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Research

COVID-19 impacts on food systems in fisheries-dependent island communities

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ABSTRACT. Policies designed to contain the COVID-19 pandemic have impacted food systems worldwide. How impacts played out in local food systems, and how these affected the lived experiences of different people is only just coming to light. We conducted a structured analysis of the impacts of COVID-19 containment policies on the food systems of small-scale fishing communities in Kenya, Papua New Guinea, and Saint Lucia, based on interviews with men and women fishers, fish traders, and community leaders. Participants reported that containment policies lead indirectly to reduced volumes of food, lower dietary diversity, increased consumption of traditional foods, and reduced access to fish for food and income. Although the initiating policy and food and nutrition security outcomes often appeared similar, we found that the underlying pathways and feedbacks causing these impacts were different based on local context. Incorporating knowledge of how context-specific factors shape food system outcomes may be key to tailoring strategies to mitigate the ongoing impacts of COVID-19 and designing timely, strategic interventions for future systemic shocks.

Key Words: *COVID-19 policy impacts; food access; food and nutrition security; food environments; small-scale fisheries; supply chains*

INTRODUCTION

COVID-19 impacts on food and nutrition security

As the COVID-19 pandemic unfolded, governments implemented policies to stop its spread, including restricting movement, enforcing physical distancing, and closing markets and meeting places (Hale and Webster 2020). These policies impacted all aspects of food systems at different scales, and some of these impacts have had ongoing consequences even as case numbers have dropped and restrictions have eased. National and global-scale value-chain analyses have shown significant changes to food production, trade and distribution, retailing, and consumption patterns (Erokhin and Gao 2020). The collapse of the tourism and restaurant sectors saw a drop in demand for high-value food commodities, including imports from low- and middle-income countries (Love et al. 2021). International food trade was disrupted by movement restrictions, quarantine procedures, and trade bans (Love et al. 2021, Schmidhuber 2020) and many small-scale producers were forced to transition to more localized food-distribution methods (Bassett et al. 2021). Market closures and movement restrictions also reduced food access (Stephens et al. 2020). In many low- and middle-income countries, declining incomes and price volatility led people to consume fewer nutrient-dense foods (Kundu et al. 2021, Harris et al. 2020), increasing the risk of micronutrient deficiencies and associated risks including birth complications, inhibited development for infants and young children, and, ultimately, stunted growth (FAO et al. 2020).

While at times severe, the scale, scope, and nature of impacts were not straightforward; they varied between different contexts and among different food system actors and consumers. Emerging evidence shows that the costs of COVID-19 containment policies were most extreme for populations and parts of society already vulnerable to poverty, food insecurity, and marginalization (FAO et al. 2020, UN Women 2020, Laborde et al. 2020), particularly in low- and middle-income countries with limited institutional capacity to cope with social, economic, and physical shocks (Phillips et al. 2020, Carducci et al. 2021). Yet, there is limited analysis of the linkages and feedback loops between different impacts within any context and how these interacting impacts were experienced by different people. While it is largely too late to alter the strategies implemented to contain COVID-19, we can take lessons from the last few years to inform ongoing impact support policies and inform responses to future systemic shocks. Without a clear picture of the mechanisms through which policies can potentially impact food and nutrition security in different contexts, it will remain difficult to design strategic policy adaptations and interventions that can help balance the trade-offs between managing future social, economic, or environmental shocks and ensuring food and nutrition security for all (Laborde et al. 2020, Global Network Against Food Crises and Food Security Information Network 2020, IMF 2020).

Food systems approach

We explored the suitability of a structured food systems approach for understanding the different pathways through which COVID-19 containment policies impacted food and nutrition security. Food and nutrition security is defined as "a situation that exists when all people at all times have physical, social and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO 2002). Food systems are comprised of all the actors and activities relating to food: from production through processing, distribution, preparation, and consumption, as well as the nutritional, socio-economic, and environmental outcomes of these processes and the external factors which influence them (HLPE 2020). Food systems analysis can be applied at multiple scales, from examining actors and processes within local communities to mapping out connections across global markets.

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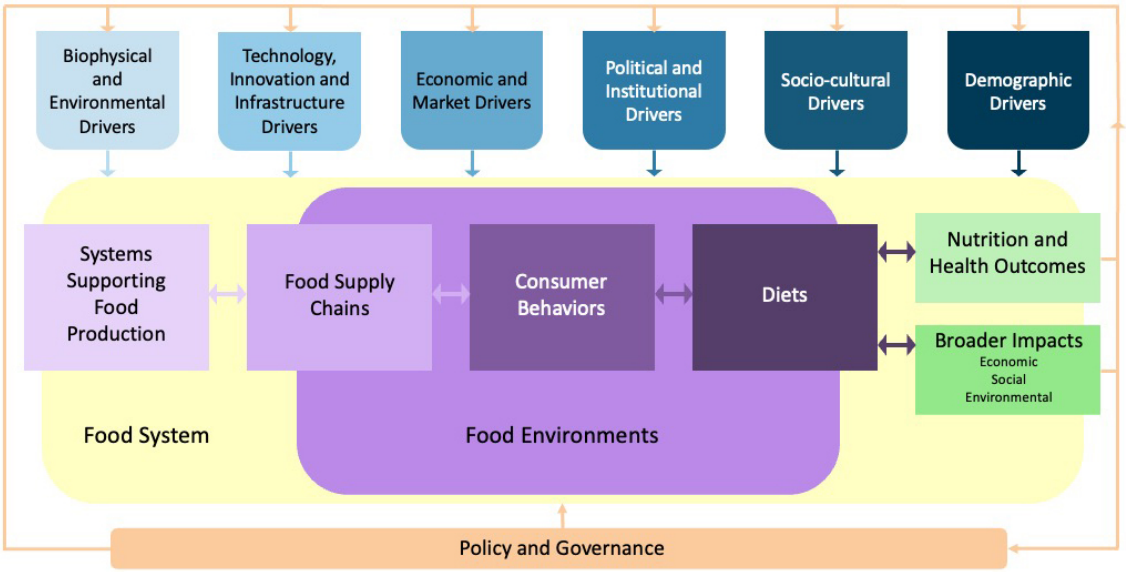
Fig. 1. Sustainable Food Systems Framework. Source: Food and Agriculture Organization of the United Nations. Adapted with permission.



The Sustainable Food Systems Framework developed by the High Level Panel of Experts on Food and Nutrition (HLPE) (Fig. 1) is arguably the most comprehensive and widely acknowledged framework developed to encapsulate these components and the relationships between them. The framework outlines five key components of food systems: 1) *systems supporting food production,* which provide inputs into the food system; 2) *food supply chains,* which include all the processes and actors involved in food production, processing, distribution, marketing, consumption, and waste disposal; 3) *consumer behavior,* or individual consumer awareness and decision making around food acquisition, preparation, and consumption; 4) *food environments,* which consist of the physical, economic, social, and political contexts which determine food accessibility, affordability, safety, and consumer preferences; and 5) *diets*, including the quality, quantity, diversity, safety, and adequacy of consumed food. The system components are tightly linked. For example, the food environment shapes food supply chains, consumer behavior, and diets. These system components also determine both *nutrition and health outcomes* and broader *economic, social equity, and environmental impacts* of food systems. Each of these components interact with complex *drivers of change* at various scales. *Policy and governance systems,* comprising both formal and informal rules and norms, both directly influence food system processes and actors, and shape environmental, social, and economic drivers of change (HLPE 2020).

Food systems analysis is grounded in the understanding of the interdependencies and feedbacks between system actors, processes, and drivers (HLPE 2020, Harris et al. 2020) and requires both examination of changes across different drivers and components in the system but also how those changes then affect actors and processes (Devereux et al. 2020). Structured analysis based on the food system framework can help identify where nutrition potential is lost from the system (or could be gained) by accounting for interdependencies, trade-offs, and feedbacks induced by shocks (Steenbergen et al. 2020, Béné 2020, Devereux et al. 2020) and can help identify potential strategic intervention points specific to local systems (Ingram 2011). We examine the impact pathways of COVID-19 containment policies through multiple, interconnected components of the whole food system, which shaped food and nutrition security outcomes in small-scale fishing communities.

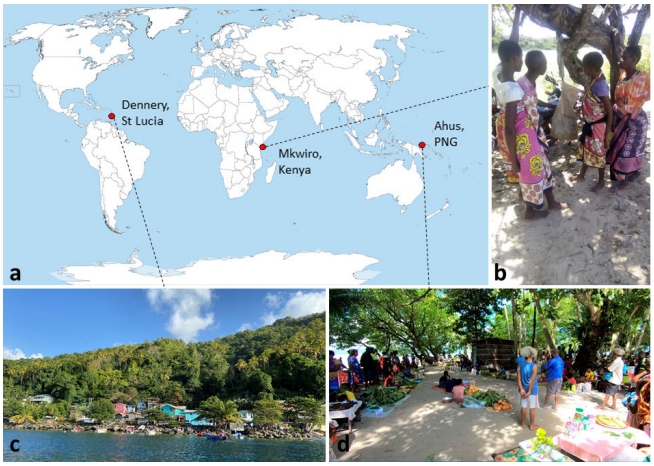
COVID-19 in small-scale fisheries

Small-scale fisheries are an essential source of income and livelihoods, and provide protein and micronutrients for the estimated 108 million people involved in small-scale fisheries value chains worldwide (Kelleher et al. 2012). However, fishers, and the aquatic foods they produce and distribute, are often overlooked in food systems literature (Tezzo et al. 2021, Olson et al. 2014, Simmance et al. 2022) despite their prevalence and significance for food and nutrition security worldwide (Beveridge et al. 2013, Béné et al. 2015). Small-scale fisheries can broadly be defined as the processes and actors (both women and men) involved in harvesting fish or other aquatic foods (hereafter collectively termed "fish") from small boats or the shore (including on foot) in coastal or inland waters, as well as post-harvest processing and distribution of these products (Allison and Ellis 2001, Smith and Basurto 2019). There is significant variation in the production and distribution strategies, and in the social, economic, and geographic contexts of fishing operations which fit this definition (FAO 2015), and therefore the ways they are affected by and can respond to shocks like COVID-19 (Bassett et al. 2021, Love et al. 2021). We focused on marine small-scale fisheries in low-income communities in the global south. In this context, small-scale fisheries are critical for poor and marginalized groups with limited resources and alternate livelihood opportunities; indeed they can provide a safety net where other livelihoods fail in the face of shocks (Béné et al. 2010).

