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COFI-35 SESSION BACKGROUND PAPER

Global Assessment of COVID-19 on Fisheries and Aquaculture

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David C. Love, Lisa M. Weltzien, Natalie S. Armstrong,
Dahiany Zayas-Toro, Andrew L. Thorne-Lyman, Elizabeth M. Nussbaumer

Center for a Livable Future, Johns Hopkins Bloomberg School of Public Health,
Baltimore, Maryland, USA

FAO COVID-19 Colleagues:
Florence Poulain, Lionel Dabbadie, Jose Estors Carballo, Alejandro Flores, Jennifer Gee,
Kathrin Hett, Jon Lansley, Felix Marttin, Maarten Roest, Nianjun Shen

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Executive Summary

COVID-19 was declared a global pandemic on March 11, 2020, and years later there remains serious ongoing economic, health, and food system challenges. Global growth is estimated to slow in 2022 as a result of COVID-19 flare-ups, tightening monetary policy, supply chain bottlenecks, climate change, and other factors. The number of people employed in early 2022 was 3.8% below pre-pandemic levels and salaries have not kept pace with inflation. On top of that, the conflict between Ukraine and the Russian Federation has also affected energy and commodity prices. Food insecurity is higher today than ever before. Countries hardest hit by the pandemic have seen the greatest increase in consumer food prices for nutritious foods. Recovery from the pandemic remains uneven and has exacerbated inequalities.

The pandemic intensified data scarcity in the fisheries and aquaculture sectors. Routine monitoring, stock assessments, meetings, and enforcement was paused or halted, and national reporting slowed. This hindered efforts to manage natural resources and understand how the pandemic affected different populations. Knowledge gaps were smaller in countries with greater institutional, financial, and technological capacity. With support from the Food and Agriculture Organization's (FAO) Fisheries and Aquaculture Division COVID-19 Task Force, a systematic literature review was conducted to characterize COVID-19 impacts and responses to the fisheries and aquaculture sectors globally. This effort focused on fisheries and aquaculture producers, their value chains, and consumers of aquatic foods.

This literature review covered the first two years of the pandemic and returned 14,628 unique records for screening, of which 671 articles were included in the final stage of data analysis. A total of 186 countries were studied; however, countries with a larger share of fisheries and aquaculture production were better represented. The largest share of studies was in Asia, which is responsible for 75% of fisheries and aquaculture production. Most studies covered the first year of the pandemic, with many focusing on the first wave of lockdowns from March through June 2020. While this literature review provides evidence of short- and medium-term impacts and responses, few reports looked at impacts beyond the first year of the pandemic.

The pandemic directly and indirectly affected all parts of the aquatic food value chain. Shocks to one sector or region had cascading effects through supply chains, shedding light on how food systems have become increasingly globalized, interconnected, and interdependent. In 2020, capture fisheries production was 4% below 2018, but within normal year-to-year variability over the past 25 years. Global satellite data indicates that fishing activity was down from January to April 2020 due to lockdowns, but rebounded by May 2020, making a faster recovery than other maritime sectors. Some coastal and inland fisheries saw increased fishing pressure to support livelihoods and subsistence. Illegal fishing was reported in many regions following gaps in monitoring and enforcement. Aquaculture grew by nearly 3% in 2020, which followed a general trend of slowing growth rates over the past two decades. Aquaculture businesses were vulnerable to the sudden downturn in demand, as well as negative impacts to labor, financing, and inputs. Thirty-eight percent of production is traded globally, making aquatic foods the most globally traded major food group. International fish trade declined more steeply than other sectors in early 2020, but appeared to show signs of recovery after the first lockdown periods ended (July 2020).

There have been clear signs of recovery and resilience among aquatic food producers and their value chains, although a complete recovery for some may take longer. A large, multi-country longitudinal study of aquatic food value chains found that one year after the start of the pandemic most individuals had stayed in business and there was increased hiring of laborers, better access to inputs, and somewhat better access to buyers compared to 2020. Producers adapted by using technology, e-commerce, and direct marketing to reach new customers. The most vulnerable groups, including women, migrant workers, and those in the informal sector in low- and middle-income countries (LMICs) continue to need attention even as groups in high-income countries may feel that the direct impacts of the pandemic are behind them. Today, inflation caused by the secondary effects of the pandemic and other factors is of great concern, which is projected to increase production costs and dampen sales.

The pandemic affected consumers in different ways and served to widen existing inequities. For consumers in LMICs and low-income consumers in high-income countries, constraints to livelihood activities, increased food prices, and closures of markets increased food insecurity. Lessons from past economic crises show that foods with higher elastic demand such as fish, meat, vegetables, and fruit are generally the first foods to be dropped or replaced during economic hardship. A similar pattern was observed during COVID-19; in fact, a meta-analysis of the pandemic's effects on diet found that households reduced consumption of fish more than any other food group. In response, some governments provided social protection including cash transfers and food aid. Further research is needed to evaluate the short and long-term effectiveness of social protection in aquatic food sectors.

In wealthier populations, the 2020 lockdown period shifted aquatic food consumption from food service to retail. Shoppers in high-income countries formed new habits, particularly using direct marketing and e-commerce to purchase aquatic food. Initial panic buying gave way to deliberate food purchasing spaced out at longer intervals, with more attention to food safety and food waste. Luxury aquatic food products performed well at retail, as households began to gain confidence cooking at home, and canned and frozen aquatic food sales also remained high. Two years into the pandemic, many consumers are more concerned about food prices than health risks from COVID-19.

The pandemic lockdown period had beneficial and detrimental effects on the aquatic environment and wildlife, suggesting that humans play a dual role in threatening and protecting nature. The pause in anthropogenic activity during lockdowns temporarily reduced air and water pollution and fishing activity in some locations, but increased the amount of discarded medical and plastic waste. More studies are needed on whether short-term gains will translate into long-term improvements for fisheries and aquatic ecosystems.

Recommendations provided at the end highlight coping mechanisms and adaptation strategies to build resilience against future shocks and stressors caused by COVID-19. The 500 studies that included recommendations were grouped into categories of research and technology, governance, social protection, risk mitigation, education and behavior change, and information access. Many of these recommendations highlight opportunities for action and influence over the food system, external drivers, and outcomes. Some solutions are context or region-specific but most are broadly applicable to the fisheries and aquaculture sectors.

Key Messages

The COVID-19 pandemic has created the opportunity to learn from a large-scale experience and prepare for the future. The below messages have been collated and synthesized from the literature review of 671 academic papers.

- **COVID-19 widened existing inequalities.** Vulnerable populations, including women, migrants, and actors in the small-scale and informal sectors need continued support, assessments of their current needs, and evaluations to track effectiveness of interventions.

- **Globally connected food system.** Shocks to one sector or region had cascading effects through aquatic food value chains showing how the food system has become globally interconnected and interdependent.

- **Aquatic food dropped from diets.** Household consumption of aquatic foods dropped more than any other food group during the pandemic, a similar trend seen in past economic crises, which may have implications for micronutrient deficiencies.

- **Consumer habits have staying power.** Consumers have gained confidence cooking at home and buying more fish at retail, but weak sales are expected in countries with high inflation.

- **A pause in human activity.** The pandemic had a short-term benefit for aquatic environments from decreased air and water pollution and other human pressures; however, and more study is needed of long-term improvements.

- **Technology and e-commerce.** Use of technology helped aquatic food producers and vendors to stay informed and connected, and to market and deliver products. Non-digital options are important for those with limited access to technology.

