Title: Emerging COVID-19 impacts, responses, and lessons for building resilience in the seafood system

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Abstract
The COVID-19 pandemic and subsequent lockdowns are creating health and economic crises that threaten food and nutrition security. The seafood sector provides important sources of employment and nutrition, especially in low-income countries, and is highly globalized, allowing shocks to propagate internationally. We use a resilience ‘action cycle’ framework to study the first five months of COVID-19-related disruptions, impacts, and responses to the seafood sector. Looking across high- and low-income countries, we find that some supply chains, market segments, companies, small-scale actors and civil society have shown initial signs of greater resilience than others. For example, frozen Ecuadorian shrimp and Chinese tilapia exports were diverted to alternative markets, while live-fresh supply chains were more impacted. COVID-19 has also highlighted the vulnerability of certain groups working in- or dependent on the seafood sector. We discuss early coping and adaptive responses, combined with lessons from past shocks, that could be considered when building resilience in the sector.

The COVID-19 pandemic and subsequent lockdowns are creating health and economic crises, leading to increasing incidence of poverty [1] and a looming food crisis [2,3]. The food system has been seriously disrupted with impacts occurring at multiple levels and across supply chains [4]. Studying these impacts identifies vulnerabilities within the food system as well as opportunities for governments, international bodies, industries, small-scale actors, and civil society to respond, adapt, and build resilience to future shocks. Seafood is highly traded, both globally [5] and regionally [6], and composed of many species and production and distribution strategies. Much can be learned about food systems in pandemics by studying COVID-19-related shocks and responses in the seafood sector.

The current pandemic began in China, the world's largest producer, consumer, and exporter of seafood [7]. As the pandemic spreads, a patchwork of impacts and responses are occurring across this sector. Strategies to absorb shocks, react, and restore the functions of the seafood sector are critical. Hundreds of millions of people rely on seafood for their livelihood, culture, and food and nutrition security [8] including women, migrant workers and young people, and a large informal sector [9] that may not see direct aid from governments or financial institutions.

In order to rebuild toward a more resilient food system, it is necessary to understand the scope of recent disruptions, impacts, and range of responses. We applied a food system resilience action cycle framework (Fig. 1) [10] as informed by concepts of coping, adaptation [11], and specified vs. general resilience [12]. We use the term resilience to mean the "capacity over time of a food system and its units at multiple levels, to provide sufficient, appropriate and accessible food to all, in the face of various and even unforeseen disturbances" [10]. Using these concepts, we ask three central questions: First, how has the seafood system been impacted by COVID-19? Second, what types of responses have occurred thus far to absorb and react to COVID-19 disruptions and what actions have been taken to restore system functions? Third, what lessons from current and past shock events can help to inform actors and institutions as they build resilience to future shocks? The period of study was the first five months of the pandemic, from January through May 2020.

Disruptions from COVID-19 to the seafood system

Published data across news, social media outlets, governments, and development partners provide an emergent picture of disruptions or shocks to multiple stages of supply chains (Fig. 2). These disruptions caused a generalizable range of impacts across different subsectors, product forms, markets, and consumer segments. Impacts from the pandemic were felt first in China and among its trading partners (Fig. 3), but quickly spread around the world. In some cases, disruptions occurred simultaneously to multiple stages of a supply chain. In other cases, the impacts propagated out as a pressure wave ahead of COVID-19 cases, causing second order impacts following shifts in trade. We also expect lagged impacts caused by high uncertainty about future demand or disruptions to production inputs that have yet to be realized. Disruptions in some regions or sectors are being magnified by existing stressors such as climate change, natural hazards (Pacific cyclone season, African locust season), resource management, and political or economic instability. Below we use data to discuss specific disruptions to seafood demand, distribution, labor, and production.

Demand disruptions. The first demand impacts were experienced in China in late January and early February 2020, as lockdowns caused domestic seafood trade to drop precipitously with high-value marine fish species sold at restaurants more impacted than lower value farmed carp sold at retail outlets (Fig. 4a). Lower consumer demand in China led to reduced import volumes, however, as the pandemic subsided within China, seafood imports and domestic carp sales rebounded (Fig. 4a, 4b). In high-income countries, such as the United States (U.S.) there was a dramatic shift in all food sourcing favoring retail over restaurants due to public health measures to reduce COVID-19 spread (Fig. 4c). As restaurants typically sell more expensive live and fresh seafood, restaurant closures constrained markets for these products. In the European Union, lower demand at restaurants led to a 30% drop in imported live-fresh seafood prices (Fig. 4d).

In low income food deficit countries, such as Ethiopia, public health interventions reduced household incomes, which translated into reduced expenditures on nutrient dense foods that, if sustained, could lead to malnutrition [13]. As COVID-19 spreads poverty and hunger will continue to be concerns in low- and middle-income countries (LMICs) [14].

Distribution disruptions. Seafood trade was disrupted, redirected, or halted by sudden shifts in demand, supply, and limits on the movement of goods and people. Many of the earliest trade impacts radiated out from China (Fig. 3). In January 2020, China banned imports of live animals which impacted trade of live lobsters from many countries (Fig. 3). Some ports were closed for quarantine, which forced cargo ships to reroute and increased congestion at other ports, or shipments were cancelled entirely [15]. Cancelled international passenger flights created logistical problems and increased air freight costs for high-value seafood products such as farmed Atlantic salmon [16]. Cancelled shipments left producers and distributors without a market for perishable products or with a shortage of freezer space. In some cases, distributors were able to shift trade to other markets, such as frozen Ecuadorian shrimp re-routed from China to the U.S. and Europe in January through March 2020, and then back to China in April 2020 (Fig. 4e). Norwegian salmon was redirected from China to other countries such as the U.S. and Brazil [17], without a significant change in volume or price (Fig. 4f). As shifts to retail purchases occurred in the U.S., China dramatically increased exports of higher priced processed tilapia products to these valuable markets (Fig. 4g, 4h).