However, small-scale fishing communities, particularly those in the global south, may be particularly vulnerable to COVID-19 and other shocks because of economic, political, and geographic isolation. Communities where small-scale fisheries are a common livelihood frequently also experience low incomes, limited livelihood choices, and poor infrastructure; face climate and non-climate related environmental degradation; and receive limited government support (Bennett et al. 2016, 2020). Small-scale fishers generally do not have access to reserve capital or insurance to see them through shocks, and they are dependent on being able to go fishing for food and for income through regular sale of catch (FAO 2020). Communities living on small islands were particularly vulnerable to the deliberate isolation required to keep COVID-19 at bay. With relatively little arable land for agricultural production, people living on small islands may have relatively few options for livelihoods and can be particularly dependent on fisheries, tourism, remittances, and food imports (Farrell et al. 2020, Hickey and Unwin 2020). Early reports of the impacts of COVID-19 containment policies in small-scale fishing communities indicate disruptions to fish value chains, resulting in loss of income and reduced availability and accessibility of food, especially in countries heavily dependent on fish for livelihoods, animal proteins, and micronutrients (FAO 2020, Eriksson et al. 2020, Rosen 2020, Steenbergen et al. 2020, Jomitol et al. 2020, Lau and Sutcliffe 2021, Lau et al. 2021, Nyiawung et al. 2022, Monirul Alam et al. 2022, Western Central Atlantic Fisheries Commission 2022).

We examined how COVID-19 containment policies interacted with food systems in three small-scale fishing communities in three distinct geographic regions (Fig. 2). The three communities have varying levels of connectivity with regional and global trade networks, supply chains, and social, economic, and political influences. We primarily focus on actors and processes within, or directly connected to, the specific communities, which we refer to as the "local food system." We sought to identify 1) what are the food and nutrition security outcomes associated with COVID-19 containment policies in small-scale fishing communities; 2) which specific components of local food systems have been impacted, and how, by COVID-19 containment policies,; and 3) how have impacts on specific system components flowed through food systems and interacted with other food system drivers. To answer these questions, we undertook a series of qualitative interviews with women and men living in small-island small-scale fishing communities in three regions (Fig. 2). We analyzed these interviews using a food systems framework (Fig. 1) to identify the impacts of containment policies during the initial months of the pandemic, and to identify the impact pathways and feedback mechanisms that women and men experienced as being particularly acute in their local food systems. First, we describe the study sites and local context and our research methodology. We then highlight the main dietary changes participants experienced during the early stages of the pandemic. Next, we describe the primary overarching process through which COVID-19 containment policies inhibited diets. We then provide a broad overview of how impacts flowed through connected components of the food system framework before providing specific examples of direct and indirect impact pathways and feedback processes in the local food system of each site.

Fig. 2. Study sites. (A) Map showing the location of the three study sites. (B) Dennery, St. Lucia, as seen from the water, with small fishing boats tied up in front of the houses. (C) Women fish traders in Mkwiro, Kenya, send their daughters to weigh fish at the landing site before buying the fish from fishers and selling it on in the village. (D) Leaders share community news before opening the local food market on Ahus, Papua New Guinea (PNG). All photos were taken pre-COVID-19.



Site descriptions

Dennery, St. Lucia

Dennery Village is a fishing community located on the island of St. Lucia, in the Eastern Caribbean (Fig. 2B). As of the 2010 census, Dennery had an estimated population of 2700 people across 955 households (Central Statistical Office of Saint Lucia 2011). The primary livelihood activities in the community are tourism, fishing, and agriculture. Most fishers are members of the Dennery Fishing Co-operative, which acts as a central point for purchasing gear and selling fish, as well as providing services to fishers such as training and financing options. Catch landed at the Dennery Fishing Co-operative is sold locally to community members, wholesale to hotels and restaurants across the island, and to traders for export to the United States and other Caribbean Islands. St. Lucia is highly dependent on imported foods (Simoes and Hidalgo 2011). Households will often travel to two of the island's main towns once a month (Vieux Fort, 32.2 km away and Castries, 24.6 km away) to purchase a monthly supply of food supplemented by small shops located in the village. The national government closed borders, established curfews and physical distancing requirements, and restricted non-essential services, movement, and gatherings in late March of 2020 (Office of the Prime Minister of Saint Lucia). Curfew hours were reduced and limited social activities were permitted by mid-June (Saint Lucia Ministry of Health 2020a). At the time of interviews (August 2020) there were 26 cases of COVID-19 in St. Lucia (Saint Lucia Ministry of Health 2020b).

Mkwiro, Kenya

Mkwiro is a fishing village located on Wasini Island, 2 km off the coast of Kenya in Kwale County, with approximately 148 extended-family households and a population of around 2100

(Fig. 2C). The main livelihood activities are fishing and tourism. Approximately 95% of households engage in fishing, and most women collect octopus. Fishers sell to local traders who then on-sell to traders on the mainland for distribution to shops in Mombasa and other large towns in south-eastern Kenya. Arable land on the island is limited, and most is owned by people from outside the community and uncultivated. Some women farm seaweed, which is sold to international agents. The main staple foods in the community are ugali, rice, fish, and beans. Produce, imported foods, and other goods and services are purchased in the closest mainland village, Shimoni, which is accessible by motorized boat. COVID-19 policies and enforcement were primarily developed and implemented at the level of national and county governments. In June 2020, the government put in place several measures to stem the spread of COVID-19, including curfews and limits on social gatherings, transport, movement, and permitted business activities. The southern coastal counties (Kilifi, Mombasa, and Kwale, where Mkwiro is located) had some of the highest case rates in the country during the first wave of the pandemic in April 2020, and, as such, were subject to more stringent restrictions, including the implementation of county border closures, which effectively cut Mkwiro off from the closest major markets in Mombasa (Ministry of Health 2020a). Restrictions were strictly enforced by police. At the time of the interviews (August–September 2020), there had been approximately 150 confirmed COVID-19 cases in Kwale county (Mvurya 2020).

Ahus Island, Papua New Guinea

Ahus is a small island in Manus province of Papua New Guinea (PNG) with a community of approximately 700 people in 140 households (Fig. 2D). The community is almost entirely dependent on marine resources for food and income. In 2018, 90% of households participated in fishing, gleaning, or marketing marine products. The island has little arable land and, therefore, limited capacity for agricultural production beyond small household vegetable gardens and fruit trees. The community is normally able to obtain "garden food" (fresh fruit, vegetables, and sago) when people from mainland Manus bring supplies to the island market (typically held three times per week prior to COVID-19). The main market for selling fish outside of the community is in Lorengau, the provincial capital of Manus Island, as well as shops selling imported "store food" (rice, flour, etc.), fuel for boats, and financial and health services. Restrictions were developed at the national and provincial government level. However, individual community leaders, in consultation with local government representatives, had significant agency in enforcing restrictions and deciding which non-mandatory recommendations they would implement and were able to undertake additional measures as they saw fit. At the time of the interviews (July–August 2020), there were no cases of COVID-19 in Manus province.

MATERIALS AND METHODS

We conducted interviews with five to nine fishers, including gleaners, and one community leader in small-scale fishing communities in Papua New Guinea (PNG) (f=3, m=4), Kenya (f=5, m=5), and St. Lucia (f=1, m=5), between July and September 2020. We asked participants to describe their experiences since the onset of the COVID-19 pandemic; particularly how containment policies had impacted fishing, fish marketing, physical and economic access to food, food decision making and consumption patterns, and how they responded to these changes (A1 and A2 for interview templates). We also asked specific questions about changes to livelihoods and wellbeing, which are directly related to food and nutrition security, either as food system drivers or outcomes. Information about the role of other food system drivers (e.g., biophysical and environmental drivers and technology and infrastructure drivers etc.) was derived from participants' explanations of the causes of different impacts. To ensure the casual links we inferred from interviews were robust, we cross-checked between interviews, key informants, local research assistants, and against policy and other government documentation when able. We did not directly ask participants to identify or project the health and nutrition outcomes of these changes. Most of these outcomes will not be immediately apparent and would generally require anthropomorphic measurements to accurately detect (though likely outcomes can be inferred from the reported dietary changes). Furthermore, the intention of our interviews was to identify participants' perceptions of changes to the food system as they happened, rather than their projections of medium to long-term outcomes. Interviews were semi-structured: interviewers particularly prompted participants to explain how and why the changes they described occurred, to elicit information about the relationships between different impacts. Community leaders were asked similar questions but acted as key informants for experiences of the whole community. The interview questions were piloted with four other fishers from Mkwiro, Kenya, and two people from a mainland community adjacent to Ahus Island in PNG and then adjusted for clarity to ensure they were fit for purpose.

This method of inference from qualitative interviews is particularly appropriate when looking at distinct, context-specific cases, as it can facilitate the nuanced exploration of people's behavior and motivations within their individual contexts without the constraints imposed by pre-defined survey tools and prioritizes individuals' perspectives on their own experiences (Bercht 2021, Denzin 2005). It is ideally suited for situations where there is a need to delve into complex situations in a timely manner but where there are constraints on data collection which prevent larger-scale quantitative approaches (Cox 2019), as was the case during the pandemic.