- **Diversification for resilience.** Businesses that diversified their harvests, product forms, and marketing channels were more resilient, while over-dependence on exports, food service, hospitality, and tourism left businesses vulnerable.

Box 1. Emerging lessons for building resilient aquatic food systems
The State of World Fisheries and Aquaculture 2022 identifies emerging lessons for building resilient aquatic food systems. These include: • Continue to monitor impacts and responses. • Improve processing, diversify supply sources and markets and manage connectivity. • Recognizing that fisheries and aquaculture is an essential sector and integral part of the food system in many countries, maintain the smooth functioning of all points of the supply chains to support food security, income and employment.

- Protect small-scale fisheries and aquaculture, small and medium scale enterprises (SMEs), women and other vulnerable groups (e.g. informal and migrant workers)
- Strengthen government economic instruments including social protection. These can contribute to improved welfare and fisheries management.
- Embed social and environmental considerations (e.g. low carbon, climate resilience) into COVID-19 recovery plans.
- Prepare for multiple known or unknown risks through integrated risk management approaches.
- Study what types of measures and broader interventions have worked in different contexts and how systems have changed, and document both longer-term impacts and emerging lessons to build specific resilience to the COVID-19 pandemic and general resilience to future shocks or stressors.

Source: FAO. 2022. *The State of World Fisheries and Aquaculture 2022. Towards Blue Transformation*. Rome, FAO.
https://doi.org/10.4060/cc0461en

Background

In April 2020, the fisheries and aquaculture division of the Food and Agriculture Organization of the United Nations (FAO) established a task force with the responsibility to provide coordinated support to measures and interventions addressing the global impact of COVID-19 on fisheries and aquaculture.

Since its establishment, FAO with support from its task force has emphasized work on assessing the impacts of COVID-19 on the fisheries and aquaculture sector, formulating policy briefs and reports, developing partnerships and communication and assisting partners in their recovery.

FAO has produced best practice guidance for developing surveys and questionnaires on COVID-19 impacts on fisheries and aquaculture [1].

FAO has conducted two global assessments of the impact of COVID-19 on activities of Regional Fishery Bodies in April and November 2020 [2,3].

FAO has produced a number of policy briefs, and information papers on how COVID-19 is affecting the fisheries and aquaculture food systems [4].

FAO has partnered with the WorldFish (which is part of one CGIAR, the world's largest agricultural innovation network) to produce a policy brief on how the crisis has played out in aquatic food systems one year into the pandemic [5].

FAO is assisting member countries' recovery through its technical cooperation programme and voluntary funding.

FAO continues to communicate and share information with partners via webinars and its webpage [4]. Voices from the fishers is an opportunity to learn directly from the fishers how the pandemic has impacted their lives [4].

Noting data scarcity during COVID-19, FAO has been collaborating with the Johns Hopkins University to document the impact and responses to the pandemic by conducting a systematic literature review and by implementing a global survey with support from Globefish, Eurofish and the other Fish Info Networks.

1 Introduction

COVID-19 was declared a global pandemic on March 11, 2020 [6], and years later there remains serious ongoing economic, health, and food system challenges. Global growth is estimated to slow in 2022 as a result of COVID-19 flare-ups, tightening monetary policy, supply chain bottlenecks, climate change, and other factors [7,8]. The number of people employed in early 2022 was 3.8% below (112 million jobs below) pre-pandemic levels and 60% of workers live in countries where their income in 2021 are below pre-pandemic levels [9]. On top of that, the conflict in Ukraine has compounded energy and commodity prices [10]. Food insecurity is higher today than ever before, which is driven by conflicts, economic shocks, food price inflation, and climate change [11,12]. In 2021, 193 million people faced acute food insecurity, which is a 40 million person increase over 2020 [11]. Countries hardest hit by the pandemic have seen the greatest increase in consumer food prices for nutritious foods [13]. Recovery from the pandemic has been uneven and has exacerbated inequalities [7]. High-income countries and groups with access to medical resources (i.e., vaccines, protective equipment, therapy), government support (i.e., financial stimulus, social safety nets), and personal savings have fared better. Households in LMICs, women, and workers in the informal sector continue to struggle, including with access to vaccinations [9,14]. Nutrient-dense foods that have more elastic demand were affected the most, such as fish, meat, fruits, and vegetables [15,16].

The pandemic has been disruptive for aquatic food systems. Compared to pre-pandemic levels (2018), capture fisheries production in 2020 declined by 4.4% and aquaculture grew by 2.7%, a lower rate than previous years [17]. Global exports of aquatic products were down 7% by value in 2020 compared to 2018 [17]. Impacts from the initial shock of the pandemic rippled through value chains at multiple stages, scales, and countries, and shifted consumer demand and access to markets [18]. COVID-19 disruptions also led to innovations such as the use of technology and reaching new markets, although some sub-sectors, businesses, and individuals were left behind.

1.1 Rationale

The COVID-19 pandemic has intensified data scarcity in the fisheries and aquaculture sectors. In 2020 there was a pause in routine monitoring, stock assessments, and scientific observations in these sectors due to physical distancing, lack of Personal Protective Equipment (PPE), and a shift in resource allocation. There was late or non-reporting of annual fisheries and aquaculture statistics among some countries [17]. Other countries used alternative data collection methods, which complicated comparisons with previous years. Data on fisheries and aquaculture production, supply, and trade was also uneven; countries and sectors with greater institutional, financial, technological, and digital capacity were better prepared to collect the data [17]. Household-level surveys and censuses by governments were paused in some countries, which further contributed to data scarcity. Gaps in knowledge were filled in part by non-governmental organizations, academia, and others to document the impacts of the pandemic on various groups, regions, and sectors, much of which resides in peer-reviewed journals and gray literature. There has not been a systematic approach to catalog this literature, make it more accessible to policymakers, synthesize findings, and elevate the top recommendations for managing responses to the current pandemic and preparing for future shocks.

1.2 Research questions and scope

The purpose of this report is to characterize the impacts and responses to the COVID-19 pandemic among fisheries and aquaculture sectors globally. The following three research questions served as a guiding framework in conducting the systematic literature review:

> How has the COVID-19 shock/stress event impacted groups, businesses, and institutions in the fisheries and aquaculture sectors?
>
> What responses did groups, businesses, and institutions in the fisheries and aquaculture sectors have to the COVID-19 shock/stress events?
>
> What has been learned from the COVID-19 pandemic that could be applied to any future shocks and stressors (i.e., general resilience) and what recommendations have been made?

The search strategy captured articles written in English, published during the first two years of the pandemic, and published in journals cataloged by three electronic databases. A separate search was conducted for white papers and government reports.

Search terms and overall framing were based on a sustainable food system conceptual framework adapted from a report by the Committee on World Food Security [19] (Figure 1). This framework presents the food system as a complex network of food producers, supply chains, food environments, and food consuming households, nested within the economy and planet. Influencing the food system are a wide range of external drivers (e.g., climate, trade, economy) that can have both positive and negative impacts. The framework follows nutrition and health outcomes as well as outcomes for the economy and the environment. Investment levers were integrated into the framework as a means of capturing opportunities for action or influence over the food system, external drivers, and outcomes [20].

