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Research Notes

Preliminary lessons from COVID-19 disruptions of small-scale fishery supply chains

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A B S T R A C T

The ongoing COVID-19 pandemic and associated mitigation measures have disrupted global systems that support the health, food and nutrition security, and livelihoods of billions of people. These disruptions have likewise affected the small-scale fishery (SSF) sector, disrupting SSF supply chains and exposing weaknesses in the global seafood distribution system. To inform future development of adaptive capacity and resilience in the sector, it is important to understand how supply chain actors are responding in the face of a macroeconomic shock. Comparing across seven SSF case studies in four countries, we explore how actors are responding to COVID-19 disruptions, identify constraints to adaptive responses, and describe patterns of disruption and response across cases. In all cases examined, actors shifted focus to local and regional distribution channels and particularly drew on flexibility, organization, and learning to re-purpose pre-existing networks and use technology to their advantage. Key constraints to reaching domestic consumers included domestic restrictions on movement and labor, reduced spending power amongst domestic consumers, and lack of existing distribution channels. In addition, the lack of recognition of SSFs as essential food-producers and inequities in access to technology hampered efforts to continue local seafood supply. We suggest that the initial impacts from COVID-19 highlight the risks in of over-reliance on global trade networks. The SSFs that were able to change strategies most successfully had local organizations and connections in place that they leveraged in innovative ways. As such, supporting local and domestic networks and flexible organizations within the supply chain may help build resilience in the face of future macroeconomic shocks. Importantly, bolstering financial wellbeing and security within the domestic market both before and during such large-scale disruptions is crucial for supporting ongoing supply chain operations and continued food provision during macroeconomic crises.

1. Introduction

The COVID-19 pandemic has reached over 48 million confirmed cases in 216 countries (as of 5 November 2020), with continuing and extensive environmental, geopolitical, societal, and technological consequences. The economic impact of the pandemic may spark the first increase in global poverty rates since 1990 (Sumner, Hoy, & Ortiz-Juarez, 2020) and localized impacts will be disproportionately experienced by socioeconomically vulnerable populations (Sumner et al., 2020; Swinnen, 2020). Ongoing efforts

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to curb the spread of the virus have disrupted transnational systems that support the health, wellbeing, and livelihoods of billions of people—including food systems. COVID-19 disruptions notwithstanding, the global food security outlook is uncertain (HLPE, 2020; Swinnen, 2020) with hunger and undernutrition expected to rise (FAO, IFAD, UNICEF, WFP, & WHO, 2020). Understanding how macroeconomic stressors affect food production and distribution is now particularly crucial.

Seafood is an essential source of nutrition for billions of people around the world. Globally, seafood is one of the most highly traded food items, generating $277 billion USD in 2016 (FAO, 2018). However, the global seafood distribution system has weaknesses. Seafood is a perishable commodity with complex supply chains that are sensitive to external shocks (Gephart, Deutsch, Pace, Troell, & Seekell, 2017). Further, the distribution of economic benefits (Béné, Macfadyen, & Allison, 2007) and food and nutrition security (Asche, Bellemare, Roheim, Smith, & Tveteras, 2015) across global seafood trade networks are often inequitable, tending to disadvantage developing nations in the global south (Prell, Sun, Feng, He, & Hubacek, 2017).

The COVID-19 pandemic is exposing weaknesses in global seafood systems, particularly in small-scale fishery (SSF)[7] supply chains (Bennett et al., 2020). SSFs constitute a crucial sector for livelihoods, food and nutrition security, and trade within global seafood supply chains. Globally, SSFs contribute 81% of catch for local consumption (World Bank, 2012) and employ 32 million fishers and 76 million post-harvest workers; more employment than industrial fisheries, oil and gas, and tourism combined (OECD, 2016).

Understanding underlying mechanisms for global seafood system vulnerabilities requires addressing the system holistically,[8] rather than by isolated supply chains (Stoll, Pinto da Silva, Olson, & Benjamin, 2015). Given their reach, SSFs are positioned to play a crucial role in addressing global food and nutrition insecurity—though may require intentional and systematic adjustments to global seafood flows (Hicks et al., 2019). As SSFs become more connected to global markets (a growing trend), their vulnerability to processes occurring at multiple spatial and temporal scales (i.e. teleconnected vulnerability), is likewise increasing in many locations (Adger, Eakin, & Winkels, 2009; Crona, Van Holt, Petersson, Daw, & Buchary, 2015; Stoll, Crona, Fabinyi, & Farr, 2018).