Drawing on sociodemographic information from the authors' previous research in PNG and Kenya (Barnes 2018, unpublished data; Barnes et al. 2020), participants were purposefully selected across a range of ages, clans/ethnic groups, family sizes, and livelihood activities (Table A3.1, for demographic summary), as well as whether they had previously indicated willingness to participate in future research. Some selected participants did not have their own mobile phone but were able to borrow one from relatives or neighbors, meaning that participation was not limited by whether they could afford a phone. Participants in St. Lucia were purposely recruited through a key informant at the Dennery Fishing Co-operative. Potential participants were initially contacted to provide them with information about the research and invite them to participate. If they consented to be interviewed, interviewers arranged to call back at a time convenient to them for the full interview. On the second call, interviewees were again given the opportunity to ask questions before verbally confirming

consent to continue. Interviewees were compensated for their time at the rates established for previous in-person interviews and surveys conducted in the community (5PGK/interview in PNG, 4XCD/interview in St. Lucia, 350KES/interview in Kenya). Interviews took between 30 minutes and one hour.

The interviews were conducted by in-country researchers with previous experience working in those communities. Interviewers were trained in both standard interview prompting and elicitation strategies, and in conducting interviews about potentially sensitive subjects, including food insecurity and the pandemic in general (McDougall et al. 2020, Townsend et al. 2020). Interviews were conducted in the local language via mobile phone. Interviews were recorded, transcribed, and translated by the interviewers; translations were cross-checked by other co-authors fluent in the local languages. Research protocols were approved by the Human Ethics Committee at James Cook University (approval H8109) and Oregon State University (IRB-2020-0678).

Following common practice in qualitative research (Linneberg and Korsgaard 2019, Newing et al. 2011), interviews were analyzed in NVivo using a combination of deductive and inductive coding. Perceived impacts of the pandemic, and policies to contain it, on the local food system were identified and then coded deductively to one or more of the components in the food system framework (Fig. 1) (HLPE 2020). Inductive coding was then used to classify and synthesize impacts within each component (A4.1). Where participants made explicit causal connections between different impacts and processes, these were coded as relationships or links between the relevant system components. For example, where one participant stated:

> *Getting money during the pandemic was a bit hard. So we go for the cheapest. If we have money, we buy rice. If not, one 10 kina is enough. You can't buy 10kg of rice, but with 10 kina you can buy a bag of sago that will sustain you for two weeks. So if I can buy rice, no, I'll say, let's get sago, because sago, you can get one bag for 10 kina, and that will keep us for two weeks.* (man, 40, PNG)

This link was coded to "economic and market drivers" (lack of income), "food environments" (affordability), and "consumer behavior" (choosing to buy sago instead of rice), and as links between these system components. We looked for dominant themes and outliers, both in the coding and through broader analysis of the interviews. Participants' descriptions of specific containment policies and processes were cross-checked against government and development agency communications, supplemented with insights from in-country partners, where additional context was required for interpretation. The food system impacts and interactions with various system drivers described below are derived directly from interviews. An initial sample of five interviews were analyzed by the primary coder, and then cross-checked by another author and the coding structure was refined accordingly. The final coding and synthesis were reviewed again by the second author. Both coders consulted extensively with the interviewers and other in-country partners to review the coding, to resolve any disagreements or clarify interpretation.

RESULTS

Material impact: changes to diets

All participants reported some changes to their diets due to policies implemented to contain COVID-19; though the nature, scope, and severity of impacts varied between sites and participants. These impacts included reduced quantity, quality, diversity, and adequacy of diets (Table A4.1). In all three sites, most participants reported eating less than they normally would because they either reduced meal sizes or skipped meals altogether. To manage for food scarcity, households carefully rationed food to make it last:

> *So we'd serve, little, little for each child and each adult. It doesn't matter if you're full up or only just full, that was your share.* (man, 44, PNG)

> *We have to watch our income we spend these days because of COVID. If you have to eat less or something, that is what we do now.* (man, age unknown, St. Lucia)

In both Kenya and PNG, participants stated they were eating simpler meals with fewer different types of food and the same meals each day (Table A4.1). In Kenya, participants reported consuming less meat and vegetables, and instead primarily consuming staple carbohydrates such as *ugali* (maize meal porridge) and sometimes rice. One woman in PNG said, "Before, we'd all eat rice often. Not now. I've cooked sago over and over, and everyone complains...but there's nothing else" (woman, 32, PNG).

Participants in all three sites reported improvements in hygiene practices such as regular handwashing. In addition, primarily in PNG but also in Kenya, some participants reported increased consumption of traditional foods, including local fruits and vegetables, due to reduced access to processed, store-bought foods. COVID-19 containment policies also resulted in additional economic, social, and environmental outcomes.

Primary processes driving dietary changes

We identified an underlying process, common across all three sites, through which COVID-19 containment policies led to dietary changes (Fig. 3). The various COVID-19 containment policies disrupted fishing activities, as well as post-harvest trading, transportation, processing, and marketing. These disruptions both reduced the physical availability of food and reduced fishers' income because they were less able to sell their fish, which in turn reduced their ability to buy other food and goods. In response to loss of purchasing power due to loss of income, people were forced to reduce food expenditure, resulting in a decline in the quantity, quality, and diversity of their diets. This pattern was articulated by one fisher from PNG:

Fig. 3. Primary process. General pattern of how COVID-19 containment policies impacted food and nutrition security.

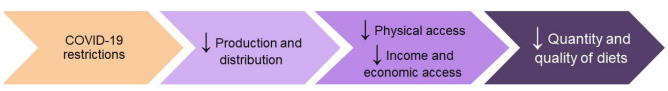
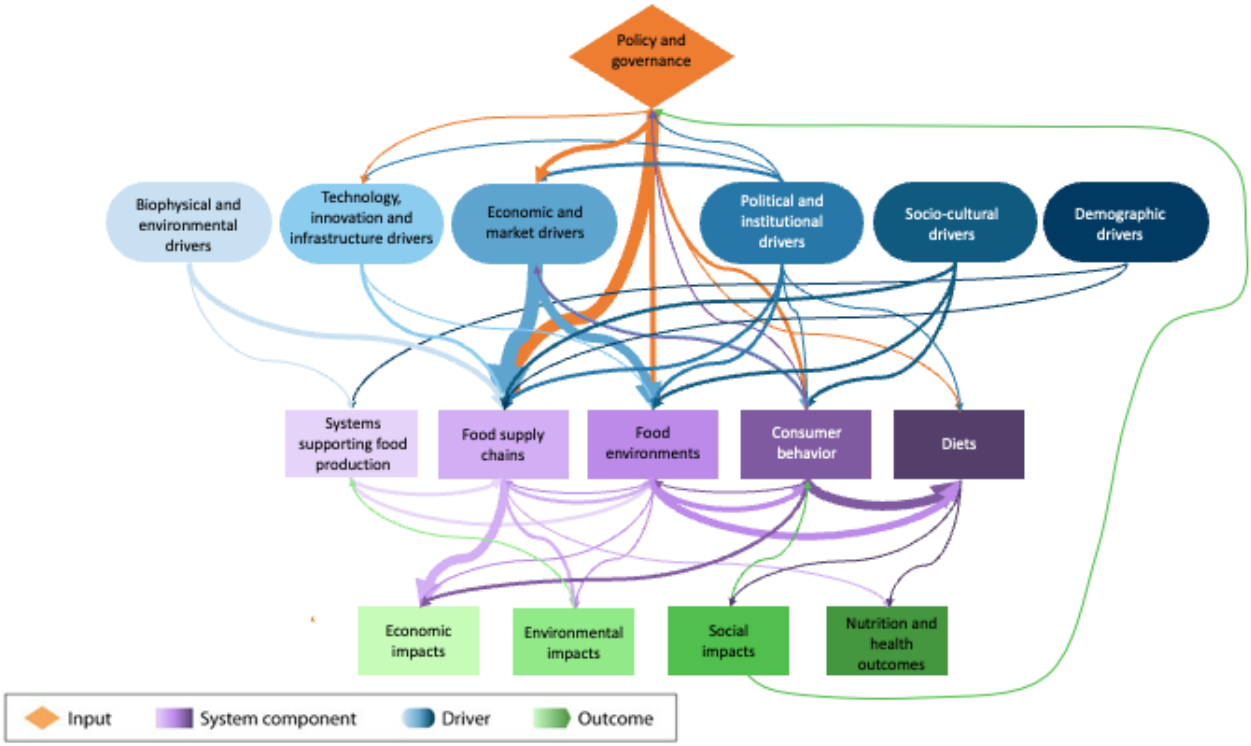


Fig. 4. Flow of impacts through the food system. Flow chart showing links between impacts on connected system components from the Food System Framework. The color of each arrow indicates the origin component, corresponding to the colors used in Figure 1. The width of the arrow represents the coding frequency of the link. Note that each driver and food system component in the model is essentially a conceptual organizational unit which contains multiple processes, for example, food supply chains include both production and distribution, so any given coded link from policy and governance to supply chains could refer to containment policies impacting either one of those things. In some cases, the links between impacts on the same specific elements within two system components were made by multiple participants, so the frequency of coding represented by the thickness of each arrow is a function of both the number of links between different elements in each component and how often each link was described.