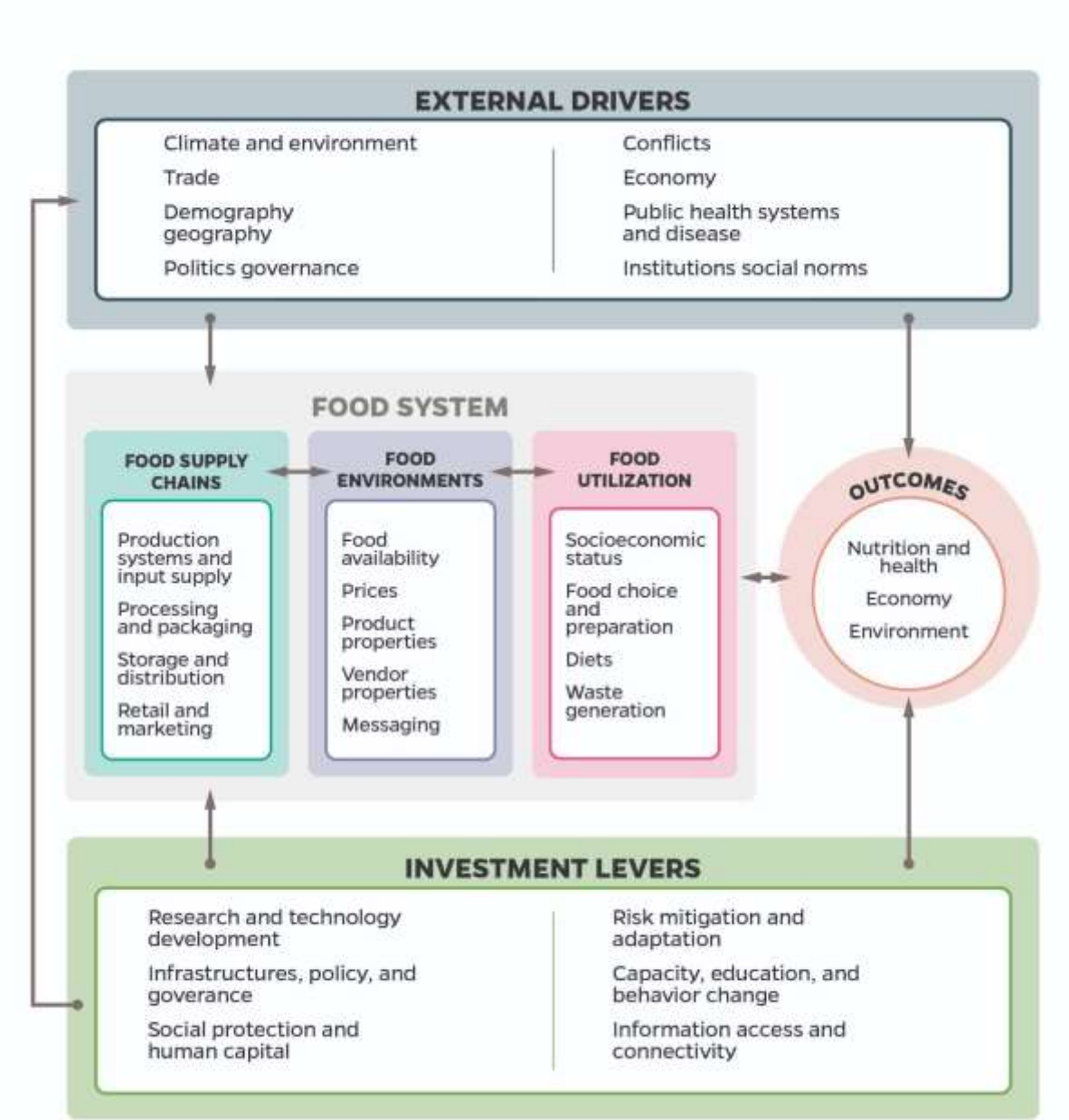


Figure 1. Food system framework to understand the effects of Covid-19 on aquatic food systems. Modified from [19–21]

2 Methods

2.1 Search strategy

A systematic search was conducted using three electronic databases (PubMed, Scopus, and Business Source Ultimate). Scientific articles about COVID-19 impacts on aquatic food systems including aquatic environments, supply chains, and aquatic foods were identified. The timeframe of the search spanned from January 1, 2020 to February 7, 2022. Records were limited to articles

written in English. Reports and gray literature were accessed from websites of organizations such as the World Health Organization, Food and Agriculture Organization of the United Nations, and the World Bank.

2.2 Study selection and inclusion criteria

Search results from electronic databases and gray literature were compiled (Endnote, London, United Kingdom) and uploaded to a systematic review management software where they were screened in two stages, first as titles and abstracts and then as full text articles. The following inclusion criteria were used to select articles for the review: i) articles written in English, ii) published after January 1, 2020, iii) related to the impacts of COVID-19 on aquatic food systems, and iv) written as a scientific article, review article, or report. Blogs, press releases, and newspaper articles were excluded. Reports about the protective effect of food, diets, or dietary supplements (e.g., fish oil, omega-3 fatty acids) against COVID-19 infections were also excluded. Screening was performed independently by two reviewers with a third reviewer who reconciled differences.

2.3 Data extraction

A data collection form was created to extract information from the full text of studies that met the inclusion criteria. Data were collected about study design, time period of analysis, and geographic area of study. As informed by a food system framework (Figure 1), we extracted data on COVID-19 impacts (and responses) to aquatic food producers, supply chains, retail, and aquatic food consumers including food waste. Upstream drivers and stressors, such as climate change or conflicts, and author recommendations for interventions were recorded. We collected additional information from studies using survey methodology, including the study population, sample selection, inclusion/exclusion criteria, recruitment methods, sample size, and survey tool deployment. Data was extracted by a single reviewer.

2.4 Analysis

Extracted records were cleaned and records with missing fields were completed after reviewing original papers. To draft sections of the report we arranged the data into groups (i.e., rows of data related to a particular topic) and identified key themes and patterns. We used the food systems framework as a guide for the topic areas for data collection and analysis (Figure 1). The report covers a broad range of food system topics including aquatic food production and supply chains, fish workers, food security, aquatic food loss and waste, and impacts to aquatic environments. Recommendations and investment levers were identified and sorted into six thematic areas according to the framework (Figure 1). Upstream drivers and outcomes were noted and incorporated into topic-area analyses. Summary statistics, tables and figures were created using RStudio (Boston, MA, USA). Time series plots were produced by arranging the dataset by

region and month of data collection. Maps presenting the number of studies per country were created in ArcGIS (ESRI, Redlands, CA).

3 Results

Here we present the preliminary findings of the literature review. FAO Members are invited to provide comments and feedback as we prepare to finalize a FAO technical report. This section begins with a description of the literature included in the review. Next, we describe the impacts and responses to the pandemic by stage of the aquatic food system, including consumers and food security. Lastly, we collate and synthesize recommendations and investment levers that were provided in the articles.

3.1 Description of literature

The COVID-19 pandemic was a dramatic shock to society that also happened to be exceptionally well-documented by many academic fields and disciplines, and from institutions worldwide. Our search strategy returned 14,628 unique results (excluding duplicates) for screening, of which 671 were included for analysis in our review. Figure 2 presents a PRISMA flow diagram for the records identified, screened, and included in this analysis. For comparison, our analysis included nearly eight times the number of records (671 vs 88 records) as a similar literature review conducted on aquatic foods just one year before the pandemic [22]. This provides a rich dataset to study the lives of people affected by the pandemic around the world. The following sections will explore the design and rigor of studies in this literature review, who was studied and using what methods, as well as their geographic and temporal distribution to explain the generalizability of the dataset.