Trade disruptions have secondary impacts on LMICs that are more distributed. For example, the diversion of China's farmed tilapia to North America corresponded with a drop in exports to some countries, notably a 50% drop in exports to developing countries in April, 2020. The drop in Chinese tilapia initially opened up markets to local fishers around Lake Victoria [18], however, this short-term benefit was dampened as the Kenyan government introduced curfews to control the spread of COVID-19. Curfews decreased night-fishing activity for both expensive export products (e.g., Nile Perch) and affordable nutritious small fish for local consumption (e.g., Dagaa)[19], which along with trade shifts, increased price volatility [20]. Tilapia farms on Lake Victoria suffered disrupted feed supplies and responded to increased demand for smaller fish and expanded market opportunities outside of the capital.

Labor disruptions. Lockdowns disrupted employment in seafood supply chains for workers, and access to labor for seafood businesses. In many low-income food deficit countries, farms and enterprises in food supply chains provide self-employment and casual work for many people. COVID-19 policy responses impacting the operation of such businesses resulted in lowered incomes and caused substantial unemployment [21]. Migrant fish workers were not able to leave fishing boats in India, ports in Thailand, or an Ecuadorian fishing vessel in the South Pacific, and closures of fish markets have rendered many fish workers jobless [22,23]. India's nationwide lockdown also forced the closure of hatcheries, feed mills and processing plants, and sharp drop in demand from the U.S. and Europe reduced international exports of frozen shrimp, which account for 70% of India seafood exports. Similar impacts have been reported in Bangladesh and Myanmar [23]. COVID-19 outbreaks have occurred among seafood process workers in Ghana [24], the U.S. [25], and elsewhere, as well as other animal processing plants [26], indicating this is not unique to seafood processing.

Production disruptions. Seafood production decreases have sometimes occurred in parallel with COVID-19 cases and at other times lagged reductions in consumer demand. COVID-19-related lockdowns have decreased industrial fishing efforts in China, Spain, France, and Italy by 40% to >50% in the first quarter of 2020 compared to 2019 [27]. Reductions in Pacific tuna fishing are due to port closures and a lack of fisheries observers, while coastal subsistence fishing has increased [28]. Other fisheries have been unaffected thus far; Alaska pollock fishing and processing vessels were at sea before U.S. lockdowns were enacted [29]. However, uncertainty remains about upcoming fishing seasons, and in Alaska, where the salmon fishery is highly dependent on seasonal workers, production may be limited by restrictions on immigrant labor.
Aquaculture production has been disrupted as farmers decide whether to restock given uncertainty over demand. For example, as of April 2002, shrimp farmers across Southeast Asia have stopped stocking ponds [30], in some cases due to difficulty importing broodstock, which will produce lagged reductions in supply. Species with long grow-out periods, such as shellfish and salmon, can be held in the water until markets improve, but not indefinitely and not without economic costs. This range of impacts across the supply chain has been met with diverse responses deployed by governments, the seafood industry, and consumers.

Reactive actions to COVID-19 by seafood system actors and institutions.
We explore the reactive actions taken by multiple actors and institutions in response to COVID-19 through May 2020. These include initial steps to absorb and react to disruptions, and to restore functions to the seafood system (Fig. 1). We categorized these actions as short-term coping and forward-looking adaptive responses. To date, responses have mostly aimed to 1) protect public health, including the health of fishery sector workers, 2) support those whose enterprises, jobs, and incomes are affected by COVID-19 related disruptions; and 3) maintain seafood supplies to consumers. Initial coping responses, in particular by governments, sought to maintain the sector's core functions through the period of wide-spread economic disruption, while protecting the most vulnerable. Longer-term adaptive measures, that often emerge outside of government, can contribute to building COVID-19-specific and generalized resilience to multiple shocks and stressors. Below we discuss specific responses by different actors and institutions which is summarized in Table 1 and Supplementary Table 1 with expanded country-specific examples.

Governments and development partners. Governments have different capacities and tendencies to respond and, when responding, have exposed intensifying tensions between public health measures to limit COVID-19 infections and preventing an economic crisis (Supplementary Table 1). Consequently, most government actions represent short-term coping strategies to address immediate challenges posed by the crisis. For example, early on, many governments, including those in Russia, Canada, and South Africa [31-33], designated fishers, fish farmers, and fish processors as "essential workers" allowing them to operate in order to maintain the food supply. Along with these actions, protective measures were taken to safeguard worker health (Table 1). These were coupled with social protections to lessen the socioeconomic toll of the pandemic and keep companies going, with efforts to distribute the funds equitably varying in their levels of success [34,35].

Development partners including non-governmental organizations (NGOs) have also acted to support governments in dealing with the immediate impacts of COVID-19. Their actions comprise adaptive responses that can form the basis for building resilience. They targeted countries and regions where governments had limited capacity to implement social and economic measures seen elsewhere. For example, the United Nations Food and Agriculture Organization and WorldFish are providing policy recommendations, technical advice, and support and/or harnessing research to guide government responses [23,36]. The World Bank is providing grants and loans to countries to assess impacts and develop responses.

Large-scale commercial sector responses. Responses to the pandemic from the industrialized sector have been rapid, detecting early signs of weaknesses in global seafood markets and making resources available to rapidly adjust marketing and distribution. Early coping responses focused on protecting worker health, consumer health, and securing production and supply chains during the pandemic (Supplementary Table 1). Nevertheless, some seafood workers remained exposed to outbreaks [24,25]. The economic response has included reducing the workforce, but some companies have also responded by shifting into or strengthening their positions in retail and online markets, where consumer demand has been high; the ability to make such transitions could represent longer-term adaptation. Companies selling frozen and shelf-stable products as well as companies with strong relationships with retailers have been particularly well positioned to adapt sales from the restaurant sector to retail markets. Use of technology such as IT has facilitated these advantages, allowing companies to promote their products and connect with consumers (Supplementary Table 1).