> *There's one way of getting money, and money is food. If you have money, you get food. If you don't have money, you can't get food. And the way we get money is from the sea alone. And if we're affected in how we sell it, and there's no fish, then there's no money to get food from the store.* (man, 40, PNG)

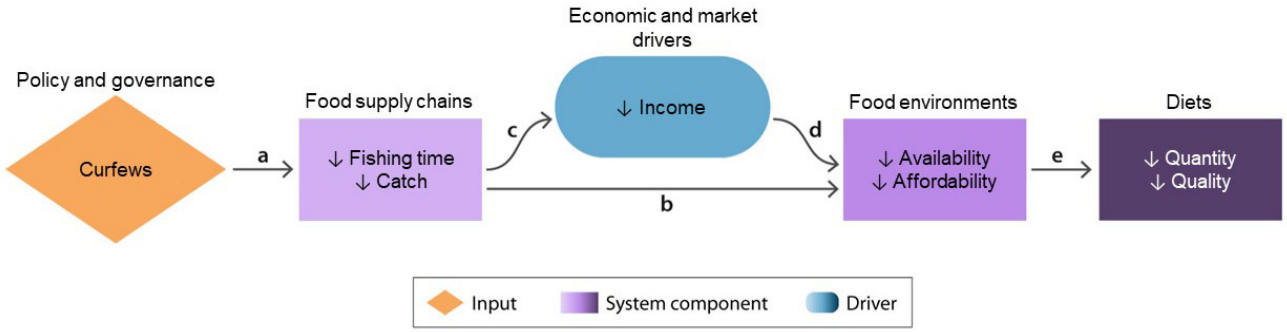
While this was the primary process responsible for reduced food and nutrition outcomes in all three sites, the mechanisms triggering the process varied and were influenced by underlying social, economic, and environmental conditions, and the resulting outcomes and system feedbacks (both direct, and more indirect and complex). In the following sections, we provide an overview of the flow of impacts across the whole food system and then provide illustrative examples of direct and indirect pathways and more complex system feedbacks.

Flow of impacts across the food system

Participants from all three sites identified changes arising from COVID-19 containment policies that corresponded to each of the components and drivers in the food system (Table A4.1, for a full list of impacts). They described a wide range of interconnections between impacts on processes in each component (Fig. 4). In sum, participants shared 260 instances across 49 directional pairs where system components or drivers influenced another (e.g., 11 instances where a change in the food environment influenced an aspect of consumer behavior, and three where consumer behavior influenced food environments). In most cases, participants described situations where an impact of COVID-19 containment policies on one system driver or component caused ripple effects through other linked components in a chain (i.e., policy *X* influenced component *Y*, which then influenced component *Z*). COVID-19 containment policies primarily directly influenced food supply chains, food environments, and economic and market drivers (Fig. 4, orange arrows). The consequences of these direct impacts then flowed through the rest of the system with successive links between supply chains, food environments, consumer behavior, and diets (Fig. 4, purple arrows).

In other cases, the impact of a policy on a particular food system component was either exacerbated or mitigated by pre-existing drivers or system structures (i.e., policy *X* and driver/component *Y* together influenced component *Z*). Many of these drivers were not themselves directly impacted by COVID-19 containment policies (as shown by the limited orange arrows connecting to

Fig. 5. Curfews and reduced production capacity in St. Lucia. The implementation of curfews in St. Lucia meant that people were unable to go out fishing during key times in the early morning and evenings, reducing overall fish catch and limiting time spent on small-scale farming and other productive activities (a). Reduced fish and agricultural production meant that less fish and produce were available to local consumers (b), and fishers' income was reduced (c), limiting their ability to purchase other foods (d), resulting in an overall reduction in diet quality and quantity (e).



blue ovals in Fig. 4) but worked in combination with COVID-19 containment policies to impact system processes, actors, and outcomes (Fig. 4, blue arrows). For example, the onset of COVID-19 containment policies in Kenya coincided with the windy season (known as *Kusi*) when catch rates are at their lowest because fishers are often unable to go out due to bad weather conditions. Physical distancing rules limited the number of fishers allowed on boats, which reduced catch efficiency, and meant some fishers were not able to go out every day if they would normally work on someone else's boat. While fishers may have been able to cope with one or the other, the combined effects of *Kusi* and COVID-19 containment policies meant that fishers were unable to catch enough fish to meet their food and income needs. As one fisher said: "One side we suffer from corona and on the other side we suffer from *Kusi*" (man, 49, Kenya). In each site, the differences in underlying drivers of change and food system structures meant that similar containment policies created different impact pathways and outcomes, including variation in the nature and severity of impacts on different vulnerable groups within each community.

Direct value-chain impacts

In St. Lucia, multiple participants reported that curfews were restricting the amount of time they could spend on fishing and agriculture (Fig. 5). Being unable to fish at peak times in the early mornings, evenings, or at night represented a direct impact on food production (i.e., a negative impact on food supply chains). This impact then reduced income for both fishers and other participants in the fishery value chain (i.e., an economic and market driver), the availability of fish for food, and the financial accessibility of other foods (i.e., a negative impact on food environments), which then in turn influenced diets. Several other containment policies directly impacted food supply chains (Table A4.1). For example, in Kenya and PNG, physical distancing rules meant fewer people than normal were allowed on fishing boats (from four or more to only two people under the new rules), reducing catch efficiency. There were also direct impacts on other system components, including food environments, e.g., where physical distancing rules and mandatory reduced market and shop operating hours reduced the physical accessibility of food.

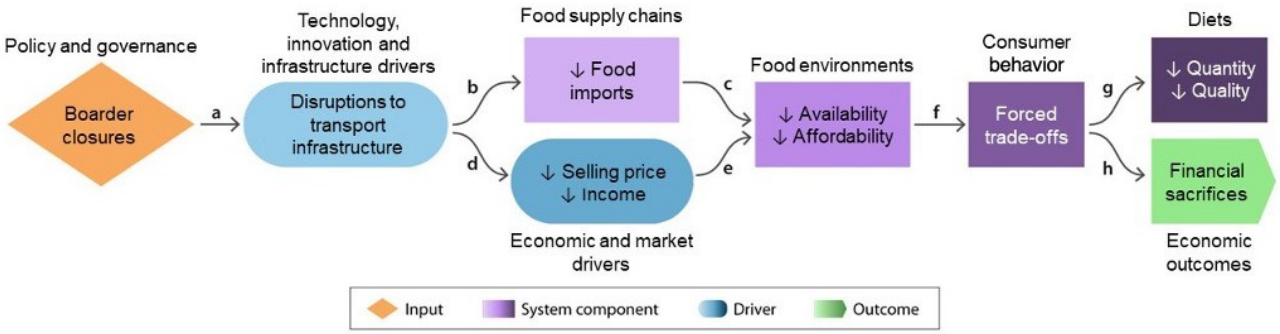
Interactions with socio-economic and environmental drivers

COVID-19 containment policies also influenced food systems indirectly through system drivers. For example, in Kenya, county border closures resulted in disruptions to national transport infrastructure systems, which temporarily broke food supply chains that relied on border crossings (Fig. 6). This disrupted formal food-distribution systems, and some stores struggled to get stock in the early stages of the pandemic, temporarily reducing food availability before containment policies were refined to restore formal supply chains. Commercial food transporters were categorized as essential services and allowed to cross national and country borders, but vehicles and drivers were required to obtain specific documentation from a formal employer, comply with curfew hours, and undergo testing when crossing borders, which resulted in significant delays (Ministry of Health 2020b, Ministry of Health 2020a, Famine Early Warning Systems Network 2020). Moreover, fish traders in Kenya often rely on public transport or carpooling to transfer relatively small amounts of fish from coastal villages, such as Mkwiro, into larger markets in cities like Mombasa. These informal food-distribution methods were completely shut down while the border closures were in place, as they were not included in the measures to preserve formal distribution chains servicing stores. Traders were forced to try to sell fish in smaller towns within their county where demand and selling prices were lower. As a result, fish traders bought less fish from fishers, and at lower prices, which reduced income and financial accessibility of other foods for fishers.

> *What can we do? The fish dealers set the price. If only they reached Mombasa the price could be higher, but they sell in local markets like Ukunda. They don't reach town (Mombasa) where they have the market they depend on.*
> (man, 61, Kenya)

Several of the participants described having to make conscious trade-offs between economic and nutritional outcomes. For example, they described having to reduce their food intake and dietary diversity or use up limited savings, sell assets, not buy other supplies, or take out store credit.

Fig. 6. County border closures and value-chain breakdown in Kenya. Food is often informally transported in and out of rural Kenyan communities, with people carrying fish and other supplies with them on buses and cars. When travel between counties in Kenya was banned, the formal goods-transport infrastructure was partially disrupted, and public transport systems largely shut down (a). This caused disruptions to supply chains bringing food into the community (b), reducing the availability of some foods in stores (c). In addition, fish traders were unable to take fish from the community to cities to sell at higher city-market prices, and, therefore, reduced the price they were willing to pay fishers for their fish, thereby reducing fishers' incomes (d). As such, fishers' purchasing power was reduced and food became less affordable (e). Limited availability and financial accessibility of food in stores influenced fishers purchasing decisions (f), causing them to reduce the quantity, quality, and/or diversity of food they purchased and consumed (g) or resort to using their limited savings or making other financial sacrifices to maintain their diets (h) or a combination of both.



COVID-19 containment policies also caused indirect impacts across the food system through other drivers. For example, gender norms (a socio-cultural driver) around childcare in Kenya meant that due to school closures, many women (in particular) were forced to stay home to look after their children during the day. Children were not able to be cared for by family and friends due to the restrictions placed on visiting other households. As such, women were unable to undertake their normal food production, processing, and marketing, or other economic activities, which reduced household income and disrupted normal household food acquisition, preparation, and consumption. Similarly, in PNG, specific economic activities generally undertaken by women were temporarily banned by the government, such as selling betelnut (a palm seed containing stimulants, commonly chewed as a social and cultural practice throughout Asia and the Pacific), removing one of the few sources of income available to women. Reduced social interaction also disrupted traditional food sharing practices (also a socio-cultural driver). One woman in PNG perceived the lack of food sharing to be a deliberate choice arising from food scarcity, fear, and uncertainty, and viewed the behavior as immoral: "There was greedy behavior when this situation happened, and I see, all our good ways from before are going finished now, and the bad is starting" (woman, 32, PNG).