In the wake of COVID-19, several vulnerabilities that risk undermining seafood system resilience have become readily visible. Examining COVID-19 disruptions to SSFs can illuminate otherwise hidden vulnerabilities relevant to a range of different shocks (e.g. political, environmental, social, or economic). Seafood system resilience has been defined as the capacity of a multi-level seafood distribution network to provide sufficient, appropriate, and accessible seafood to all, in the face of unforeseen disturbances (Tendall et al., 2015). As SSF supply chains face COVID-19 disruptions, whether and how they evolve will be shaped, in part, by existing adaptive capacity: the "ability of a system to evolve in order to accommodate environmental hazards or policy change and to expand the range of variability with which it can cope" (Adger, 2006: 270). Domains of adaptive capacity particularly relevant to SSF supply chain actors include assets (e.g., financial and material resources to draw on in times of need), the agency or self-efficacy to initiate change, flexibility, organization (including social networks), and learning (Cinner et al., 2018; Cinner & Barnes, 2019).

Here we examine how COVID-19 has disrupted seven SSF supply chains located in four countries—Indonesia, India, Peru, and the United States. Specifically, we examine how SSF supply chain actors reacted to these disruptions, consider how actors drew on aspects of adaptive capacity, and where they faced limitations. We focus specifically on adaptive capacity within SSF supply chains, while acknowledging that these capacities are shaped and constrained by broader social, economic and political structures.[9]

2. Methods

We take a case study approach to outline recent events and changes in seven SSF supply chains (Table 1). Case studies were selected based on the authors' pre-existing relationships with and knowledge of the examined fisheries. They capture a diversity of supply chain characteristics, distribution strategies (including distribution channels with domestic and international destinations) and social, political, and economic contexts. The scope of each case study varies in the geographic extent of SSFs and their respective supply chains, as determined by the authors' ongoing work in the regions. Peruvian SSF supply chains are discussed at a national level and include export and domestic oriented fisheries (PE and PD respectively), while case studies from Langkat, Indonesia (LE and LD), the Andaman and Nicobar Islands, India (AE and AD), and California, U.S.A. (CU) focus on supply chains of one or two SSFs in a province, island chain, and state, respectively.

Information on each SSF supply chain before and during the COVID-19 pandemic is based on data collection and experience with the fishing communities prior to and during the pandemic's onset. Data sources include personal communications with fishery representatives or actors, content analysis of fishery websites, public communications (e.g., blogs, emails, newsletters, etc.), and news articles published by third parties.

For each case, we describe the supply chain structure and distribution channels prior to the onset of COVID-19 (Table 1), then identify how distribution has changed since (Fig. 1). SSF supply chains are described by their length (i.e., number of linked nodes, or actors making up the supply chain), distribution strategy (i.e., local, domestic, or international), and types of actors involved (e.g., processors, brokers, traders, etc.). Change in activity along

[7] Small- and large-scale fisheries differ in scale of operation, sophistication of technology, extent of livelihoods generated, and the degree of capital intensity and investment (see for example, Carvalho, Edwards-Jones, & Isidro, 2011; FAO, 2020; Kolding, Béné, & Bavinck, 2014), though definitions of SSF remain elusive and contested (e.g. Berkes, Mahon, McConney, Pollnac, & Pomeroy, 2001; Allison & Ellis, 2001; Defeo & Castilla, 2005; Johnson, 2006).

[8] In line with HLPE (2017), we define **food system**, as a collection of all elements and actions that occur between or affect the production and consumption of food, and the socio-economic and environmental outcomes. Within a food system framing we consider fish (and seafood) supply chains, rather than value chains. The **food supply chain**, comprises all activities and actors involved in the processes between the production and consumption of food, whereas a **food value chain**, focuses on the addition of value (monetary and non-monetary) to the product, from the consumer's perspective, and how demand varies due to preferences, practices, and custom (Feller et al., 2006). We refer to points within either supply or value chain where seafood changes hands or ownership as **nodes**, which usually represent a new actor. **Distribution** is an activity within either the supply or value chain that facilitates the flow of product between nodes from the producer to the consumer (HLPE, 2017). The **distribution channel** is the specific path of product flow from one node to the next (Aziz et al., 2017; Indahsari & Farid, 2020). As such, actors can have several distribution channels for their seafood, within one supply or value chain. Preference between distribution channels is affected by **distribution strategy**, or the choices made by a given actor to facilitate the movement of product to the next node (Gunasekaran et al., 2004).