Small scale-sector and non-governmental organization responses. Small-scale fisher responses to the pandemic have predominantly comprised actions that can translate into longer-term adaptive strategies that build resilience. Early on, some small-scale fish worker networks, which are often global with strongholds in LMICs such as India or South Africa, mobilized to share information, document impacts, and advocate for government resources [37]. Others formulated recommendations to fight against COVID-19 and improve the working conditions of artisanal fisheries with a specific focus on women [38], who represent a large share of the total workforce [39]. In some cases, producer organizations have bought back fish from their members by applying the withdrawal price — a minimum price guaranteed throughout the year even in the absence of demand. Artisanal fishers and small holders have also turned to food banks and other forms of food sharing to distribute the catch [40,41]. Some NGOs are working with local fishers and women fish workers to connect catch to private households to support direct marketing of catches that would otherwise go unsold. There has also been a surge in direct producer-to-consumer sales. User traffic on the Local Catch Network in the U.S. was up by 310% from March 15, 2020 to May 14, 2020 compared to the previous year.

Consumer responses. Consumer response has been largely conditioned by public health measures that have confined people to their homes. Early responses included panic buying, a shift from restaurants to retail purchases and home delivery and local seafood purchasing [42]. Consumers in high-income countries have focused on buying seafood products with longer shelf-life and frozen products, while in low income food deficit countries there are early examples of reduced household income leading to shifts towards staple foods and away from nutrient dense foods [13]. There has also been some concern about the safety of seafood but others have responded that there is no connection between seafood and COVID-19 [43].

Learning and building resilience to future shocks

COVID-19 has exposed vulnerabilities and power imbalances in the food system, as well as highlighted broader inequalities and health disparities across society [44,45]. Coping and adaptive measures represent early responses during the first five months of the COVID-19 pandemic. While short-term coping will remain important as the pandemic spreads and possibly re-emerges in countries, actors and institutions within the seafood sector can carry adaptive responses forward and engage in a process of learning and building robustness to prevent future shocks (Fig 1). Based on the literature and findings from this study, we provide three key concepts to guide this 'adaptive cycle' process.

Identify resilience, vulnerability, and power imbalances in seafood systems. The seafood system is a meshed network of formal and informal producers and distributors, retailers, and consumers. Some supply chains, market segments, companies, small-scale actors and civil society have shown initial signs of greater resilience than others. In high-income countries, food retailers and supply chains selling shelf-stable and frozen seafood have done well following COVID-19-related shifts in food sourcing, while live-fresh and high-value producers selling to restaurants were particularly hard hit. A surge in direct producer-to-consumer sales in the U.S. may foretell a longer-term shift in consumer purchasing habits. Conversely, in many LICs, such as India, the informal sector was particularly hard hit by restrictive government responses to the crisis that prevented many actors from engaging in their livelihood activities [46], which could lead to less household income and decreased food security.

Maintaining and building diversity and connectivity at the community, company, and country level are ways to build resilience and guard against bad outcomes. Communities with diverse networks, such as in Mexico, were able to mobilize for support in the form of food aid and relief [47]. Strengthening local food systems, for example in India, is another way to build resilience in communities [48]. Companies with diverse portfolios and connections to more markets could more easily switch between commodities or divert products at a global scale (e.g. Ecuadorian shrimp, Chinese tilapia) thus enabling them to continue their business. Diversity and connectivity to markets at the country-level enables continuous supply of seafood.

Many countries, however, are increasingly reliant on food imports from a shrinking number of exporters [49], which makes them more vulnerable to disruptions. The tendency towards concentration in the seafood sector creates power imbalances that risk undermining food security in low-income countries and communities [50]. Companies and countries that were able to diversify and adapt did so, in some cases, by exposing other aspects of the global system (e.g., low-value markets in low-income food deficit countries) to trade shocks. Efforts to build resilience following COVID-19 should consider resilience to what?, for whom?, and for what purpose? [11], and be attentive to the possibility of propagated impacts from these decisions.

Transition from short-term coping to longer-term adaptation. As the pandemic shifts and possibly re-emerges in countries, there will be continuing need for coping responses to maintain the sector's core functions and protect vulnerable populations working in- or dependent on the seafood sector. Some coping responses, such as removing normal restrictions on fishing or increasing fishing quotas, which result in over-harvesting, may be maladaptive or have unintended consequences that undermine the resilience of the seafood system in the long-term. Responses will vary across regions and countries reflecting the different levels of economic, social, and political capital available to address the impacts across sectors in the seafood system, as well as the nature of the labor market. Informally employed workers, many of whom are women and migrants and are especially prevalent in Asia and Africa, are often omitted from social protection schemes and other entitlements.

A key transition point for actors in the seafood sector, and other food sectors, will be knowing when to shift from short-term coping strategies to the development and implementation of longer-term adaptation strategies and resilience building that is necessary to prevent future shocks and respond to ongoing stressors such as climate change or political instability. These shifts will be staggered in time as the pandemic progresses through countries and regions of the world. An additional consideration is how specialized adaptations should be, because increasing resilience of the seafood sector to future pandemics may reduce general resilience to an unknown array of future shocks [12]. Lastly, the United Nations recommends using the COVID-19 shock as an opportunity to transform the food system to be more green, inclusive, and resilient [51]. The idea of shocks as "windows of opportunity" to engage in transformations is a key feature of resilience thinking [12]. The current seafood system does not work for all people; it falls short in addressing concerns over environmental sustainability [52], social equity [53], or nutrition security [54]. Returning to 'business as usual' following this shock would be missing an opportunity to 'build forward better'.

Avoid mistakes of past responses. While COVID-19 presents a somewhat novel shock to the seafood sector in terms of magnitude, extent of supply chain influence, and global scope, previous shocks offer useful lessons. Three key lessons relate to trade restrictions, overstimulating production, and food prices and aid.