Economic and market drivers, particularly loss of income, also indirectly influenced food systems. In St. Lucia, fishers normally sell large proportions of their catch to hotels and restaurants. When the local tourism industry collapsed due to border closures, fishers lost a significant income stream, which reduced their food purchasing power.

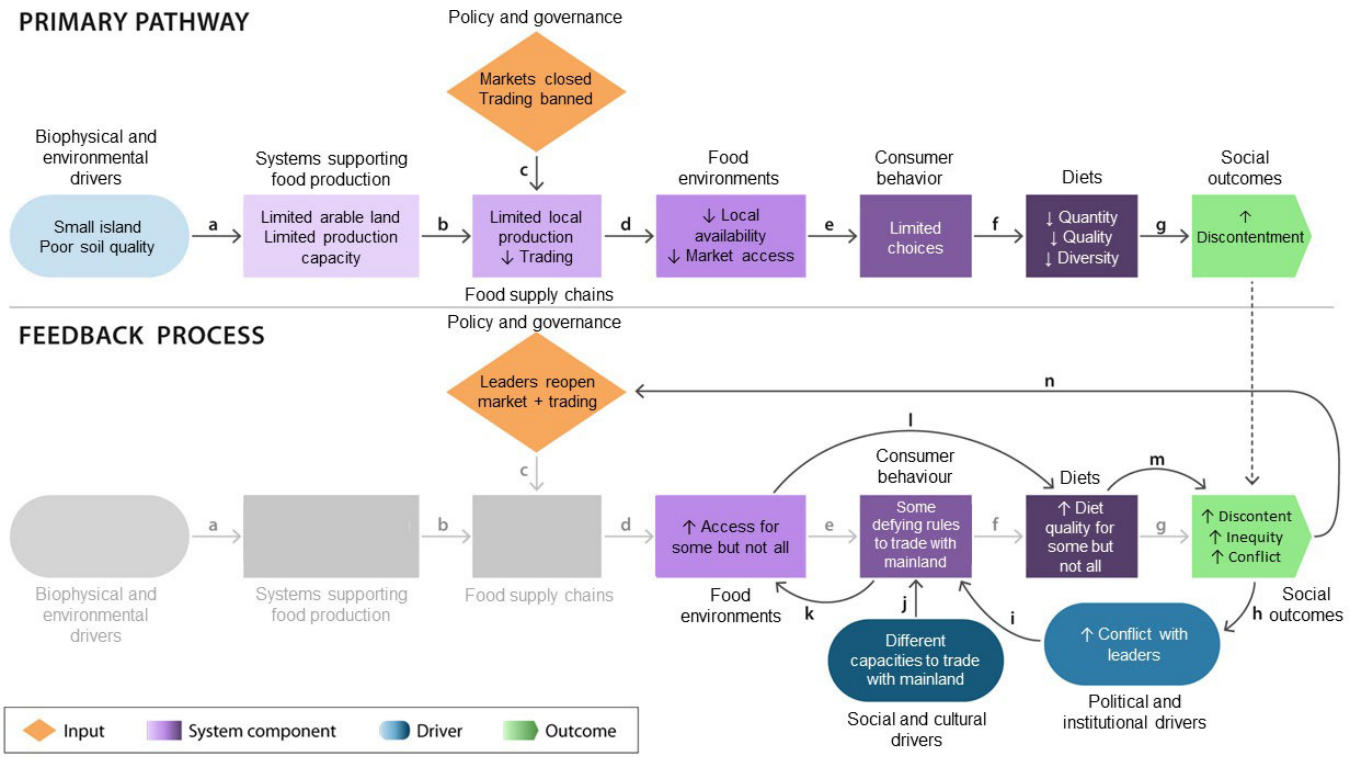
In PNG, physical distancing rules limited the number of people allowed in boats. To comply with physical distancing rules, only four people could take a motorboat to the mainland market to sell fish and buy food, compared to up to 12 prior to the pandemic. Fewer people meant the ticket cost, to cover the cost of fuel, was higher for each passenger. Fuel was also harder to obtain (a technology, innovation, and infrastructure driver). In response, boat drivers decreased the number of trips, meaning fewer places available each day, and used smaller engines to reduce fuel consumption, meaning that what had been a 30-minute trip now took over two hours. Alongside less demand for fish and reduced prices in the markets, the financial and time costs of accessing the market outweighed the profit made from selling fish. In addition, the increased transport costs of traveling into town made purchasing store food more expensive and inconvenient. Some participants reported a resurgence in traditional fish-for-produce exchanges with nearby villages instead of cash purchases in the later stages of the study period, which was partly due to the reduced accessibility of mainland shops and partly due to overall reduced cash flow in the community.

> *The market was bad because there was no money... We used only fish, and we exchanged it. Some people (from the mainland) came, and we exchanged just some fish for sago, we exchanged fish for bananas, so we could get food to help us, and the mainlanders could get fish.* (woman, 54, PNG)

System feedbacks

COVID-19 containment policies led to a range of adaptive responses at multiple scales, social feedbacks, and system changes, which in turn, in some cases, lead to changes to the original containment policies and system drivers. In Mkwiro, Kenya, the breakdown in fish distribution chains (i.e., a negative impact on food supply chains) resulted in reduced income for fishers and, therefore, reduced the financial accessibility of fresh produce and grain (i.e., a negative impact on food environments), which fishers would normally purchase from small stores on the island or markets in Shimoni (the closest mainland town). In response to

Fig. 7. Market closures and social feedback mechanisms in PNG. Ahus is a small island relative to its population size, with poor soil quality, making it an unfavorable environment for growing food crops (a). As such, on-island food production is limited to small household gardens and fruit trees, and people are largely dependent on food brought to the local market from the mainland (b). In the early stages of the pandemic, community leaders decided to close the markets to prevent too many people aggregating, stop mainlanders coming to the island, and ban direct trading with mainland communities (c). Availability of fruit and vegetables on the island became limited, and mainland markets were inaccessible (d). People were only able to obtain food from fishing and what they could grow in small gardens if they had them (e), resulting in severe restrictions in diet quantity, quality, and diversity (f). This caused increasing discontent in the community (g) and escalated existing conflict between leaders and young men (h). Some people (primarily young men) chose to defy the rules established by the community leaders and paddled across to the mainland at night in canoes to trade fish for vegetables directly with relatives (i), but only those who had access to canoes; relatives on the mainland willing to trade with them; were physically able to make the journey; and were willing to break rules were able to trade (j). As such, some households in the community got access to fruits and vegetables from the mainland, but most still had restricted access (k), meaning that diet quality improved for some but not all (l), increasing social inequity, discontent, and conflict in the community (m). In response, leaders decided to re-open the market with physical distancing measures in place (n).



the lost income and threat of food insecurity (i.e., a negative impact on diets), some fishers (those with sufficient adaptive capacity to do so) invested in small-scale farming projects (i.e., a feedback altering food supply chains) with plans to sell a proportion of the yield in the community, which would increase the physical availability of fresh produce on the island overall (i.e., food environments) and replace some of the lost income from fishing (i.e., a feedback to economic drivers).

In a more complex example, Ahus Island has limited agricultural capacity. The community is largely dependent on external markets and outsiders bringing (non-fish) food to the local market. Local leaders decided to close the local market in the early stages of the pandemic for fear of transmissions and banned interaction between communities to prevent gatherings and maintain isolation. Participants explained that their community was unlike "mainland communities" because on the small island most people were unable to fall back on local small-scale agriculture as a safety net. As one man said, "If you're in a city, in a town or an urban area, you're ok compared to us on islands and in villages. And the mainland is alright as well because they have gardens...For us on this island, it is hard" (man, 44, PNG). The effects of these containment policies on food availability and accessibility were severe and led to additional social consequences such as exacerbating ongoing tensions between leaders and young men in the community. This then created a negative feedback loop where already disadvantaged groups within the community were disproportionately affected, increasing social inequity (Fig. 7). To obtain food, people broke rules banning travel between communities, thereby undermining the original intention of closing the market to minimize inter-community contact. In response to these negative social, food, and nutrition security outcomes, leaders revised the rule and re-opened the markets with physical distancing measures in place to minimize risk.

> *The leaders all sat down, they saw that, they set rules, they told us, but people didn't follow them. So, they said, ok, these things will stay, but we have to follow government's rules about physical distancing between us in all social activities.* (man, 32, PNG)

DISCUSSION

The consequences of COVID-19 containment policies reverberated throughout the fisheries-dependent food systems we studied. In sum, we found households experienced reduced volumes of food and lower dietary diversity, increased consumption of traditional foods, and improved hygiene practices. Fishers experienced reduced access to fishing grounds and markets, which led to reduced availability of fish and a decline in income. The hardship that people faced due to COVID-19 containment policies are concerning and in some instances alarming. If diet quality and quantity remain lowered for protracted periods while economies remain repressed, this could lead to severe health outcomes, particularly for women of reproductive age and children aged under five (Pérez-Escamilla et al. 2020). Insufficient macro and micronutrient intake can inhibit growth and development in children and are associated with a range of long-term health issues (Bloem et al. 2005, Black et al. 2013). There were some shifts in behavior that could be considered as positive outcomes, particularly if they are maintained long-term, for example, improved hygiene practices could lead to improved food safety and nutritional outcomes (Schmidt 2014). Moreover, increased consumption of fresh local produce (i.e., a more traditional diet) could help combat the rapid nutrition transition toward an industrialized diet, which is characterized by high consumption of processed, imported foods high in added fats and sugars associated with high rates of nutrition-related chronic conditions such as overweight and obesity, type 2 diabetes, and cardiovascular disease (Popkin 2003, Savage et al. 2020).