[9] While we examine adaptive capacity of supply chain actors in this study, we are not implying that supply chain actors are responsible for the way in which COVID-19 has affected them, their ability to respond, or improving their adaptive capacity going forward. Rather, we see adaptive capacity within groups as the result of complex and systemic social dynamics and that should be considered within a larger political economy lens (Bavinck et al., 2014; Leal, 2010). Examining adaptive responses in the context of a crisis can inform policy actions in order to support increased adaptive capacity in preparation for future crises. Here we consider adaptive capacity as one component that contributes to a group's vulnerability, when considered with the group's exposure (i.e. the stressors' magnitude, frequency, duration, and areal extent (Burton et al., 1993)) and sensitivity (i.e. the extent to which each system and actor group is affected by the disruption (Adger, 2006)).

Table 1
Summary of case study fisheries from Indonesia, India, Peru and the United States pre-COVID-19. Pseudonyms are used to maintain anonymity.

Location	SSF (abbreviation)
Langkat, North Sumatra, Indonesia North Sumatra is the largest seafood producing province in Indonesia, the second largest marine capture producer globally (FAO, 2018; BPS-Statistics Indonesia, 2020). The coastal regency of Langkat in North Sumatra produces much of this fish, supplying a range of consumers locally and within Indonesia, and to export markets such as Malaysia, China, Europe, and the U.S. Two key actors in Indonesia's SSF supply chains are processors and mobile traders.	**Export-oriented processors (LE)** Processors largely act as middlemen, buying from fishers and selling prepared seafood products to distributors. Rio is one such processor who employs between 50 and 100 people at his crab and sea snail processing facility. Only unprocessed crab is sold locally, so Rio's shelled crab and sea snails are sold to buyers in Medan, the provincial capital. From there, 15% is sold locally, 15% is exported to Malaysia, and the remaining 70% is further processed for export to Europe and the US (pers. comm., Rio). **Domestic-oriented mobile traders (LD)** Mobile traders act as local distributors by buying seafood primarily from wholesale markets and selling to local consumers directly from their motorbikes. These independent traders carry up to 100 kg of product, including vegetables, chicken, tofu, and tempeh, of which fresh seafood has the highest profit margin (pers. comm., Langkat Trader 1).
Andaman and Nicobar Islands, India The Andaman and Nicobar Islands (ANI) are an archipelago off the eastern coast of India. From 1955 onwards, the Indian government settled fishing families from India's east coast on the ANI to supply seafood for the larger populace. These families and subsequent waves of voluntary migrants formed the archipelago's fishing industry comprising fishers, processors, intermediaries, local seafood vendors, and exporters (Jaini et al., 2018).	**Grouper fisheries (AE)** In the late 1990s, many Junglighat fishers switched to the nascent export-oriented grouper fishery, along with intermediaries and exporters who shipped chilled groupers and other luxury seafood to South-East Asian markets via mainland India. In recent years, the majority of the fishing industry's annual revenue is from exports of luxury seafood, with prices and demand peaking just prior to Lunar New Year (Jaini et al., 2018). **Mixed-species pelagic fisheries (AD)** Junglighat is the largest fishing settlement, port, and airport, and is the center for fisheries trade in the archipelago. Due to its large size and population's heterogenous origins, the fishing sector is largely unorganized, with a few defunct fishing cooperatives that enable access to subsidies (pers. obs., S. Advani). Junglighat fishers use seine nets to catch baitfish and schooling pelagics to supply local markets via intermediaries and seafood vendors.
Peru Peru is known for its industrial anchoveta fishery, despite the majority of product entering the domestic market coming from the small-scale and artisanal fisheries that employ over 76 thousand fishermen (PRODUCE, 2019). The SSF sector is informal. More than 60% of boats lack official documentation and 24% of captures in Peru are illegal, unregulated and unreported (Gutiérrez & Sueiro, 2019) .	**Export-oriented artisanal fisheries (PE)** Artisanal landings move from fishers to consumers through three principal distribution channels facilitated by midchain brokers. Seafood is sold to plants, where it is processed, packaged and exported; to wholesale terminals, where it enters the domestic market; or flows directly to end market clients via direct sale (Christensen, De la Puente, Sueiro, Steenbeek, & Majluf, 2014). **Domestic-oriented artisanal fisheries (PD)** There is also a non-brokered portion of catch which is used for household consumption or gifting within the local community (pers. comm., Peru Fisher 1). Seafood of all kinds is central to traditional Peruvian coastal cuisine, such as ceviche, with annual per capita seafood consumption increasing steadily since the early 2000s and reaching 24.4 kg in 2017 (PRODUCE, 2018). Peruvians frequent *cevicherias* or *picanterías*, and women commonly purchase seafood (fresh, salted, or dried) for the household from vendors at local open-air wet markets.
California, USA The U.S. is the top seafood importer and among the top five exporters worldwide (FAO, 2018). California is not a top seafood producing state, but is one of the top eight employers in seafood processing and wholesale plants (NMFS, 2018).	**Red sea urchin dive fishery (CU)** The California red sea urchin (CA RSU) fishery operates statewide, with three regions accounting for the bulk of landings (CDFW, 2019). Although relatively small with 262 licensed (CDFW, 2020), and only around 80 active, divers (pers. comm. P. Halmay), the CA RSU fishery has been consistently valuable over the past decade, bringing in around $12,000,000 annually between 2001 and 2014 (CDFW, 2019). Harvested urchin roe, or 'uni,' is sold domestically in restaurants and exported to Asia via a few in-state processors (pers. comm., N. Rosser). Recently direct-to-consumer sales have burgeoned, such as the Tuna Harbor Dockside Market in San Diego and a freelance fishmonger in central California (pers. obs., H. Bassett). Over the past two decades, annual landings by weight have declined consistently (16,000,000 lbs in 2000 to 2,375,173 lbs in 2019; CDFW, 2019). Despite increasing market price, in 2016 and 2017, annual earnings for the Northern California portion of the fishery dropped below the prior five-year average qualifying them for federal disaster relief; the details and amounts of which are still being determined (pers. obs., H. Bassett).