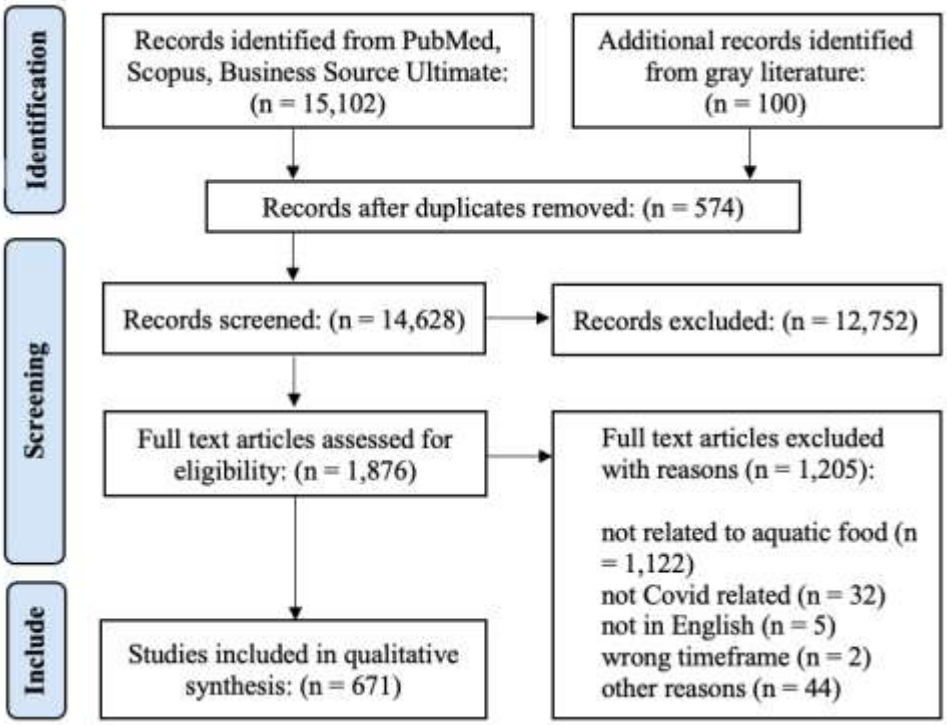


Figure 2. PRISMA flow diagram and study selection for review.

3.1.1 Design and rigor of included studies

Most studies (88%) were peer reviewed with the remainder (12%) being gray literature (i.e., white papers or government reports). Most studies (71%) involved primary or secondary data collection, and the remainder were either review articles (17%) or commentaries (12%). Many studies working with primary or secondary data used surveys as the means for data collection. Surveys (n = 293 studies) were primarily deployed as online questionnaires (59%) and phone or online interviews (24%) because of concerns over social distancing, although 18% of surveys were still collected in-person. Surveys ranged in size from 4 to 382,000 respondents with the median of 520 respondents. Surveys were typically a convenience sample (70%) often using social media to recruit participants. The benefit of a convenience sample is its ease and speed to deploy, but the drawback is an inability to generalize the findings beyond the respondents. Some studies used purposeful sampling methods (19%) where key informants were selected by the study team or advisors. Only 11% of studies used random sampling methods, which are the gold-standard for producing generalizable study findings.

3.1.2 Type of study respondents

Surveys involving primary data collection were conducted with a range of groups, focusing on the general population (44%), fisheries producers (15%), aquaculture producers (10%), consumers (7%), traders (7%), wholesale (6%), fish processors (5%), government or policymakers (4%), shopkeepers (2%), food service, hotel or restaurant (2%).

3.1.3 Geographical distribution of studies

3.1.3.1 Regional representation

By region, the largest share of studies were in Asia, Europe, and North America (Table 1). Relative to population size, Asia and Africa were under-represented in this literature review and Europe, North America, and Oceania were over-represented. Oceania is highly dependent upon marine resources which explains their higher share of studies. Relative to fisheries and aquaculture production, the literature review is underrepresented in Asia, while all other regions are over-represented. Non-western countries are likely under-represented in general because the search was restricted to English-language articles and there is a known Western bias in scholarly publishing [23].

Table 1. Regions in the literature review. Data source: [24,25]

Region	Percent of studies in literature review (n = 671)	Percent of world population in 2020	Percent of fisheries and aquaculture production volume in 2020
Asia	33.5	54.9	74.6
Europe	22.4	10.8	8.9
North America	13.8	6.5	3.9
Africa	9.7	17.2	4.2
Latin America and Caribbean	9.7	6.8	6.8
Oceania	6	0.6	0.9
Middle East	4.9	3.3	0.7

3.1.3.2 Country representation

The literature review captured data on 186 countries, which provides a broad global coverage (Figure 3). Some countries and parts of regions were better studied than others. For example, in Africa, Eastern and Western Africa were well studied with a focus on Kenya, Nigeria, Democratic Republic of the Congo, Ghana, and Tanzania. In Asia, the focus was on India, China, Bangladesh, Indonesia, Japan, Malaysia, Philippines, Thailand and Vietnam. In Oceania, the larger countries– Australia, Papua New Guinea, New Zealand, and Fiji– received more attention than smaller countries. Southern Europe (Italy and Spain) and Western Europe (including France, the United Kingdom, and Germany) had more studies than Eastern Europe. Notably, the Russian Federation was underrepresented given its large role in global capture fisheries. The United States was the most studied country in North America. In Latin America

and the Caribbean, Brazil, Peru, and Chile were the focus. In the Middle East, Egypt, Israel and Iran were most studied. Break-out maps and figures are provided at the region and country-level, and over time, in the supplement.