First, to avoid propagating shocks through trade, as occurred in the 2008 grain crisis, countries should maintain food supply buffers and cooperate internationally to avoid export bans and hoarding behavior [55-57]. As of mid-April, 20 countries representing 5% of the global calorie market had implemented restrictions on food exports, mainly for cereals and grains, and limited restrictions on animal products (eggs, chickens) [58]. While these actions have seemingly not triggered a cascading crisis, seafood flows were disrupted with impacts worse in some areas than others, and additional stressors such as a recession or future waves of COVID-19 could worsen the situation.

Second, surges in fishing effort in Europe after WWII [59] or more recently in Sri Lanka following the 2004 tsunami [60] led to overfishing. As governments and industries try to reboot the economy in the coming period, there is a risk of overstimulating production in some regions and fisheries, which could harm fish populations and the marine environment. Related to overfishing is the need to continue tracking lapses in monitoring, enforcement, and observers aboard vessels as they could lead to illegal, unreported, and unregulated (IUU) fishing and subsequent environmental impacts [41].

Third, during past shocks, the quality of the diet often suffers as families shift purchasing behavior to less expensive staple foods. For example, during the 1997-8 Asian financial crisis in Indonesia, households were largely able to maintain calorie intake, but anemia rates rose following decreased consumption of micronutrient rich foods (e.g., eggs, meat, fish) due to high prices [61]. This is confirmed in Bangladesh, where maintaining low staple food prices can benefit lower income consumers by freeing up money to access fish and other pricier foods [62]. It is estimated that the COVID-19 pandemic could double the number of people who are acutely hungry, from 130 million currently to 265 million [3]. Understanding the complex interplay between household income, food prices, and access for staple foods and micronutrient dense foods (including fish) can help governments and institutions better respond to current and future shocks.

This paper describes disruptions to- and responses by actors at multiple levels in the seafood system to fast moving, continually evolving shocks that have a direct impact on livelihoods, economies, food and nutrition security. We use a resilience 'action cycle' framework to study the first five months of COVID-19-related disruptions, impacts, and responses to the seafood sector. As the pandemic continues to spread there is much we need to learn, and we propose a series of immediate and longer-term research needs to guide strategic research investments (Table 2). COVID-19 has also highlighted the vulnerability of certain groups working in- or dependent on the seafood sector. Early coping and adaptive responses, combined with lessons from past shocks, should be considered when building resilience in the sector.

Methods

Data. Seafood production, trade, and retail sales were collected from March 28 to June 2, 2020 from national government agencies and market reporting companies. Data sources include the following: China domestic fish sales [63] and imports [64], European Union seafood imports [65], U.S. reservations for >20,000 restaurants [66], U.S. retail food sales using an aggregate of six major food groups [67], U.S. national food expenditures by food source [68], Ecuador shrimp exports [69], Norway farmed salmon exports [70], and international trade data (i.e., United Nations Comtrade) [71]. These data include the volume and/or value of seafood published on a weekly or monthly basis for the period of January 1, 2018 through April 30, 2020. Year-over-year percent change was calculated as the current trade volume (for a week or a month) minus the previous year's volume divided by the previous year's volume times 100. Prices were converted to U.S. dollars per kg and calculated as the total value divided by the total volume for a time period.

Reported impacts and responses on the seafood sector were compiled from April 3 to May 30, 2020, which includes (n = 175) articles published from January 28 to May 27, 2020. News articles were collected by monitoring Google News alerts for ("seafood" OR "fish") AND ("COVID-19" OR "covid"), daily data scraping of Twitter posts for "seafood" and "COVID-19" OR "covid," website searches of primary seafood industry news outlets (e.g., Seafood Source, Undercurrent, and IntraFish), and compiling information shared through the authors' professional networks. All news articles containing information about an impact on or response to the COVID-19 pandemic relating to any stage of the seafood supply chain were considered relevant. For each post, we extracted information on the date of the article, date of the reported impact, the type of impact, reported countries, sector(s), supply chain stage(s), species/taxa, and product form(s) involved. The extracted data and links to original news articles are available through the COVID-19 Seafood Impacts database [72]. While this database is not intended to represent a complete accounting of all impacts and responses, it does represent a sampling of the early impacts and responses across small-scale and industrial production, wild-capture and aquaculture systems, all supply chain stages, and over 40 high- and low-income countries/territories.

Examples of responses were drawn from the database [72] as well as emerging policy statements and technical reports published by governments and development partners during our study period to create Tables 1 and Supporting Information Table S1. Utilizing these latter sources, enabled us to rapidly evaluate early responses and strategies around the world and across sectors in the seafood supply chain. Responses and strategies were inventoried and then organized thematically using an iterative and inductive approach as new information became available.

Terms and definitions. We distinguish between specified resilience (specific to one type of shock) and general resilience to a range of shocks and stressors (e.g., economic, political, climatic, or biotic) [12]. For either dimension, 'building resilience' can be an explicit goal of seafood system governance in the future. When considering responses to shocks, we refer to coping as short-term reactive measures that cannot be sustained for long periods and adapting as longer-term and planned change in practices [11].

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Author Contributions
DC Love, EMN, JSS, PPdS developed the initial concept. DC Love and JAG wrote the abstract. DC Love and EHA wrote the introduction. RSC and DC Love led the section on COVID-19 disruptions with writing and review by MT, JAG, HA, AR, JSS, FP, MFT, and MT. JSS and FP led the section on reactive actions with writing and review by HF, EHA, CH, PPdS, FP, MT, and ALTL. EHA led the section on learning and building resilience with writing and review by JAG, RSC, MFT, FP, CS, PPsD, MT, and DC Love. JSS, FP, CH and ALTL created Table 1. DC

Little and ALTL created Table 2. EHA, and DC Love created Fig 1. MFT, MT, DC Little, DC Love, JAG, and EHA created Fig 2. RSC, JAG, HEF, EMN, and JSS created Fig 3 and collected data and reviewed media publications/impacts for Fig 3 and Table 1. DC Love, FA, BB, DC Little, AR, and WE created Fig 4. All authors contributed to the study design and reviewed the manuscript.

