2017.09.015.

Daily, China. 2020. Policies Improve People’s Livelihoods in 2020 2021-1-23, 2021, from. http://english.www.gov.cn/policies/policywatch/2020/12/28/content_WS 5fe94422c6d0f72576942969.html.

Demirgüç-Kunt, A., Martinez Peria, M.S., Tressel, T., 2020. The global financial crisis and the capital structure of firms: was the impact more severe among SMEs and non-listed firms? J. Corp. Finance 60, 101514. https://doi.org/10.1016/j.jcorpfin.2019.101514.

Djekic, I., Nikolic, A., Uzunovic, M., Marijke, A., Liu, A., Han, J., et al., 2021. Covid-19 pandemic effects on food safety - multi-country survey study. Food Contr. 122, 107800. https://doi.org/10.1016/j.foodcont.2020.107800.

FAO, 2020a. FishStatJ - Software for Fishery and Aquaculture Statistical Time Series. Rome: FAO Fisheries Division [online]. Retrieved from. http://www.fao.org/fishery/.

FAO, 2020b. Fishery and Aquaculture Statistics 2018. FAO Yearbook. https://doi.org/10.4060/cht1215t.
FAO, 2020c. GLOBEISHF Highlights July 2020 issue, with Jan. - mar. 2020 Statistics – a quarterly update on world seafood markets. GLOBEISHF Highlights 2020 (3). https://doi.org/10.4060/cb1125en.

FAO. 2021. COVID-19 Cats Oyster Demand | GLOBEISHF | Food and Agriculture Organization of the United Nations 2021-2-5, 2021, from. http://www.fao.org/en-in/news/c主要内容/globeishf-market-reports-resource-detail/c/1263810/.

Feenstra, B., Hanson, G., 2005. Ownership and control in outsourcing to China: estimating the property-rights theory of the firm. Q. J. Econ. 120, 729–761. https://doi.org/10.1162/0022050053701889.

General Administration of Customs. P. R. China [GACC]. (2020). Customs Statistics 2020/12/18, 2020, from http://43.248.49.97/index2la.

Global Times, 2020. Imported Cold Chain Logistics Face Tighter Inspections in China Following Fresh COVID-19 Outbreak Linked to Frozen Food Contamination 2021-1-26, 2021, from. https://www.globaltimes.cn/page/202101/t20210126_1408613.shtml.

Godoy, M.G., Kibenge, M.J.T., Kibenge, F.S.B., 2021. SARS-CoV-2 transmission via food? A review. Aquaculture 536, 736460. https://doi.org/10.1016/j.aquaculture.2021.736460.

Han, J., Zhang, X., He, S., Jia, P., 2020. Can the coronavirus disease be transmitted from food? A review of evidence, risks, policies and knowledge gaps. Environ. Chem. Lett. https://doi.org/10.1007/s10311-020-01101-x.

Hao, N., Wang, H.H., Zhou, Q., 2020. The impact of online grocery shopping on stockpile behavior in Covid-19. China Agricultural Economic Review 12 (3), 459–470. https://doi.org/10.1108/CAER-04-2020-0064.

International Monetary Fund [IMF]. (2020). POLICY RESPONSES TO COVID-19 2020/12/20, 2020, from lmf.org/en/Topics/imf-and-covid19/Policy-Responses-to-COVID-19.

Jalava, K., 2020. First respiratory transmitted food borne outbreak? Int. J. Hyg. Environ. Health 226, 113490. https://doi.org/10.1016/j.ijheh.2020.113490.

Lee, H.L., Padmanabhan, V., Whang, S., 1997. The bullwhip effect in supply chains. J. Retailing Consum. Serv. 30, 33–39. https://doi.org/10.1016/j.jretconser.2015.12.006.

Li, H. (2020). China Regulates Community Group Buying, Cautions against Monopoly Behavior 2021-1-28, 2021, from https://news.cgtn.com/news/2020-12-22/China-regulates-community-group-buying-260326_html.

Liu, H., Gao, J., 2020. Constructing freshness: the vitality of wet markets in Beijing. China. J. Dev. Stud./Rev. Can. Etudes Dev. 40 (1), 78–96. https://doi.org/10.1080/00472336.2013.782224.

D. Peng, D., Hou, X., Li, Y., Mu, Y., 2019. The difference in development level of marine shellfish industry in 10 major producing countries. Mar. Pol. 106, 103516. https://doi.org/10.1016/j.marpol.2019.103516.

Liu, X., Peng, D., Yang, Y., Zhang, Z., 2020. The oyster fishery in China: trend, concerns and solutions. Mar. Pol. 129, 104524 https://doi.org/10.1016/j.marpol.2020.104524.