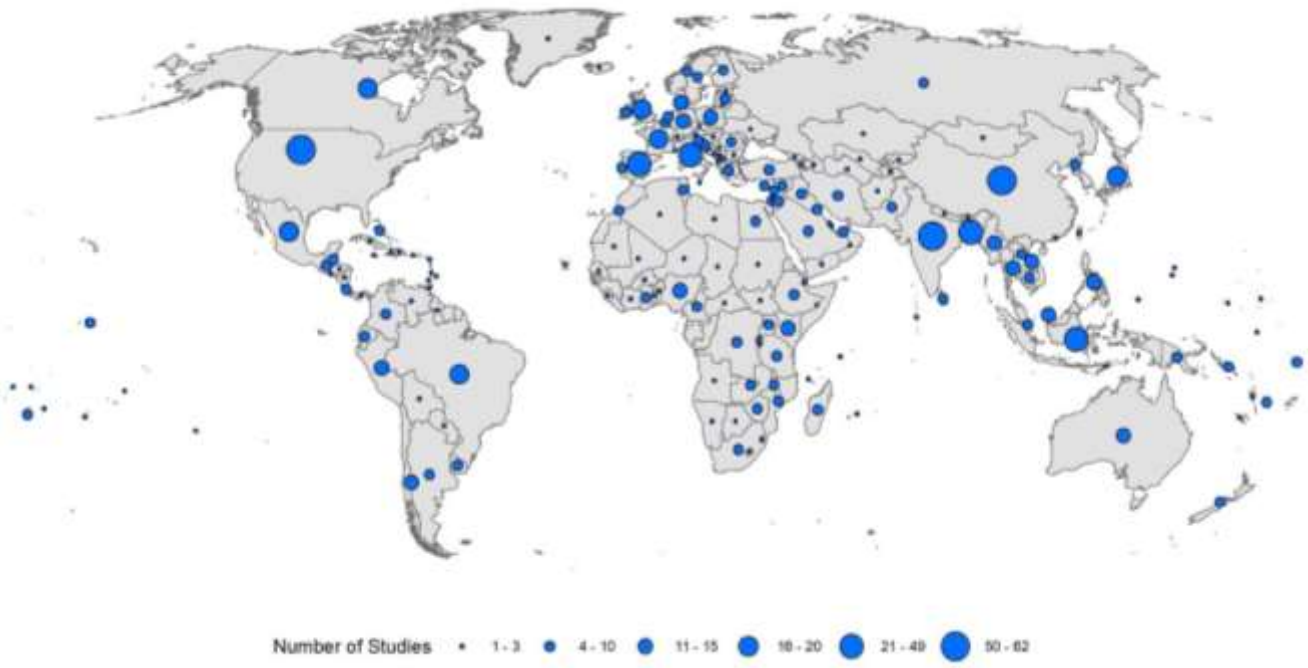


Figure 3. Map of countries in the literature review (n = 617 studies, n = 186 countries). The top-10 countries studied were India (n = 62), United States (n = 53), China (n = 50), Italy (n = 42), Spain (n = 40), Bangladesh (n = 39), Indonesia (n = 25), Brazil (n = 20), France (n = 20), and Mexico (n = 19).

3.1.3.3 Aquatic food producing countries

Countries with a larger share of fisheries and aquaculture production were better studied for COVID-19 impacts (Figure 4). We would expect to see this type of trend. It also reveals that countries with smaller fisheries and aquaculture sectors did not receive much attention from the research and NGO communities during the pandemic.

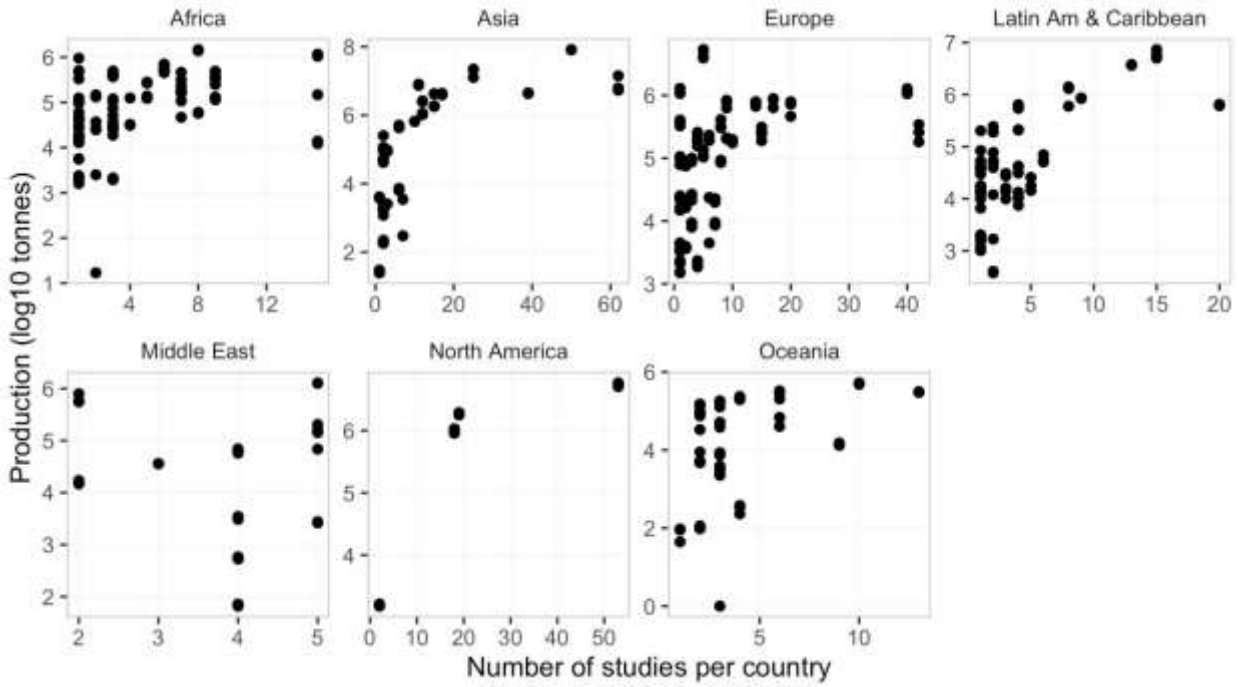


Figure 4. Number of studies per country compared to fisheries and aquaculture production volumes, average 2018- 2020 (FAO FishStatJ).

3.1.4 Timing of studies and data collection

The COVID-19 pandemic has come in waves, however, the literature we collected focuses mainly on the first year of the pandemic (Figure 5). Among the studies using primary and secondary data, the majority (90%) of their data collection ended by March 2021. Over a third (38%) of data collection among studies was performed in just four months (March through June 2020) corresponding to the first wave of lockdowns and movement control orders in much of the world.

By region, there were large spikes in data collection during the first lockdown periods in Asia and Europe. A second peak was also present in Europe in late 2020 corresponding to a second wave of the pandemic in that region. By mid-2021 some regions had no data being collected and published in time to be included in our review.

We wanted to know why the majority of the literature focused on the first year of the pandemic? Is this a true finding or biased by our search window which closed in February 2022. There is typically a 4 to 6 month lag between submission and acceptance at scholarly journals [26], therefore conservatively, manuscripts submitted to journals after September 2021 may not have been accepted by editors in time to be included in our electronic database searches. However, even by early 2021 the quantity of articles was tailing off. This indicates that our search window was appropriate for capturing the bulk of aquatic food systems articles related to COVID-19.