distribution channels is defined as an increase or decrease in trade by volume relative to pre-COVID-19 operations.

Comparing across cases, we then identify themes of (a) COVID-19-related supply chain disruptions, (b) adaptive responses employed by supply chain actors, including innovations and coping strategies, (c) limitations on the actors' adaptive responses, and (d) preliminary impacts of the combined effect of disruptions and responses. To gain a preliminary understanding of the role of SSF supply chains' adaptive capacity in responding to a macroeconomic shock, we highlight which domains of adaptive capacity—assets, agency, flexibility, organization, and learning—facilitated innovative actions or coping strategies and identify where a lack of capacity in these domains hinder supply chain responses to COVID-19.

3. Results

3.1. Supply chain disruptions

In all cases, supply chains with international target markets became effectively inactive since the onset of COVID-19 (as of 31 May 2020; Fig. 1), partially due to associated restrictions on movement and market instability (Table 2). Grouper harvested in the

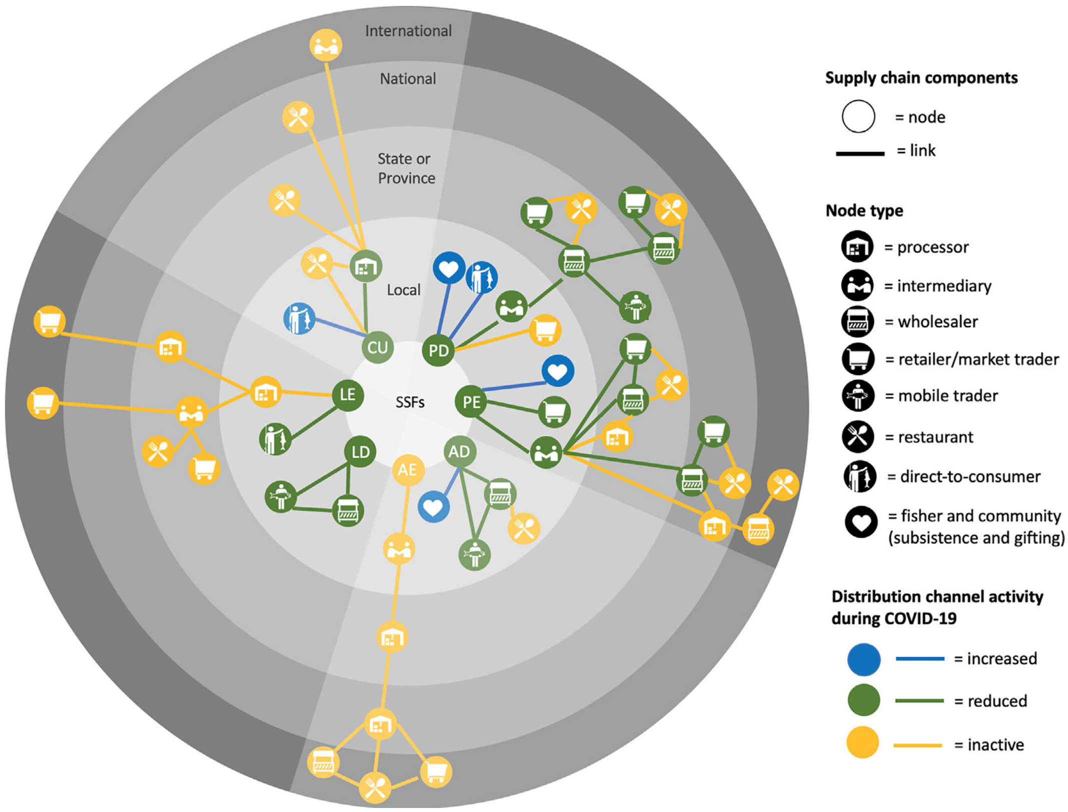

Fig. 1. Changes in distribution channel activity since the onset of COVID-19 in supply chains of all seven examined SSFs: Langkat export-oriented processors (LE) and domestic-oriented mobile traders (LD), Andaman and Nicobar Islands grouper fishery (AE) and mixed-species pelagic fishery (AD), Peru export-oriented (PE) and domestic-oriented (PD) artisanal fisheries, and California red sea urchin dive fishery (CU). Colors represent links and nodes activities that increased (blue), reduced (green) or became inactive (yellow) during Covid-19 (as of 31 May 2020), across a range of scales from local SSF locations (inner circle) to global/ international scale (outer circle). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Andaman and Nicobar Islands (AE) destined for markets in South East Asia, and both mahi-mahi destined for the US and jumbo flying squid destined for China or Spain from Peru (PE), remained grounded in-country (Carrere, 2020; pers. comm. M. Mondal). Halted exports affected actors at every stage of international supply chains. In Langkat, Indonesia, Rio (LE) reduced his purchases of fresh seafood for a month, then shuttered his business with 85% of his intended export product remaining (pers. comm., Rio). In all cases, trade decreased precipitously in volume and value with ripple effects throughout the supply chains (Fig. 1).

The abrupt shift from export-oriented markets to limited local markets with less demand and less-developed distribution channels led to initial gluts of supply, resulting in lost income and fish wastage (Table 2). For instance, in Langkat, despite fishers reducing their catch, restricted mobility for distribution (LD) combined with decreased local consumption, resulted in a large proportion of fish remaining in local markets, where inadequate cold storage resulted in reduced fish quality and increased wastage (pers. comm., Langkat Trader 1). In California (CU), *uni* processors could not get their product to its usual destinations in Asia, and, with local restaurants closed, there was no market for the perishable product, resulting in processors throwing out substantial amounts of recently purchased urchin hauls (pers. comm., N. Rosser).