Competing Interests

HEF serves on the Technical Advisory Group for Aquaculture Stewardship Council. JAG is a member of the Oceana Science Advisory Board. DC Little is a Member, Standards Oversight Committee for Global Aquaculture Association, Director Nam Sai, Thailand. JSS owns and operates a small-scale oyster farm; coordinates Local Catch Network. MFT is on the Scientific and Nutritional Advisory Council for Seafood Nutrition Partnership, the Standards Oversight Committee for Global Aquaculture Association, and a judge for Future of Fish Feed Challenge.

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Tables and Figures

Table 1. Reactive actions to COVID-19 by seafood system actors and institutions. (See Supplementary Table 1 for country-specific examples and references.)

Governments and Development Partners
Health and safety responses to protect public health, as well as safety and working conditions for fishers and fish farmers, including through the use of technologies
Social protection and employment response including non-contributory assistance programs (one-off cash transfer, food distribution), social insurance (e.g. unemployment benefits) and labor market interventions (e.g. wage subsidies) to mitigate short-term impacts. These responses differ according to national fiscal policies.
Economic responses to provide emergency assistance including aid, reallocation of financial resources, loans and subsidies to mitigate the short-term impacts of the crisis on commercial fisheries and aquaculture. These responses have been observed in both high- and low-income countries, but appear to be significantly larger in high income countries. In both, challenges have been reported in accessing funds, especially for small holders and the informal sector.
Management measures and other technical responses to respond to the impacts of COVID-19 on commercial fisheries and aquaculture
Large-Scale Commercial Fisheries and Aquaculture
Health and safety responses to ensure the health and safety of workers along the supply chain as well as social support to national efforts
Social protection and industry responses, including advocating for and pursuing social protections and reducing workforce in response to diminished demand and/or changes in the marketplace
Economic responses targeting retail and consumer markets, including online and home delivery
Small-Scale Sector and Non-Governmental Organizations
Health and safety responses, including arrangements and information to support and strengthen communities and vulnerable populations

Social protection and sector responses, including collective action and networking within or across small-scale fishing sector as well as fish workers and small fish farmers to maintain safe employment opportunities **Economic responses** via local and seafood direct marketing
Consumers **Shift in consumer purchasing** as a result of the pandemic with uncertainty about the future

Table 2. Short-term and longer-term strategic research needs to support learning from COVID-19 impacts and responses.

Immediate research needs: ● To complement price and production data, use survey tools to document and better understand COVID-19 impacts on people working at all levels in seafood value chains and seafood consumers in order to direct support to vulnerable actors in the seafood system. ● Document and share case-experiences of actors in the value chain that have successfully adapted to shifts in supply and demand of perishable seafood so lessons from their strategies can be more widely adopted ● Improve open data and data sharing platforms to facilitate the exchange of information about the societal impacts of COVID-19, to enable more rapid and coordinated responses to future shocks
Longer-term research needs: ● To design future response strategies in support of the 'tropical majority' of small-scale fish producers and traders, draw on lessons from social safety net programs in other food sectors, and experience with implementing the Human Right to Food ● Improve information systems to track fish prices and trade volumes typically consumed by different types of consumers (particularly in LMICs) to reduce wasted fish and enable value chains to respond to consumers' nutrition needs and demand preferences. This may include full traceability of species and stocks based on molecular/DNA analysis. ● Focus resilience research on those parts of the aquaculture and fisheries system that supply populations most nutritionally dependent on seafood and those which, through employment, support food security of low-income value chain actors. ● Develop and apply an evaluation framework and resilience indicators for seafood value chains, that include social economic and environmental aspects, to identify and learn from resilience 'hot-spots' ● Study temporal effects of the shock on employment in the sector, on migration, on adoption of technologies for production and processing, to better design future crisis-coping strategies and recovery efforts ● Study immediate and longer-term impacts on natural resource systems to identify means to sustain resources during and after future system shocks