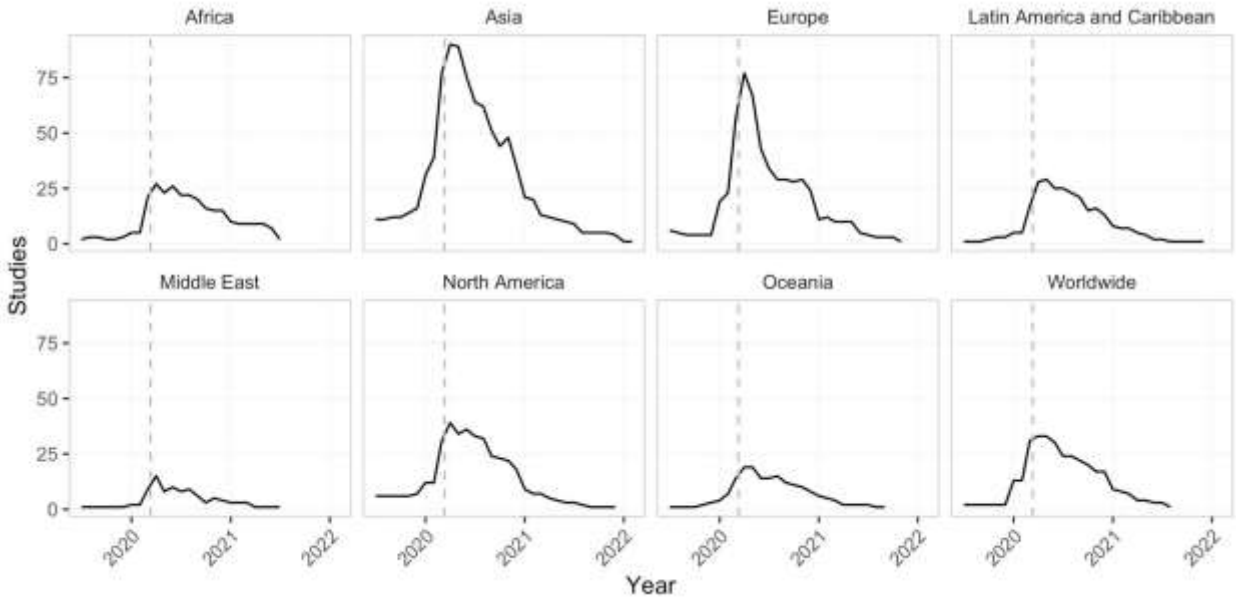


Figure 5. Study dates by region. The number of studies per month, based on the time periods that study data were collected and analyzed. Reviews, opinion and commentaries not included. Dashed line at March 11, 2020 the date COVID-19 was considered a global pandemic.

3.2 COVID-19 impacts and responses within the aquatic food system

The COVID-19 pandemic affected many parts of the aquatic food system from production through consumption. This section summarizes the key points identified in the literature as they relate to specific stages or sectors based on the food systems framework (Figure 1). Our findings focus mainly on the first year of the pandemic (2020 and early 2021), which represents the bulk of the literature published to date. Lockdown periods from March to June 2020 were particularly well studied, although not exclusively the focus of this report. We report on certain countries or sectors as examples of the types of findings generally found in the literature. Although we list impacts and responses as separate research questions, many of the articles in our review did not distinguish impacts versus responses, therefore we have grouped them together in the analysis.

3.2.1 Fisheries and aquaculture production

In 2020, global capture fisheries production declined relative to 2018, but production was within normal year-to-year variability over the past 25 years. Aquaculture grew but at a slower rate compared to pre-pandemic years and following a general trend towards lower growth rates [17]. There was a significant reduction in fishing effort and operational hours of production facilities worldwide in 2020 [27]. The restricted movement of people and goods during lockdown periods in the early phase of the pandemic highlighted how interconnected countries are for attaining inputs and producing outputs of aquatic food production [28–32]. In this review, the small-scale sector was better studied than the large-scale sector.

Small-scale producers and workers in the informal sector were particularly vulnerable to the economic shocks caused by COVID-19 because they had more unpredictable sources of income and many lacked social protection [18,33–35]. Fisheries and aquaculture producers exporting live or fresh products were more vulnerable, as well as producers in low-and middle-income countries compared to high-income countries [27]. Border closures disrupted the availability and affordability of inputs for both aquaculture (e.g., feed and seed inputs) and fisheries (e.g., bait). There was also a sharp drop in consumer demand for aquatic foods, especially for high-end products, due to the closure of the food service, hospitality, and tourism sectors. Subsequent subsections explore specific impacts and responses by the fisheries and aquaculture sectors.

3.2.1.1 Capture fisheries

Fishing activity was greatly diminished during the first lockdown periods at the beginning of the pandemic when travel restrictions and public health measures were introduced in many parts of the world [36]. Many fishers were not exempt from public health measures put in place to prevent viral transmission, which made it difficult to continue working. For example, there was a 50% reduction in fishing effort in the Adriatic Sea (in the Mediterranean) in the first lockdown period in early 2020 [37]. While the number of active fishers declined overall during 2020, there was significant heterogeneity with some regions seeing more fishing activity [36]. In small scale fishing villages in Indonesia in March and April 2020, the number of active fishers declined by 90%, but the daily catch volume was maintained due to higher average catches [38] (Box 2). By May 2020, global fishing activity rebounded [36] and fishers began to adapt to a new reality [39]. Spatial and temporal trends in fishing vessel movements are reported in Box 3. In a subsequent section (3.2.13 Environmental Impacts) we look at how the reduction in fishing effort affected fish stocks and the environment.

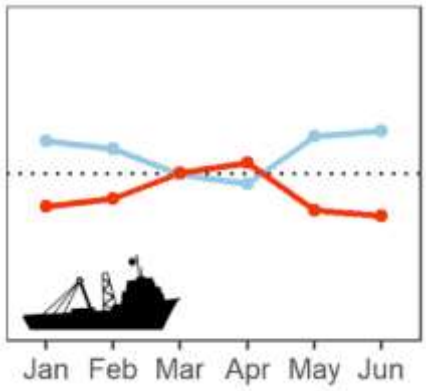
Box 2. Dual shocks increase local fishing pressure in Pacific Island countries
The COVID-19 pandemic and Tropical Cyclone Harold reshaped community life in Pacific Island countries. The cyclone destroyed 80-90% of homes in Vanuatu in April 2020, displacing over a quarter of the 300,000 population. Loss of home gardens and crops led to increased fishing pressure in 65% of surveyed communities in Vanuatu. Migration from urban centers to rural areas was noted in the Solomon Islands as well which puts pressure on resources. In parts of the Solomon Islands, there was a 25-50% increase in local fishing efforts in 2020. This is in stark contrast to global fisheries which declined by 4% in 2020.[40] Davila et al. (2021). COVID-19 and food systems in Pacific Island Countries, Papua New Guinea, and Timor-Leste: Opportunities for actions towards the sustainable development

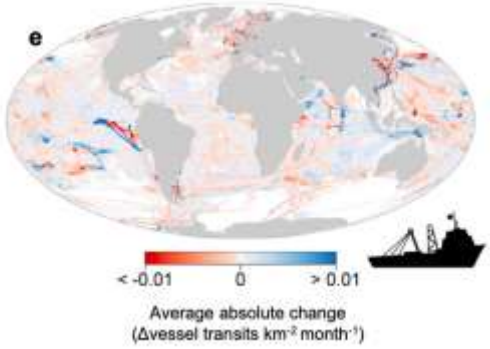
goals. *Agricultural Systems*, *191*, 103137.

Box 3. Global fishing sector rebounded in 2020 but lower overall production than pre-pandemic.

Marine traffic was severely impacted in the first few months of the COVID-19 pandemic, as shown by global satellite data of vessel movements. Activity in the fishing sector decreased from January through April 2020 and rebounded in May 2020 (left plot). Notably, the fishing sector bounced back faster than other ocean industries. For example, cargo vessels rebounded but at a slower rate than fisheries, and passenger vessels were the most impacted ocean industry. Fishing vessel traffic was highly variable spatially (right plot) with fishing vessel movement increasing in areas of blue and decreasing in areas of red. This spatial and temporal variability indicates a patchwork of impacts to the fisheries sector. [36]

March et al. (2021). Tracking the global reduction of marine traffic during the COVID-19 pandemic. *Nature communications*, *12*(1),1-12.





Fishers responded to the pandemic and secondary impacts caused by lockdowns in different ways. Technology and e-commerce played a prominent role in many countries. In Mexico, small scale fishers used technology to stay informed, engage in online sales to market their products directly to consumers, and to stay connected to others [41]. Small-scale fishing communities in South Africa and elsewhere also utilized technology to directly deliver aquatic food to households [42]. In Thailand and the Philippines, electronic records from fisheries registries were used to receive direct support including emergency relief funds [33]. Older fishers received support from the younger generation on how to use various electronic devices and digital platforms.