The timing of COVID-19 shutdowns coincided with important cultural events, Lunar New Year and Lent, exacerbating negative impacts on fishers and supply chain actors. SSFs that export to places where Lunar New Year (January 25th, 2020) is celebrated (AE, AD, LE, and LD) experienced lower than expected prices around the holiday (pers. comm., V. Rao; pers. comm., Langkat Trader 1). These events typically serve as financial safety nets due to increased prices and sales. Similarly, in Peru (PD), fishers rely on the high grossing periods of Lent and the week of Easter to recover losses from the previous year and pay off accrued debt (pers. comm., Peru Expert 1); the absence of which may have sustained financial implications.

In other cases, multiple interacting COVID-19-related stressors had compounding effects. In California (CU), the COVID-19 crisis and impending drain on federal resources triggered a sped-up timeline for federal disaster relief funds discussions; in the midst of the pandemic, fishers, processors, and managers were required to negotiate allocation percentages and plans for the use of funds rather than address real-time market impacts on the fishery (pers. obs., H. Bassett). In other cases, consumers with lowered incomes and financial uncertainty led to further reduced local demand. Many Peruvians (PD) turned to cheaper and more accessible protein sources (largely chicken) from local markets (pers. comm., Peru Expert 1). In Indonesia (LD), despite up to 50% decreases in fish prices, local households still reduced seafood consumption, opting for less expensive proteins such as tofu and tempeh (pers. comm., Langkat Trader 1).

3.2. Coping within constraints

In the face of COVID-19 disruptions, many supply chains examined (CU, LE, LD, and AD) contracted to local-only distribution, with varying activity levels and constraints (Fig. 1; Table 2). Domestic movement and labor restrictions constrained supply to domestic consumers. Lack of recognition of SSFs as essential food-producers, inequities in access to technology, and inadequate knowledge of bureaucratic processes further exacerbated chal-

Table 2
Observed patterns in impacts of the COVID-19 pandemic on SSF supply chains, associated adaptive responses of supply chain actors (including both innovative actions and coping strategies), apparent limitations on adaptive responses, and preliminary combined effects of impacts and responses. Case studies in which the patterns were observed are noted in parentheses following the disruption description. Domains of adaptive capacity relevant to innovations, coping, or limiting adaptive responses are noted in parentheses, where A = assets, G = agency, F = flexibility, O = organization, and L = learning.