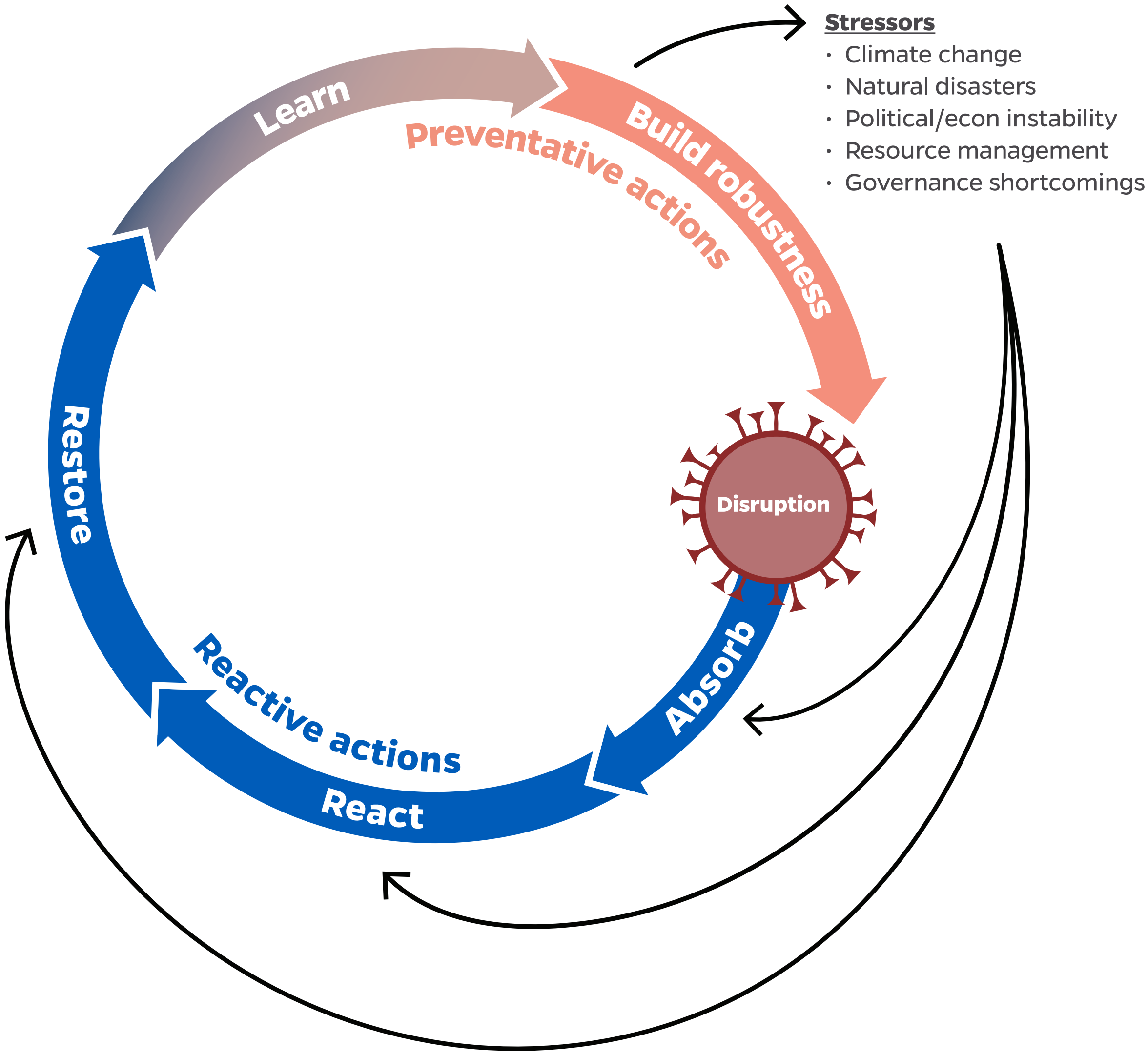

Fig. 1 Food system resilience action cycle. Actors and institutions respond to- and to prepare for disruptions and ongoing environmental, political, and economic stressors using a series of reactive and preventative actions. Modified from [10].

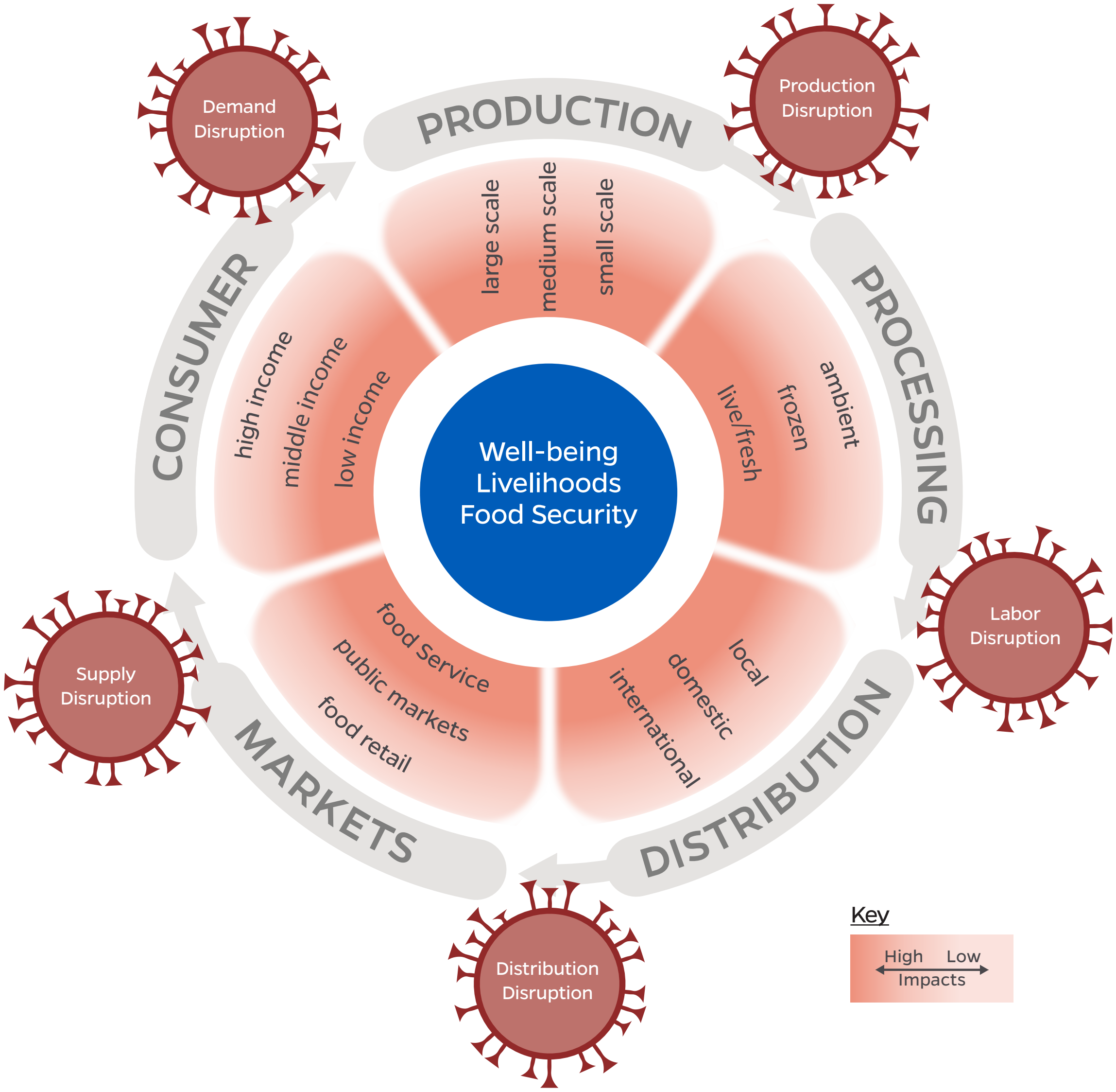

Fig. 2 COVID-19 disruptions and impacts on seafood supply chains. Disruptions to production, labor, distribution, supply and demand create a range of impacts. The color gradient indicates the hypothesized relative impacts to different components of- or actors within seafood supply chains. The ordering of groups is based on multiple data streams collected through May 2020 but is not intended to be a quantitative or absolute ranking. In the center of the figure are key outcomes we focus on in this paper: human well-being, livelihoods, and food security.