While digital platforms benefited many, some faced inequities as they were unable to access or afford the internet.

Many studies reported renewed focus on direct sales, for example in the United States and Canada [43]. The re-localization of aquatic food sales showed the importance of local and regional food systems during crises. Others found that community-supported fisheries, which often use direct marketing, emerged to fill gaps in market disruptions [42].

Fishers also responded by fishing for different species and closer to shore. In Mexico, fishers adapted by reducing fishing effort, targeting lower-value species, traveling shorter distances, and using PPE and hygiene to reduce disease risks [39]. Fishers in parts of Asia adapted by switching to fish species that were domestically popular and by working with fewer crew members and resources [33,43,44]. For example, fishers in Indonesia substituted soft-shell crab with other species such as shrimp and squid [45].

3.2.1.2 Aquaculture

In early 2020, lockdowns, travel bans, and border closures disrupted the availability of aquaculture inputs, workers, and veterinary services [46,47]. The closure of retail markets and processing plants left producers to maintain an oversupply of unsold stock [48] which increased operational costs and compromised aquatic animal health and welfare [49,50]. In March 2020, input prices increased by 20% compared to the previous month using an index price from Bangladesh, Egypt, India, Myanmar, and Nigeria [51]. Retail prices also peaked during the initial lockdowns periods in 2020 but dropped later due to lower demand [51]. During the initial shock, aquaculture producers struggled to maintain production cycles due to limited supplies and lower demand. As producers were slower to restock farms, there was an oversupply of seed and many hatcheries had to dispose of unsold seed stock [52].

Aquaculture producers responded to the pandemic by selling to domestic markets, sourcing production inputs domestically, diversifying the aquatic products sold to match market conditions, and shortening supply chains [34]. In the Mekong Region, the majority of aquaculture farmers adopted stocking practices to appeal to domestic markets while others drew on savings or assets, sought new markets , and borrowed money (33%) [28]. Box 4 presents a range of coping mechanisms for aquaculture producers in the Mekong Region. Producers also reduced the amount of food fed animals to slow down growth and save on costs.

Box 4. Aquaculture producers in the Mekong Region find many ways to cope.

Aquaculture producers in five countries in the Mekong Region (Cambodia, Laos, Myanmar, Thailand, Vietnam) used a variety of coping mechanisms to respond to the COVID-19 pandemic. Coping mechanisms include adjusting to stocking practices, reducing workforce inputs, relying on savings, exploring alternative markets, and borrowing money from family and friends. Large and small producers were affected in different ways, for example, large producers were impacted more by increasing value chain costs and decreasing market costs compared to small producers. Large producers across multiple countries were more likely to depend on borrowed money and diversify their market selections than small producers. Coping strategies by country are reported in the figure. [28]

Lebel et al. (2021). Impacts of the COVID-19 pandemic response on aquaculture farmers in five countries in the Mekong Region. *Aquaculture Economics & Management*, *25*(3), 298-319.

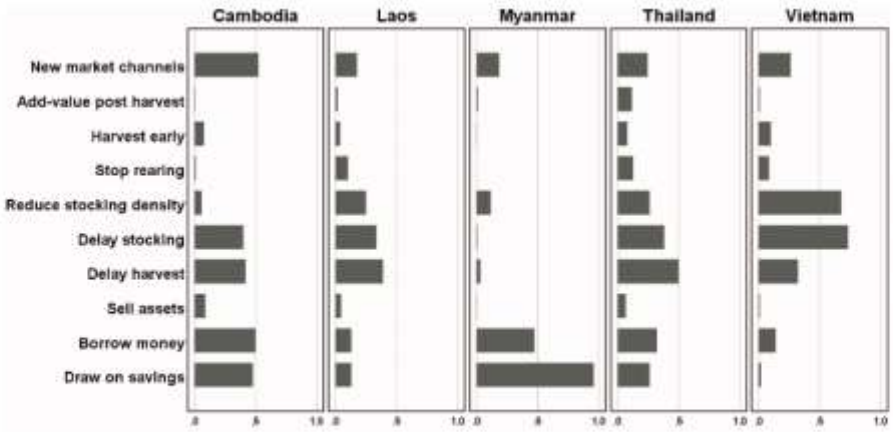


Figure 4. Farm financial management and rearing practices in response to the COVID-19 outbreak during the first 6 months of 2020 in five countries (proportion of farms surveyed).

The short term impacts from the lockdown period suppressed aquaculture growth; however, surveys in major aquaculture producing regions in Africa, Asia, and the Middle East in early 2021 indicate that many individuals stayed in business and saw signs of recovery one year after the pandemic [53–57] (Box 5). Additional data from 2021 and 2022, including national production and trade statistics will shed further light on the recovery process.

Box 5. Signs of recovery in 2021 for aquaculture and aquatic food supply chains

WorldFish conducted a series of studies in early 2020 and a one-year follow-up in early 2021 in five countries (Bangladesh, Egypt, India, Myanmar and Nigeria). Participants were fishers, farmers, input suppliers, retailers, and traders. They found that most respondents remained in

business one year after the pandemic. All but one respondent in Odisha, India was still in business in 2021. In Bangladesh and Myanmar, 86% and 92% of respondents were still in business, respectively. Additional positive signs were an increase in laborers, better access to inputs. Respondents in some but not all countries had better access to buyers in 2020 than 2021 across all sites. Sales were mixed in 2021 showing that a complete recovery may take more time. In Egypt, business activity stabilized in 2021 but lower than pre-pandemic levels. In Myanmar, anticipated sales in 2021 were expected to be low. Overall, findings illustrate positive signs of recovery and resilience among many respondents. [53–57]

Haas et al. (2021). COVID-19 impacts and adaptation in aquatic food supply chains in Bangladesh -- One year into the pandemic. WorldFish.

Haas et al. (2021). "COVID-19 Impacts and Adaptation in Aquatic Food Supply Chains in Myanmar -- One Year into the Pandemic." WorldFish.

Haas et al. (2021). "COVID-19 Impacts and Adaptation in Aquatic Food Supply Chains in Egypt – One Year into the Pandemic." WorldFish.

Haas et al. (2021). "COVID-19 Impacts and Adaptation in Aquatic Food Supply Chains in Nigeria -- One Year into the Pandemic." WorldFish.

Haas et al. (2021). "COVID-19 Impacts and Adaptation in Aquatic Food Supply Chains in Odisha, India -- One Year into the Pandemic." WorldFish.

3.2.2 Processing of aquatic foods

Aquatic food processing activities significantly decreased during the pandemic [27,33,58]. Processing operations for meat, fish, and aquatic food struggled relative to other food groups because they were less automated [59]. Some processing plants closed due to a decrease in demand [60], a shortage in raw materials [35,61–63], and insufficient storage space [61]. Mobility and social distancing restrictions imposed by governments [60], as well as COVID-19 outbreaks among workers [64–72], resulted in labor shortages [62,73–77]. The closure of processing facilities made it difficult to manage post-harvested aquatic foods that did not sell or were slower to sell [64]. Related, the decline in export of pelagic fish during COVID-19 led to the oversupply of frozen fish in the canning industry [78]. For processing facilities that remained open, many incurred additional costs to maintain hygiene and increase storage capacity [79].

Gender differences and dynamics are important to consider. In Africa, 60% to 90% of post-harvest processing workers are women [80]. Studies found women were impacted more than men due to their greater participation in post-harvest activities [2727,32,81]. Competition and bargaining increased, leaving some women entrepreneurs losing their fish processing businesses entirely [82].