Supply chain disruptions	Adaptive responses		Limitation(s) on adaptive responses	Preliminary impacts
	Innovative actions	Coping strategies		
Export-oriented distribution channels inoperable (AE, PE, LE, CU)	Build local consumer base using social media or online sales to increase visibility or shift consumption norms (O, L, F, G, A)	Trade activity shifts to existing local or regional distribution channels (F, O)	• Disconnect between producers and consumers (F) • Lacking local organization to develop new supply chains (O) • No local market for niche products (F)	• Reduced overall demand • Reduced or no work and income for fishers and other actors • Loss of access to food and nutrition source for usual consumers • Some investment in building local networks
Food distribution by smaller fisheries inhibited due to exclusion from defined essential activities or bureaucratic barriers (AD, PE, PD)	Leverage pre-existing social networks to access legal permission to distribute (O, G)	Trade activity shifts to existing local or regional distribution channels (F, O)	• Exclusive bureaucratic operations (G, O, F) • Lack of access to knowledge regarding options and rights (A, L, O)	Reduced distribution and sales overall
Loss of restaurant-oriented supply chains (CU, PE, PD)	Promote in-home consumption (F, L, O, G, A)	Shift distribution to retail markets (F)	• Lack of storage (A) • Social norms inhibit shifts in consumption (F, L)	• Reduced overall demand • Reduced or no work and income for fishers and other actors • Fish wastage
Initial glut of harvest with no market access (AE, CU, LE, LD, PE)	None	Some fishers opt to consume fish to avoid losses, despite being considered undesirable locally (F, G)	• Lack of storage (A) • Social norms inhibit shifts in consumption (F, L)	• Initial economic losses • Fish wastage
Reduced demand due to reduced income and financial insecurity amongst consumers (LE, PE, PD)	Build local consumer base using social media to increase visibility (O, L, F, G, A)	Lower frequency of fishing trips and volumes captured to reduce expenditures (F, G)	• Lack of savings and assets to cover income reduction (A) • Trip costs place a barrier on price minimum (F)	• Lower seafood prices • Reduced overall demand • Reduced or no work and income for fishers and other actors • Shifts in demand toward less expensive protein options

lenges. In Peru (PD), domestic transit restrictions limited movement of seafood to Lima and other distribution hubs from the north (which supplies 60% of domestically consumed fish), halting further countrywide distribution (pers. comm., Peru Intermediary 2). Public roads were limited to essential service vehicles and required transit permission from the National Police, which informal actors in the fishery sector struggled to procure online (pers. obs., C. Giordano). Similar barriers were faced in the Andaman and Nicobar Islands; initially, fishing and allied activities were deemed a non-essential activity and locked down (Giles, 2020b). When they re-opened in mid-April, fishers had to comply with social distancing rules, 'movement permits' requiring additional paperwork, and reduced crew. These constraints challenged export-oriented longline fishers (AE) who started supplying local markets with net-caught schooling pelagic fish (AD) (Giles, 2020a; pers. comm., M. Mondal). With low savings and no access to aid, women-headed households and recent migrants in the fishing community became food insecure (pers. comm., M. Mondal).

In addition, socio-cultural consumption norms and socio-economic factors have shaped and constrained the ability of longer distribution channels to shift to supplying local markets. In Indonesia (LE), high-end fish products, such as shelled crab and sea snails, are too expensive for the local market, thus Rio could not re-orient these products to local distribution (pers. obs., S. Suri). Similarly, in the US, *uni* (CU) is a niche product consumed in restaurants, which were largely closed initially, and not commonly prepared in homes (author knowledge, H. Bassett; Table 2), though direct-sellers saw increased demand as interest grew in novel food products and activities (pers. comm., P. Halmay). In Peru (PD), consumers prefer fresh fish, believing frozen fish is unhealthy (pers. obs., C. Giordano). Concerned about contracting COVID-19, many consumers shop at supermarkets, which are perceived as cleaner and safer, however primarily sell frozen, not fresh, fish (ibid). Peruvians also prefer white fish and high-end species, which are less available in markets due to regional distribution barriers (pers. comm., Peru Expert 2).

In many cases, mismatches in supply and demand led to further losses, as trade activity changed. For example, with the closures of restaurants in Peru (PD), wholesalers sold more catch to retailers or markets (Fig. 1; Table 2). However, markets had insufficient cold storage and, without a matching increase in demand, fish spoiled. Even in cases with increased local demand, similar infrastructure limitations constrained supply. In California (CU), the Tuna Harbor Dockside Market saw increased local interest in *uni*; however, existing storage tanks capped their supply. They now regularly sell out and are only able to support sales by two of the local divers (pers. comm., P. Halmay).