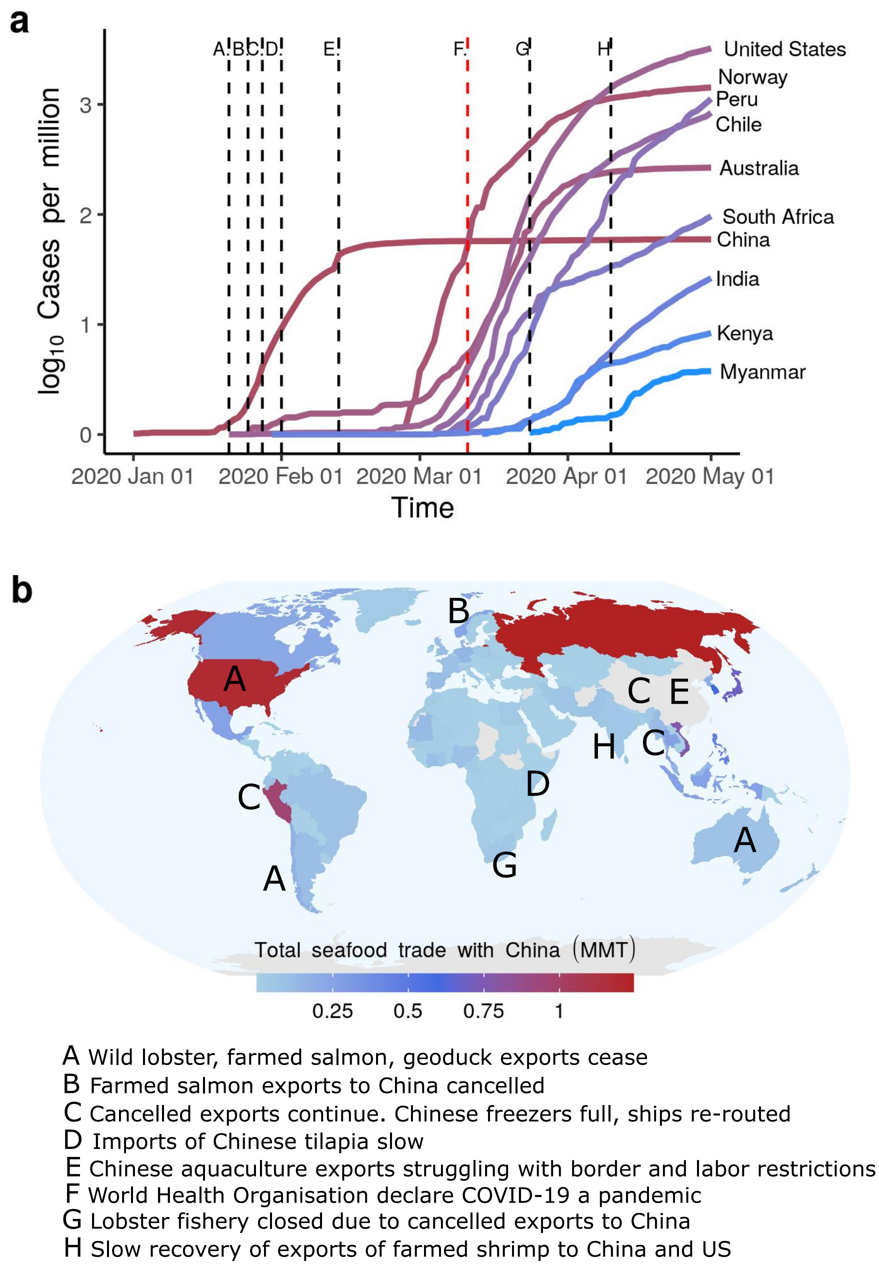

Fig. 3 COVID-19 timeline and seafood-related impacts first affected China and their trade partners. **a,** COVID-19 case rate in select countries that trade with China [73]. **b,** Exemplary impacts identified in media and trade articles [72]. Total seafood trade = sum of imports and export flows with China.