Primary process driving dietary changes

The pattern we identified, of reduced availability and accessibility of food and lower diet quality and quantity in these three communities, is consistent with reports of food and nutrition security impacts in rural agricultural or fishing communities, during COVID-19 (Jomitol et al. 2020, Blazy et al. 2021, Harris et al. 2020) and previous social, environmental, and economic shocks (Béné 2020). Similar impact pathways of shocks through food systems have been reported during and after conflicts and following natural disasters (Israel and Briones 2012, Cohen and Pinstrup-Andersen 1999).

Compounding impacts and compromised safety nets

In each community, there were multiple factors compounding reduced food availability and access, sometimes with interacting ripple effects, which curtailed people's capacity to cope and adapt to the situation. Adaptation to food system shocks may lie in alternative food sources, engaging in alternate livelihood activities, or relying on assistance from less-affected people in their social networks (Ziervogel and Ericksen 2010, Tam et al. 2014). In fact, during economic shocks, fisheries have historically functioned as a livelihood safety net when salaried employment opportunities or capital-intensive production activities have been compromised (Béné et al. 2010, Belton et al. 2021). However, our findings and those of others suggest that normal adaptive strategies were undermined by the compounding impacts of COVID-19 (Fiorella et al. 2020, Kruczkiewicz et al. 2021). Almost every aspect of daily life was impacted in some way for all community members. Thus, people were unable to draw on the back-up livelihood activities, resources, and social support systems they would normally use to cope with smaller, isolated shocks, such as remittances or food sharing networks (Wossen et al. 2016). For example, Pacific Island communities have historically relied on food sharing and exchange networks, both within and between communities, as a food and nutrition security safety net during crises, particularly for the most vulnerable (Campbell 2015). Traditional food sharing also plays an important role in broader community cohesion and relational wellbeing. Our results suggest that food sharing networks were unable to compensate for reduced physical and economic accessibility of store-bought and garden foods because of the breakdown in both traditional inter- and intra-community exchange and forced isolation. Across all three sites, the barriers to catching and selling fish experienced by people already dependent on fisheries also undermined fisheries' potential function as a safety net for people who lost salaried employment. Future investigations into if and how communities were able to cope with and adapt to the multiple simultaneous effects of COVID-19 may provide insights into their ability to adapt to future complex and compounding effects of simultaneous climate change impacts and other social and environmental shocks.

Implications for the design of strategic interventions

Many studies have found that COVID-19 containment policies resulted in restricted food availability, accessibility, and diet quality (Stephens et al. 2020, Carducci et al. 2021, Erokhin and Gao 2020). By using a structured comparison, we were able to illuminate that the same outcome was driven by different, context-specific mechanisms. As such, policy and interventions require design and adjustment according to specific food system characteristics. For example, the three communities in this study were connected to external food supply chains to different extents. As such, each would require different types of interventions to restore or replace supplies. With limited agricultural capacity (limited land), island supply chains rely on the mainland and are extremely vulnerable to the loss of this connection (Charlton et al. 2016). Unlike the community in St. Lucia, and other coastal regions of PNG and the Pacific, small and isolated islands like the PNG community are unable to fall back on small-scale agriculture to mitigate some of the impacts of reduced access to external markets (LMMA Network et al. 2020, Steenbergen et al. 2020). In this case, small policy adjustments were able to restore connectivity and resume relatively normal food trade. In PNG, provincial borders were closed in a similar way to county borders in Kenya, but this policy appears not to have significantly impacted the community once access to the mainland market was restored. While the community on the island itself is not self-sufficient, its food system is relatively geographically constrained, and both the physical and economic food access issues could have been (and in some ways were) substantially alleviated by local leaders facilitating increased (COVID-safe) provincial-scale market connectivity. In this instance, it was key that local leaders had the ability to self-organize to decide how best to balance the specific needs of the community within the scope of national requirements and recommendations.

In contrast to the relatively locally bounded local food system in PNG, the community in Kenya was primarily impacted through disrupted connections with external markets due to the provincial border closures. Throughout Africa, national COVID-19 containment policies underestimated rural-urban food market integration when imposing movement restrictions, failing to preserve domestic food supply chains to, and income streams for rural producers (Liverpool-Tasie et al. 2021). As such, the value-chain disruptions in Kenya would likely have required national-level policy changes to support the longer, often informal, value chains that are critical to both rural and urban food and nutrition security (Zimmerer and de Haan 2020) while minimizing potential virus transmission. At a larger scale, St. Lucia fishers were significantly impacted by international movement restrictions, because their main income stream is from selling high-value fish to wholesalers for overseas exports and to hotels and restaurants servicing international tourists on the island. In this case, and perhaps also in Kenya, a significant transition to more local fish distribution channels was likely necessary. To varying extents, all three communities still shared the common characteristic of being highly dependent on fishing for food and income and to trade for non-fish foodstuffs. Communities which still have a strong cultural and economic link to fishing but also have more potential for livelihood diversification and nutritional self-sufficiency, for example, coastal and inland fisheries with higher agricultural potential, may have been more resilient to the breakdowns in fish trade experienced in these communities (LMMA Network et al. 2020, Marschke and Berkes 2006, Allison and Ellis 2001, Allison 2011).

Understanding how communities are vulnerable to changes at different scales is one of many contextual factors critical for designing effective policy responses to shocks. It is also critical to ensure that any future pandemic containment or impact mitigation policies, or indeed responses to any systemic shocks, address not only differences between, but also within, communities. Different food system actors are vulnerable to different impacts and have different capacities to adapt to meet food system changes arising from shocks (Smith and Frankenberger 2018). Shocks, particularly those related to climate change, are projected to increase in frequency and severity (Barnett 2011). COVID-19 may provide an opportunity to identify target areas and strategies for building food systems that are more resilient against complex, intersecting, and protracted shocks (Klassen and Murphy 2020, Phillips et al. 2020).

The instances in which multiple impact pathways converge or diverge around a single point, or bottleneck, in the food system may represent a point for strategic intervention. For example, in the PNG site, access to the mainland market was a major food access bottleneck. COVID-19 containment policies reduced connectivity between the island and the mainland through infrastructure closures, transport restrictions, and social gathering limits, and led to reduced incomes, limited access to diverse foods, and essential services. Supporting connectivity, while minimizing transmission risk, may have been a single-entry point to resolving multiple barriers to food access. For instance, women drew on social and communication networks by asking friends to buy and sell on their behalf when they could not travel into town. Similar adaptations have been noted in other instances of reduced physical connectivity; some small-scale food producers and distributers have successfully utilized digital technologies to restructure local food-distribution channels to facilitate the movement of foods in more controlled and predictable ways with minimal physical contact (Mittal and Grimm 2020, Bassett et al. 2021).

Limitations and applications

Our qualitative study focused on gaining a deeper understanding of people's lived experience with the food security impacts of COVID-19 in fishing communities. We attempted to interview people from a range of backgrounds within each community, including both men and women, to capture variation in the experiences of actors who connect to the food system in different ways and are influenced by different drivers. However, we were limited in the number of interviews we could include in the study, which affects the generalizability of the experiences we captured. Our methodology could be applied more extensively within a community to build a more comprehensive understanding of the local food system or in multiple communities for further contextual comparisons. Additionally, our interviews were conducted approximately five months into the pandemic, and interviewees were asked to reflect on changes since the onset of the pandemic. Recall bias may have impacted the results, particularly participants' reflections of the initial months of the study period, as the accuracy of individuals' recollections of their own experiences can decline rapidly over time.

Beyond tracing linear value chains and direct impacts, taking a food systems approach allowed us to identify feedback loops, interacting drivers, and more convoluted impact pathways. We found that even where mechanisms and food and nutrition security outcomes at first seem similar, the underlying pathways and feedbacks causing these impacts may be very different. The ability to identify these processes and contextual influences is the key strength of the food system approach. However, it is also a weakness in that it requires significant time and resources to identify and apply locally tailored responses when shocks are occurring at large scales. There are some inevitable trade-offs between timeliness and nuance when it comes to evaluating and meeting diverse needs. These trade-offs are amplified during protracted shocks, as repeatedly conducting analysis at this level of detail is costly for public agencies, but it is critical to ensure that any negative feedbacks and unintended consequences of policy interventions are being addressed.

CONCLUSION

The context-specific understandings of processes and drivers which can be gained through systems analysis are key to designing appropriate policy responses or additional interventions in local food systems which address the specific needs of communities. While in-depth mapping across multiple local food systems can be time and resource consuming (Delaney et al. 2018), our analysis shows that the substantially different specific needs across different contexts call for more nuanced policy approaches which account for this degree of variation. In general, supplementing high level, quantitative analysis of food supply chains and diets with qualitative explorations of experiences at smaller scales can provide a more comprehensive picture to inform effective policy responses to COVID-19 and future shocks.

Conflicts of interest

Authors declare that they have no competing interests.