3.3. Innovations

To adapt to the aforementioned changes and constraints to supply chains, small-scale fishers, supply chain actors, and the stakeholders closest to them, have further developed and repurposed existing networks, modified distribution strategies, and taken on new roles (Table 2). Some fisheries drew on existing networks or relationships to create new consumer markets and diversify their distribution strategies, often employing digital platforms in innovative ways. Others shifted the focus of existing organizations to better fit current needs. In Peru (PD), for example several fishing associations previously focused on political representation and social organization adapted to take on commercial roles, such as marketing, in support of local sales (pers. obs., C. Giordano). Some fishing associations started advocating for greater health and safety at landing sites. In mainland India, the Dakshin Foundation, a fisheries non-profit organization, harnessed a network of fisheries organizations in the Andaman and Nicobar Islands (AE and AD) to secure food aid for fishers and their families (pers. comm., M. Mondal; Vohra, 2020).

Many of these adapted networks and roles have been supported by technology, allowing actors to overcome geographic barriers and create online marketplaces to directly access a larger consumer base. Communities with limited internet or computer access used a smartphone app, WhatsApp, to identify and coordinate aid (AE and AD; pers. comm., M. Mondal) and set up informal fish distribution networks (PE and PD; pers. obs., C. Giordano).

In other cases, actors leveraged existing networks together with digital technology resources to build their consumer market via diversified distribution strategies. In Peru (PE), plants and distributors launched new services, such as door-to-door delivery (pers. obs., C. Giordano) and in California (CU), the CA Tuna Harbor Dockside Market quickly developed an online platform to serve new direct-sale customers (pers. comm., P. Halmay). The Market relied on the expertise of their network to develop the online marketplace and oversee their social media accounts, which saw a 22% increase in followers in the first two weeks of the shutdown (pers. comm., P. Halmay).

4. Discussion

Our case studies highlight several key findings regarding how different SSF supply chains are experiencing and responding to the COVID-19 pandemic (Table 2). Firstly, in all cases there was a shift toward local distribution and shorter supply chains facilitated by multiple aspects of adaptive capacity, particularly social organization in the form of social networks. Secondly, our findings emphasize the vulnerabilities inherent in over-reliance on global supply chains.

Our case studies illuminate how actors drew on different dimensions of adaptive capacity to navigate initial COVID-19 disruptions. Adaptive capacity includes accessible *assets*, *flexibility* in strategies, *organizational* ability, *learning* to recognize and respond to change, and the *agency* to adapt or not (Cinner et al., 2018; Cinner & Barnes, 2019). The *organizational* aspects of adaptive capacity, through social networks in particular, may be highly important in SSFs (Dacks, Ticktin, Jupiter, & Friedlander, 2020). Specifically, actors leveraged existing networks to both cope and innovate. Networks 1) allowed for *learning* by providing access to different forms of knowledge; 2) were used *flexibly* and repurposed to meet pressing needs; 3) facilitated sharing of *assets*; and 4) supported the *agency* of supply chain actors via facilitating collective efforts to meet shared objectives. In several instances, lack of *networks* was a limitation to coping or innovating—fishers faced with bureaucratic barriers in both Peru and the ANI may have been able to overcome those technological and administrative blocks with the support and knowledge of a diverse network.

Indeed, other studies show that diverse networks allow for groups to benefit from differential adaptive capacities of various actors (Barnes, Lynham, Kalberg, & Leung, 2016; Bodin & Crona, 2009; González-Mon, Bodin, Crona, Nenadovic, & Basurto, 2019). Networks with sufficient connections and clear organization increase overall productivity in meeting shared objectives and addressing issues at appropriate spatial scales (e.g., Sayles & Baggio, 2017). Rather than create new local distribution channels or networks, fishers, supply chain actors, non-profits, and stakeholders leveraged and repurposed existing channels and networks. This finding emphasizes that organizations and connections to support adaptation (Bennett et al., 2020) need to be in place before a macroeconomic shock hits. During or after a crisis, the substantial resources and time required to develop new networks will likely be stretched.