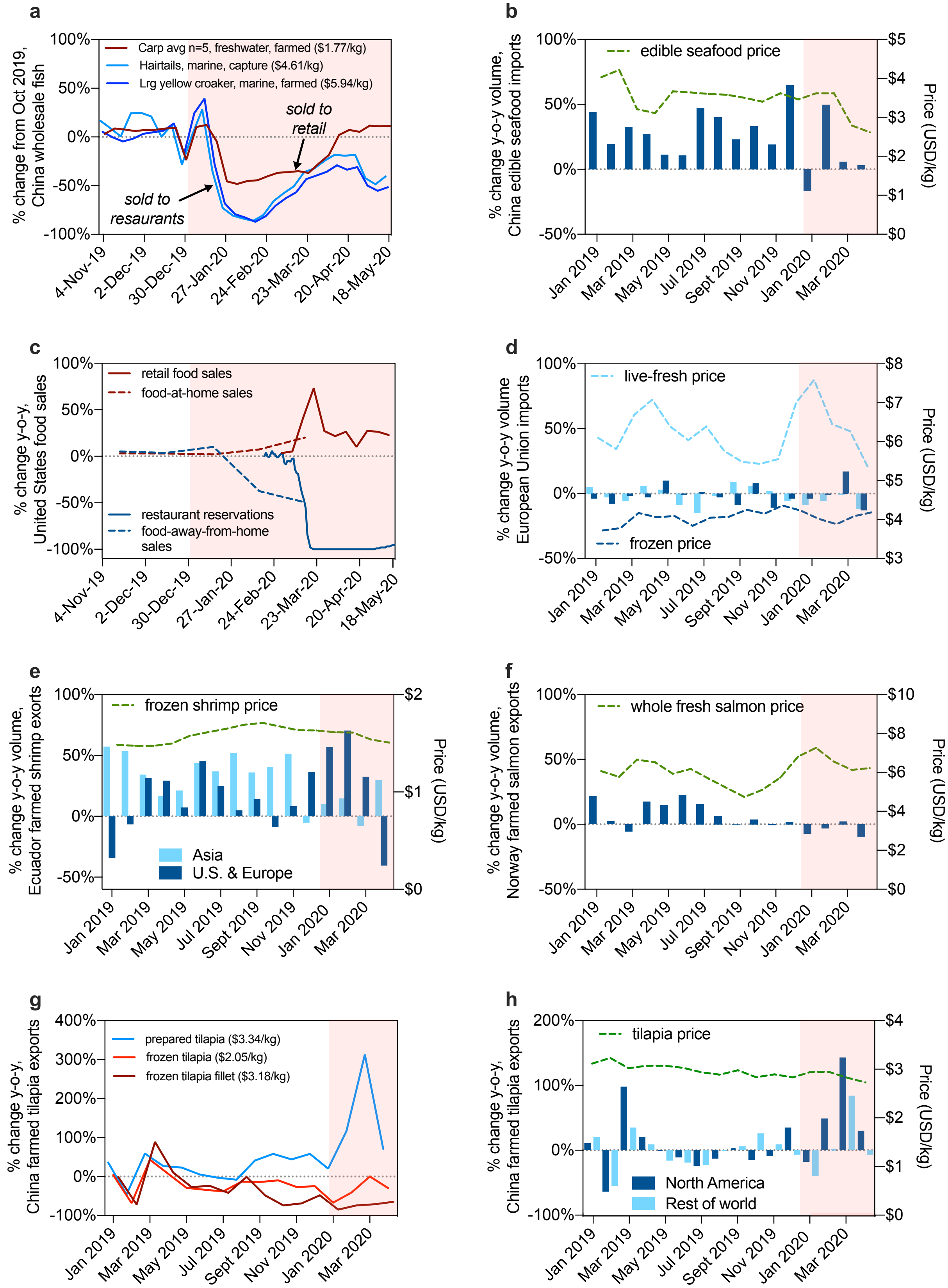
a
% change from Oct 2019, China wholesale fish
Carp avg n=5, freshwater, farmed ($1.77/kg)
Hairtails, marine, capture ($4.61/kg)
Lrg yellow croaker, marine, farmed ($5.94/kg)
sold to retail
sold to resaurants
100%
50%
0%
-50%
-100%
4-Nov-19
2-Dec-19
30-Dec-19
27-Jan-20
24-Feb-20
23-Mar-20
20-Apr-20
18-May-20
b
% change y-o-y volume, China edible seafood imports
edible seafood price
Price (USD/kg)
100%
50%
0%
-50%
$5
$4
$3
$2
$1
$0
Jan 2019
Mar 2019
May 2019
Jul 2019
Sept 2019
Nov 2019
Jan 2020
Mar 2020
c
% change y-o-y, United States food sales
retail food sales
food-at-home sales
restaurant reservations
food-away-from-home sales
100%
50%
0%
-50%
-100%
4-Nov-19
2-Dec-19
30-Dec-19
27-Jan-20
24-Feb-20
23-Mar-20
20-Apr-20
18-May-20
d
% change y-o-y volume European Union imports
live-fresh price
frozen price
Price (USD/kg)
100%
50%
0%
-50%
$8
$7
$6
$5
$4
$3
Jan 2019
Mar 2019
May 2019
Jul 2019
Sept 2019
Nov 2019
Jan 2020
Mar 2020
e
% change y-o-y volume, Ecuador farmed shrimp exports
frozen shrimp price
Asia
U.S. & Europe
Price (USD/kg)
100%
50%
0%
-50%
$2
$1
$0
Jan 2019
Mar 2019
May 2019
Jul 2019
Sept 2019
Nov 2019
Jan 2020
Mar 2020
f
% change y-o-y volume, Norway farmed salmon exports
whole fresh salmon price
Price (USD/kg)
100%
50%
0%
-50%
$10
$8
$6
$4
$2
$0
Jan 2019
Mar 2019
May 2019
Jul 2019
Sept 2019
Nov 2019
Jan 2020
Mar 2020
g
% change y-o-y, China farmed tilapia exports
prepared tilapia ($3.34/kg)
frozen tilapia ($2.05/kg)
frozen tilapia fillet ($3.18/kg)
400%
300%
200%
100%
0%
-100%
Jan 2019
Mar 2019
May 2019
Jul 2019
Sept 2019
Nov 2019
Jan 2020
Mar 2020
h
% change y-o-y, China farmed tilapia exports
tilapia price
North America
Rest of world
Price (USD/kg)
200%
100%
0%
-100%
$4
$3
$2
$1
$0
Jan 2019
Mar 2019
May 2019
Jul 2019
Sept 2019
Nov 2019
Jan 2020
Mar 2020

Fig. 4 COVID-19 impacts on seafood production, trade, and wholesale and retail sales through April 2020. a, China domestic fish sales volume at 147 domestic wholesale markets using an index of key species. **b,** China edible seafood imports. **c,** United States all food sales by food source using two nationally representative datasets and reservations at > 20,000 restaurants. **d,** European Union seafood imports of live/fresh and frozen products using aggregate product forms representing 80% of the total value of imports. **e,** Ecuador farmed shrimp (36-40 ct, shell on) exports by region. **f,** Norway farmed Atlantic salmon exports (fresh, whole fish). **g,** China tilapia global exports by product form. **h,** China tilapia exports to North America and the rest of the world. The percent of exports by region in 2017 and 2018 was as follows: North America (51%), Africa (30%), Asia (10%), Europe (7%), and South America (2%). References provided in the methods section. Pink indicates the time period of COVID-19.