Author Contributions:

Conceptualization: SS, JL, MB, PJC, JC Methodology: SS, JL, MB, EM, PJC, JC Investigation: SS, JL, MB, EM, EW, WH, IM, SW, NM, JC Visualization: SS, JL, MB, JC Supervision: JL, MB, JC Writing - original draft: SS, JL Writing - review & editing: SS, JL, MB, EM, EW, WH, IM, SW, NM, PJC, JC Project administration: SS, JL, MB, EM, EW, NM, JC Funding acquisition: SS, JL, MB, EM, EW, NM, JC

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Data Availability:

Summaries of NVivo coding outputs which support the findings of this study are available in Appendix 3. The interviews that support the findings of this study are available on request from the corresponding author (SS). None of the data are publicly available because they contain information that could compromise the privacy of research participants. Research protocols were approved by the Human Ethics Committee at James Cook University (approval H8109) and Oregon State University (IRB-2020-0678).

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Appendix 1 Individual interview template

I'd like to hear about the changes you and your household have experienced in the past month, related to COVID-19 and government rules that have been put in place.

General

- What are the main changes you have experienced since March 2020?

Livelihoods

- Please tell me about how COVID-19 has impacted how you and your family have brought in food and income compared to how you normally would at this time of year.
    - Have you and your family made any changes to cope with these impacts? Please tell me about them.
- I am interested in understanding how COVID-19 has affected how you and your family have been fishing and gleaning.
- Has COVID-19 changed how much you've been catching compared to how you normally would at this time of year? How so?
- Has COVID-19 changed the type of catch you've been catching compared to how you normally would at this time of year? How so?
    - Have you and your family made any changes to cope with these impacts? Please tell me about them.
        - *[If they say that they're catching less fish (above), ask]* Are you selling less fish, eating less fish or a combination, or something else?

Fishing and access to markets

- Please tell me about how COVID-19 has impacted how you [buy and] sell fish (including markets)?
    - Have you and your family made any changes to cope with these impacts? Please tell me about them.
- Is it easier or harder or the same to access markets (or buyers) to buy and sell fish compared to normally at this time of year? Why?
    - Have you and your family made any changes to cope with these impacts? Please tell me about them.
- Has the price of fish changed to buy and to sell compared to this time of year normally? How?
    - Have you and your family made any changes to cope with these impacts? Please tell me about them.

Food security

- Please tell me about how COVID-19 has affected the types and variety of food you and your family are eating now, compared to normally at this time of year.
- Are there foods you normally eat at this time of year that you are not eating at the moment? Why?
- Is store-bought food easier or harder to get? Why?
    - Have you and your family made any changes to cope with these impacts? Please tell me about them.

Wellbeing

- How has COVID-19 impacted other aspects other aspects of your quality of life, for example your normal routines, social interactions and level of happiness and day-to-day life compared to normal? (E.g. Church, soccer/ football).
- Have your social relations with others in the community changed? How?
    - Have you made any changes to cope with these impacts? Please tell me about them.

General

- Is there anything you'd like to add?

Appendix 2 Community leader interview template

I'd like to hear about the changes the community has experienced due to the COVID-19 pandemic and the government rules that have been put in place.

General

- What are the main changes that COVID-19 has had on the community?

Institutions

- Please tell me about changes caused by COVID-19 to meetings and activities in the community compared to before? Are there regular community meetings? Has COVID-19 impacted fisheries (or reef) management? How?

Migration

- Please tell me about changes that COVID-19 is having on people coming and going in the community? Have more people come here or more people left? If so, what impact is that having?
    - Has the community made any changes to cope with these impacts? Please tell me about them.

Livelihoods

- Please tell me about impacts that COVID-19 has had on livelihoods in the community. Have the number of people fishing changed? Has the intensity of fishing changed?
    - Has the community made any changes to cope with these impacts? If so, what are these changes?

Access to markets

- Please tell me about impacts that COVID-19 has had on buying and selling fish. Are people in the community able to access markets? Why/ why not?
    - Has the community made any changes to cope with these impacts? Please tell me about them.

Food security

- Please tell me about impacts that COVID-19 has on food. How is the community making food last for everyone? Are there any projects or plans to support the community to access food? Are people in the community changing how they access food?
    - Has the community made any changes to cope with these impacts? Please tell me about them.

Wellbeing

- Please tell me about impacts that COVID-19 has on the wellbeing and day to day lives of the community as a whole, for example, have church gatherings continued, are sports still played? Have social relations in the community changed? How?

    - Has the community made any changes to cope with these impacts? Please tell me about them.
- Do you think COVID-19 has impacted some people in the community more than others? How and why?

Support

- Has there been any external support? E.g. government, CBOs, NGOs? What sort?
- What further outside support is needed? (Specify that we don't provide this – we will pass this on as recommendation.

General

- Is there anything you'd like to add?

Appendix 3 Participant demographic information

Table A3.1 Interviewee demographics

ID	Gender	Age	# people in household	Clan group
Ahus				
AH1	M	40	7	Pacha
AH2	M	32	4	Paneheu
AH3	M	44	8	Bulungol
AH4	W	32	3	Bulungol
AH5	W	54	2	Bulungol
AH6	W	23	2	Pacha
AHLeader	M	65	3	Bulungol
Mkwiro				
MK1	W	29	4	
MK2	M	27	12	
MK3	M	43	8	
MK4	W	40	9	
MK5	W	44	13	
MK6	M	61	8	
MK7	M	40	6	
MK8	W	28	5	
MK9	M	49	10	
MKLeader	M	Unknown	Unknown	
ID	**Gender**	**Yrs. in fishing industry**		
St. Lucia				
SL1	M	20	-	
SL2	M	20		
SL3	M	15		
SL4	M	15		
SL5	W	8		
SLLeader	M	Unknown		

Appendix 4 Supplementary results

Table A4.1 Impacts of COVID-19 containment policies on each component of the food systems framework. Based on final NVivo codebook. Superscripts indicate which sites each impact was reported in (P= Ahus island, PNG; K= Mkwiro, Kenya; S= Dennery, St. Lucia).

Impacts of COVID-19 containment policies on each component of the food systems framework	
Policy and Governance	Direct COVID-19 containment policies
	Movement restrictions
	Ban on travel between counties [K]
	Recommended self-isolation and limited movement [K, P]
	Ban on leaving community and/or visiting other communities [P]
	Curfews [K, P, S]
	Lockdowns [S]
	Social distancing rules
	While fishing [K]
	At markets and stores [P, K]
	At banks, petrol stations etc. [P]
	Limits on people in boats [P, K]
	Limits on people in cars and trucks [S]
	Ban on gleaning in groups [K]
	Ban on community gatherings and meetings [K, P]
	Compulsory use of masks [K, S]
	Market closures [P]
	Reduced market and shop operating hours and days [K, P]
	Creation of a community COVID-19 taskforce [P]
	Declaration of a National State of Emergency [P]
	Promotion of good hygiene practices [P]
	Distribution of hygiene supplies [P]
	Leaders instructing community members to buy less in market [P]
	Ban on raising prices in stores and markets during pandemic [P]
	Ban on selling betelnut [P]
Systems supporting food production	Ecosystems [K,P]
Food supply chains	Production
	Foods produced
	Seafood [K, P, S]
	e.g. Fish, octopus, molluscs, seaweed
	Grains [K, P, S]
	e.g. Maize, rice
	Vegetables [K, P, S]
	e.g. Sweet potatoes, banana, cassava, plantains, leafy greens
	Engaging in new production activities
	Gleaning [K]
	Fishing [K, S]
	Growing crops [K, S]
	Seaweed farming [K]
	Changes in fishing methods
	Changes in gear types [P]
	e.g. from trolling to spear fishing
	Changes in fishing sites [K]
	e.g. only fishing close to village
	Gleaning instead of fishing [K, P]

- Deployment of a Fish Aggregation Device [P]
- Reduction in production activities esp. fishing
  - Fewer people allowed on boats to fish [K]
  - Bad weather [K, P]
  - Not fishing in prime locations [K]
  - Fishing/farming for less time or at bad times due to curfew [S]
  - Not fishing for fear of getting sick [P]
  - Not fishing while self-isolating, staying on island [P]
  - Unable to get production inputs e.g. fuel for boats [P, S]
  - Low demand [K, P]
  - Low catch due to overfishing [P]
  - Only fishing for consumption not sale [P]
- Introduction of safety measures while fishing/farming
  - Social distancing [K]
    - *e.g. not gleaning in groups, limits on people in boats*
  - Wearing masks [K, P, S]

Processing

- Increase in production of prepared snack foods and meals to sell in community [K, P]
  - *e.g. scones, cassava chips, mahamri, soup*
- Processing fish, octopus etc. to sell in community (as opposed to selling fresh or to traders) [K, S]
  - *e.g. salting, drying, frying*

Storage, trade and distribution

- Travel restrictions blocking imports and exports to cities [K, S]
  - Shift from selling in cities to smaller close towns [K]
  - Sending fish on transport trucks instead of travelling to sell in-person [K]
  - Traders buying less fish, or buying at lower prices [K]
  - Fishers looking for alternative markets with better prices [K]
- Disruptions in food sharing practices [P]
- Fewer traders and wholesalers to sell to [K, S]
- More traders to sell fish to [K]
- Use of fridges to store fish until it can be sold [K]
  - Lack of access to cold storage [K]
- Government, NGO and industry food aid distribution [K]
- Ban on travelling to mainland to trade [P]
  - Breaking rules to trade with mainland [P]

Retail and marketing

- Food shortages in stores and markets [K, P, S]
- Market closures and reduced hours [K, P]

Food Environments

Availability and physical access

- Unable to access fishing grounds [P]
- Less fish available [P]
- Not fishing out of fear [P]
- Unable to leave island to get food [P]
- Growing own food [K, S]
- Inability to grow own food [P]
- Food stockpiling [K, S]
- Garden foods more available and accessible than store food [P]
- Insufficient food available in stores and markets [K, P, S]