Our findings also support research that emphasizes the risks of overreliance on the global seafood trade and calls for balancing economic portfolios with better-developed local supply chains and networks (e.g. Stoll, Bailey, & Jonell, 2020). International trade networks can provide important services (Asche et al., 2015; Thorpe, 2005; Toufique & Belton, 2014). However, our study suggests that a diversity of supply chains at smaller geographical scales may be important for the resilience of SSFs in the face of macroeconomic shocks. Global trade and export-oriented markets can both reduce connectivity of local networks and increase teleconnected vulnerabilities (Adger et al., 2009; Crona et al., 2015; Liu et al., 2013; Stoll et al., 2018). In our case studies, actors highly-connected to local consumers have been able to leverage and repurpose networks flexibly, whereas those connected to distant markets, for instance with niche seafood commodities, have faced challenges connecting with local consumers (Crona et al., 2016). These findings are in line with reports that increased trade has led to geographic, socioeconomic, and cultural separation, resulting in a decoupling of marine ecosystems, harvesters and consumers (Cheung & Chang, 2011; Fabinyi & Liu, 2016), including weakened feedback between value chains and supply chains (Crona, Daw, et al., 2016).

Such teleconnections and decoupled social-ecological systems may undermine the resilience of an already vulnerable SSF sector, in which seasonal catch often leads to erratic take-home pay, inadequate access to financing (Pomeroy, Arango, Lomboy, & Box, 2020), and limited distribution options (Kolding et al., 2014). Our study suggests that diversifying and strengthening local and domestic supply chains and networks will support the resilience of SSFs as they face the continuing impacts of COVID-19 and future crises. Nonetheless, identifying domestic markets for high-value species may pose an ongoing challenge for many SSFs. Approaches could include, but are not limited to, marketing to local wealthier demographics, subsidizing local purchases, or enlisting a combination of local subsidies and broader marketing of local high-value species, as is the case for North American alternative seafood networks (Stoll, Harrison, et al., 2020). More broadly, addressing systems that perpetuate social inequity would help to increase overall wealth and buying power of local people. The risk of reliance on international markets should be acknowledged and mitigated in some form even when accessing a local or domestic market is not possible. Mitigation efforts could include insurance programs, disaster relief programs, or other social programs that provide SSF actors with security during disasters.

Finally, there are several limitations and caveats to our approach. Firstly, a focus on SSF adaptive capacity may obscure broader structural causes of SSF vulnerability, which cannot be addressed solely by the actors in question, nor by simply building adaptive capacity. Analysis of how intertwined distal drivers (e.g. power structures, market dynamics, cultural shifts, etc.) shape adaptive capacities within specific communities (Leal, 2010) will strengthen future research on bolstering adaptive capacity, and are an important corrective to approaches that place undue responsibility on local communities and normalize the status quo (Ribot, 2014). Thus, while our case studies are framed around SSF and community-level adaptive capacity, this is not the only avenue to reducing vulnerability and must be understood within a broader political economy (Bavinck, Jentoft, & Scholtens, 2018). Secondly, our broad case studies were not granular enough to disaggregate the different adaptive capacities of individuals and groups within SSFs, which likely obscured differences (for instance between genders, castes, ages) in how sub-sects of actors coped or innovated.

5. Conclusions

SSF responses to COVID-19 disruptions provide invaluable insights into opportunities for and barriers to supporting resilient fisheries systems and communities. While COVID-19 represents one type of shock, it nonetheless illuminates vulnerabilities to other similar shocks that may disrupt the international distribution of goods. The demonstrated shift to local and national distribution channels, and actors' reliance on pre-existing networks, highlight the need to support development and maintenance of a diversity of distribution channels during 'normal' times to meet the need for resilient local distribution systems during crises. Recognizing SSFs as essential providers of local food, nutrition, and livelihoods, supporting supply chain actors to navigate bureaucratic and technological systems, and promoting development of institutional capacity and networks (to increase flexibility, connection, and knowledge), would reduce negative impacts on fishers, post-harvest workers, and consumers through increased abilities to maintain operations during crises. As the impacts of COVID-19 continue to unfold and SSFs face other shocks, such as climate change, further research on opportunities to both enhance near-term adaptive capacity at local scales and shift broader structural drivers that increase vulnerability or reduce adaptive capacity will be important.

CRediT authorship contribution statement

Hannah R. Bassett: Conceptualization, Investigation, Methodology, Project administration, Visualization, Writing - original draft, Writing - review & editing. **Jacqueline Lau:** Conceptualization, Writing - original draft, Writing - review & editing. **Christopher Giordano:** Conceptualization, Investigation, Writing - original draft, Writing - review & editing. **Sharon K. Suri:** Conceptualization, Investigation, Methodology, Visualization, Writing - original draft, Writing - review & editing. **Sahir Advani:** Conceptualization, Investigation, Writing - original draft, Writing - review & editing. **Sonia Sharan:** Conceptualization, Writing - review & editing.

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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