People’s Bank of China [PBC]. 2021. China Banking and Insurance Regulatory Commission [CBIRC], MOF, National Development and Reform Commission [NDRC], & Ministry of Industry and Information Technology [MIIT], (2020, 2020-07-01). Stepping up Credit Support for Micro and Small Businesses 2021-2-6 from http://www.scb.gov.cn/en/368906/3995557/4035880/index.html.

Perillo, G.M.E., Botero, C.M., Milanes, C.B., Ellif, C.I., Cervantes, O., Zielinski, S., Bombana, B., Glavovic, B.C., 2021. Integrated coastal zone management in the context of COVID-19. Ocean Coast Manag. 210, 105687 https://doi.org/10.1016/j.ocecoaman.2021.105687.

Stata Administration for Market [SAMR]. 2020. Stata Administration for Market and Ministry of Commerce Held an Administrative Guidance Meeting to Regulate the Order of Community Group Buying 2021-1-27, p. 2021 from. http://www.samsung.com.cn/utils_xtc2021222324567.html.

State-owned Assets Supervision and Administration Commission of the State Council [SASAC]. 2020. Notice on the Further Improvement of Rent Relief for Small and Micro Enterprises and Individual Entrepreneurs in the Service Industry 2021-1-23, p. 2021 from. http://www.sasac.gov.cn/n588035/n588820/n588835/c14767569/content.html.

Si, Z., Scott, S., McCordic, C., 2019, West markets, supermarkets and alternative food sources: consumers’ food access in Nanjing, China. Can. J. Dev. Stud./Rev. Can. Etudes Dev. 40 (1), 78–96. https://doi.org/10.1007/s10460-018-9304-4.

Spearman, C., 1904. The proof and measurement of association between two things. Am. J. Psychol. 15 (1), 72–101. https://doi.org/10.2307/1412159.

Teng, P., 2020. Assuring food security in Singapore, a small island state facing COVID-19. Food Security 12 (4), 801–804. https://doi.org/10.1007/s12751-020-01077-9.

Wang, X., 2020. Beijing’s outbreak data shared with world 2021-1-26, p. 2021 from. http://www.pbc.gov.cn/en/368906/3995557/4035880/index.html.

Weisswig, D., 2020. The Battle for China’s Community Group Buying Market 2021-1-27, 2021 from. https://technode.com/2020/07/28/the-battle-for-chinas-community-g.jpg-buying-market/.

White, E.R., Froehlich, H.E., Gephart, J.A., Cottrell, R.S., Branch, T.A., Agrawal Bejarano, R., et al., 2020. Early effects of COVID-19 on US fisheries and seafood consumption. Fish. Fish. 21 (2), 232–239. https://doi.org/10.1111/faf.12525.

Weinig, A., Lowe, M., 2002. Reading Retail: A Geographical Perspective on Retailing and Consumption Spaces. Routledge, London.

WTO, 2020. Chapter III World Trade and GDP, 2019-20 World Trade Statistical Review 2020. Reprinted, Geneva.

Xinhu, H., 2020a. Living novel coronavirus isolated from packaging of imported frozen food in Qingdao, China CDC. From. http://www.xinhuanet.com/english/2020-10/18/c_139448045.htm.

Xinhu, H., 2020b. China Focus: Beijing’s Xinfadi Wholesale Market Reopens as COVID-19 Outbreak Ebbs 2021-1-26, p. 2021 from. http://www.xinhuanet.com/english/2020-01/08/c_139293095.htm.

Xu, L., Yang, S., Chen, J., Shi, J., 2021. The effect of COVID-19 pandemic on port performance: evidence from China. Ocean Coast Manag. 209, 105660 https://doi.org/10.1016/j.ocecoaman.2021.105660.

Yang, H., Sturmer, L.N., Baker, S., 2016. Molluscan Shellfish Aquaculture and Production. University of Florida IFAS Extension.

Zhang, Z., 2020. China’s Support Policies for Businesses under COVID-19: A Comprehensive List 2021-2-6, p. 2021 from. https://www.china-briefing.com/news/china-covid-19-policy-tracker-benefiting-business-enterprises-comprehensive-updated-list/.

Zhong, S., Crag, M., Zeng, G., 2020. Constructing freshness: the vitality of wet markets in urban China. Agric. Hum. Val. 37 (1), 175–185. https://doi.org/10.1007/s10460-019-09987-2.
Early Impact of COVID-19 Pandemic on the Molluscan Shellfish Supply Chain in China

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