- Breaking rules to access food on mainland (dependent on having canoe and ability to paddle there) [P]
- Gifting and family support
  - Community support for struggling people [P]
  - Normal gifting and food sharing practices stopped [P]
  - Support for people with family outside community [P]
- Government, NGO and industry food aid [K]
  - No aid despite past instances [P]
- Market and shop accessibility reduced
  - Transport limitations [P]
  - Social distancing and safety requirements [K, P, S]
  - Reduced opening hours/days [K, P]
  - Market closures [P]
  - New markets opened [P]
  - Use of intermediaries to buy food [P]
  - Staying home to socially distance [P]
  - Return to normal [P]
  - No differences [K]
- No difference [K, P]

Affordability/economic access

- Loss of income reducing economic accessibility of food [K, P]
- "luxury" foods unaffordable [K, P]
- Canteens in community more expensive than markets in town [P]
- Only able to afford limited range of basic staples [K, P]
- Only able to afford smaller quantity of food [K]
- Only able to afford limited range of foods [P]
- Price freezes to maintain affordability [P]
- Price increases [K]
- Price reductions [K, P, S]
  - Sellers intentionally lowering price in own community to maintain affordability [P]
- Shopkeepers allowing people to get food on credit and pay later [K]
- Reversion to exchange instead of cash transactions [P]
- Producing own food when unable to afford to buy [P, K]
- Ability to buy other foods dependent on fish sales [K, P]
- Government aid increasing purchasing ability [K]
- No change [K, P]
- Trading and negotiating exchanges instead of cash purchases [P]

Food quality and safety

- Increased food safety due to improved hygiene practices [K, P, S]

Acceptability

- Forced to make do with less preferred but more affordable and accessible foods [K, P]

Information, guidelines and advertising

- Encouragement from community leaders to eat garden food [P]

Policy conditions

- Ban on raising food prices [P]
- Social distancing and other safety requirements [K, P, S]
- Promotion of hygiene practices [P]

Consumer Behaviour — Reduction in amount of food acquired, prepared and consumed

- Buying less overall [K, P]
- Budgeting/rationing food [K, P, S]
- Preparing/eating less food at each meal [K, P, S]
- Eating fewer meals per day [K, P]

Changes in food acquisition behaviours
- Avoidance of markets out of fear [P, S]
- Breaking rules to obtain food [P]
- Pooling resources to be able to buy food [K]
- Reliance on fishing for food [P]

Changing types of food acquired, prepared and consumed
- Purchasing decisions based on price [P]
  - Expensive foods consumed less frequently [P]
- Preparing simpler meals with fewer ingredients [K, P]
- Buying a reduced variety of foods [K]
- Substitutions
  - Vegetables instead of meat [K]
  - Less preferred but more affordable/accessible foods [K, P]
  - Gleaned seafood instead of fish or store food [K]
  - Village food instead of store food [P]

Proportion of catch sold vs. retained for consumption
- Both selling and eating less (reduced catch) [K]
- Eating less and selling more [K]
- Proportion sold based on availability of other food [P]
- Selling less and eating more [K]

Diets

Perceived inadequacy
- Feeling hungry [P, K]
- Feeling unsatisfied [P, K]
- Feeling unsustained [K]

Reductions in quantity
- Not eating enough [K, P]
- Eating less than normal overall [K, P, S]
- Eating fewer meals per day [P, K]

Reductions in quality
- Not consuming preferred foods [K, P]
- Mostly consuming nutritionally poor staple carbohydrates [K]
- Less meat and/or vegetables [K]

Reduced dietary diversity
- Fewer different foods in each meal [K]
- Consuming same basic meal every day [K,P]
- Only eating fish [P]
- Fewer foods affordable [K, P]

Improved food safety due to increase in hygiene practices [K, P, S]
Reversion to traditional instead of store bought food [K, P]
Reduced alcohol consumption [P]
No changes [K, P, S]

Broader impacts

Economic impacts
- Not enough money for other things after buying food [K]

	Strict budgeting [K]
	Savings depleted or exhausted [K]
	Transition to exchange instead of cash economy [P]
	Social impacts
	Breakdown of informal social support systems like food sharing
	Results in damaged social relations and perceptions of greed and selfishness in community [P]
	Civil disobedience [P]
	Conflicts with leadership [P]
	Mental health impacts of poverty and food insecurity
	e.g. hopelessness, fear, distress at being unable to provide for family [K, P, S]
	Perceived lack of opportunity to improve quality of life [K]
	Loss of social aspects of eating food with friends and family [P]
	Reduced alcohol consumption good for the community [P]
	Environmental impacts
	Increased fishing pressure leading to overfishing [P]
	Reduced fishing pressure potentially allowing recovery [P]
Biophysical and environmental drivers	Bad weather conditions for fishing *e.g. strong winds, rough seas*
	Seasonal bad weather *e.g. (Kusi, windy season)* [K,P]
	Unseasonal bad weather [P]
	Seasonal produce availability [P]
	Reef health *e.g. overfishing* [P]
Technology, innovation and infrastructure drivers	Breakdown in food transportation and market access infrastructure
	Fewer, slower, more expensive boats to mainland [P]
	No trucks taking fish to city markets [P]
	Lack of freezers to store fish while transport unavailable [K]
	Inability to obtain inputs
	e.g. fuel for boats [P]
	Inability to access banks [P]
	Damaged water infrastructure inhibiting hygiene practices [K]
	Deployment of FAD [P]
	Distribution of boat maintenance supplies [S]
Economic and market drivers	Lack of money generally [K, P]
	Limited cash circulation in communities [P, S]
	Family budgeting [K, S]
	Government support payments
	Helpful [K]
	Insufficient [K]
	Not frequent enough [K]
	Not distributed to everyone [K]
	No government support [P]
	Increasing reversion to exchange instead of cash economy [P]
	Remittances [P]
	Depletion and exhaustion of savings [K]
	Price reductions [P]
	Markets
	Formal market closures [P]
	Reduced operating hours [K, P]

- Establishment of new markets [P]

Livelihood impacts

- Job loss [K, S]
  - Collapse of tourism [K, S]
  - Can't sell prepared foods [K]
  - Passenger boats not operating [P]
  - Goods trading and distribution [K]
  - Ban on selling betelnut [P]
- Fishing and fish selling
  - Fishing as only/primary income source [K, P, S]
  - Uptake/increase in fishing due to job loss [K, S]
  - Reduced income from selling fish
    - Reduced prices [K, P, S]
      - Distribution chains blocked, traders buying for less [K]
      - Only selling locally at low prices [K, S]
      - Off-season prices [K]
      - Choosing to sell at lower prices so its affordable in poor economy [P, S]
      - Selling directly, competing with wholesalers [S]
    - No buyers
      - No tourists [K, S]
      - People afraid to buy [P, S]
      - People can't afford to buy [P, S]
      - Traders and wholesalers not buying and exporting [K, S]
    - Market access for selling
      - Transport restrictions [K, P]
      - *e.g. travel bans, limits on numbers in boats, physical inability to paddle distances, increase costs of boats, reduced frequency of boats*
      - Social distancing rules [K, P, S]
      - Reduced opening hours and days [K, P]
      - Selling roadside instead of on dock [S]
    - Traders buying less fish [K]
    - Intermediaries unwilling to sell fish on behalf of others [P]
  - Reduced catch or fishing effort
    - Fewer people on boats [K]
    - Time restrictions due to curfew [S]
    - Fishing less due to reduced demand [K, P, S]
    - Fishing less out of fear of virus [P]
    - Bad fishing conditions [P]
    - Can't get inputs *e.g. fuel* , [P, S]
  - Exchanging instead of selling for cash [P]
  - Focus on high-value gleaned species to sell [P]
  - Insufficient to meet needs [K, P]
- Making a loss from previously profitable work
  - Food production, processing and selling activities [K]
  - Operating boats [P]
- Salaried income
  - Those with salaried jobs increase community cash flow [P]
  - Easier for people with salaried jobs than fishers/village people [P]
- Uptake or increase in alternative livelihood activities
  - Cooking and selling prepared meals and snack foods [K, P]
  - Casual labour work [K]
  - Making and selling charcoal [K]

	Growing and selling food crops [K, S] Seaweed farming [K] Focus on high-value gleaned species to sell [P]
Political and institutional drivers	Food aid and support payments from government, industry and NGOs [K] *e.g. money, maize, beans, rice, sugar, cooking oil, maize or wheat flour* Infrequent or one off [K] Regular [K] Irregular [K] Not fairly distributed [K] Helpful [K] Insufficient [K] Lack of institutional support and interventions [P] Distribution of hygiene supplies and information [P] Distribution of boat maintenance supplies by fisheries Co-op Civil strife, conflict and disobedience [P] Police enforcement of COVID safety policies [K, P] Deployment of a FAD [P]
Socio-cultural drivers	Influence of fear on individual and community behaviour Not buying fish directly from fishers [S] Not visiting markets [P] Not fishing [P] Largely adjusted and returned to normal [P] Social norms and traditions Food sharing practices Social obligation to assist struggling community members [P] Breakdown of normal food sharing practices [P] Unable to move around and share meals [P] Loss of social aspects of food and sharing meals in community [P] Perception of greedy and selfish behaviour [P] Distribution of some fish from FAD to needy [P] Valuing self-sufficiency [P] Fishers choosing to lower prices to keep food affordable [P] Loss of social aspects of food and sharing meals in community [P] Sharing of resources and responsibilities between family members [K] Ability to get food on credit from stores owned by trusted friends [K] Not following rules that go against normal social behaviours [K, P] Social stratification Age Gender Increased care burdens for women [K] Lack of support for widows [P] Only “strong young men” able to break rules and paddle to mainland to trade for food [P] Women responsible for obtaining food [S] Family status People without off-island family received less support [P] Employment status [P, K]
Demographic drivers	Family size [P] Over-population [P]