Women also played a greater role in childcare during periods when schools were out, leaving them juggling work and family responsibilities. Quotes from a study of women fish processors in Sub-Saharan Africa summarize many of these challenges (Box 6).

Box 6. Challenges facing women fish processors in Sub-Saharan Africa
"There are very few fish from the farms in Africa. Most of our fish comes from the wild, and women do not own any boats. The men do. In this COVID-19 season, we have seen decline in catches, which has resulted in fish-for-sex trade." *"We [women] are spending so much time taking care of babies, being teachers, instead of us doing [the paid] work. We have added another task of being teachers because schools are closed. This is something we could not foresee or plan for, and it is really taking much of our time, in as far as time budgeting is concerned."* *– key informants, Uganda* *"There are some women who are very strong in business and they have the power, the bargaining power. They have the power to buy and assemble … Those who are really, really poor are the ones who have been affected more when it comes to access to the resources … Those that have financial stability, they can maneuver better than those who don't have the capacity."* *- key informant, Tanzania* [80] Atkins et al. (2021). COVID-19 impacts on women fish processors and traders in sub-Saharan Africa: Insights and recommendations for building forward better. Penang, Malaysia: CGIAR Research Program on Fish Agri-Food Systems. Program Report: FISH-2021-12.

Actors in the processing sector increased their capacity to adapt by processing multiple species and shifting efforts to align with market demands [83]. In some ports, freezing plants purchased aquatic food from fishers at very low prices with the intention to sell it once export markets opened again and prices increased [84]. Countries that lacked the infrastructure and capacity for cold storage were vulnerable [45,85,86]. Processors also utilized digital technology to procure from farmers and sell directly to consumers [87].

3.2.3 Fish workers

The COVID-19 pandemic had a negative impact on the livelihoods and welfare of fish workers. The pandemic's disruptions to trade affected local fishers and supply chain workers [28,42,88–96].

Fishers suffered from unstable employment conditions [78,97–100] and mental health issues including the loss of fellow workers, neighbors, and loved ones [101]. Fish workers were at high risk of exposure to COVID-19, but often lacked access to medical care and PPE [39]. Social distancing remained a major challenge at fish landing sites [102], and hygienic protocols were not feasible due to a shortage in PPE supplies [103]. Social distancing also decreased access to safety training for fish workers [104]. For example, the United States canceled 58 workshops, leaving 1000 fish workers with no safety training before the start of the fishing season [43]. The livelihoods of migrant workers in the informal market, especially women [80,105], were most negatively affected [35]. Harmful gender dynamics forced poorer women to engage in risky sex-for-fish transactions and endure other forms of gender-based violence [80,105].

Port closures severely affected the quality of life for those at sea [106]. Seafarers were excluded from many basic labor and human rights afforded to workers in other sectors [107]. Fishing vessel workers were stranded at sea, worked in tight living quarters with minimal protection, medical care, and little to no contact with their family [93,106]. They faced higher unemployment rates [108] and lower incomes with no economic stimulus packages to get through the pandemic [109]. Migrant workers were subject to racism and were often labeled as "contagious" [110]. As such, many seafarers dealt with physical, mental, and emotional strains, which impaired their ability to operate a ship or perform safety-related duties [111,112]. Seafarers attempted to defend their rights and stay connected to family, friends, and colleagues through digital platforms such as WeChat [113].

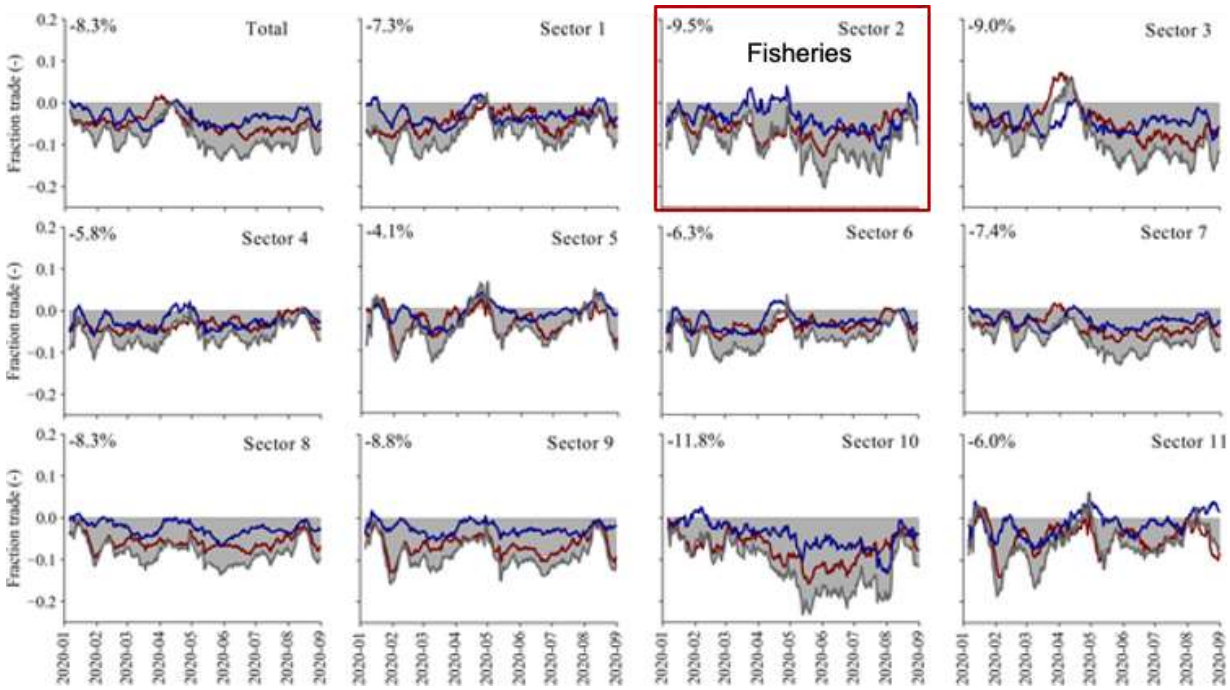
Government support was a major determinant for the health and wellbeing of fish workers. Producers that received government support were more resilient to the shocks caused by the pandemic. Some small-scale fishers received lower interest loans, livelihood support, and relief assistance from the government and private sector [114]. Local governments also showed support by purchasing catch from small-scale fishers to distribute to other families in need [33]. In Italy, the Cura Italia Decree supported workers in the agri-food sector through bank loans, food distribution, and implementation of repairs to damages [115]. On the other hand, food production was more adversely impacted in countries where the government did not provide adequate financial and social support [101,116–118]. Some government practices failed to protect the life of the fishing workers, failed to treat them with dignity [119], and limited accessibility to external food and government food-aid programs [120]. Many fishers and their families received no specific social welfare provisions [121,122] because they were not considered essential workers or government assistance was not available to them. COVID-19 also redirected government funding away from projects unrelated to the pandemic, hurting vulnerable communities dependent on external financial support [123,124].

3.2.4 Distribution and trade of aquatic foods

In 2020, international trade of all goods declined by 9% due to closure of ports and restrictions on transport [60,125]. The overall drop in marine cargo and fleet traffic started in March 2020 and

stayed low through July 2020 [94,126–128]. Globally, 44% of seaports reported a decrease in vessel traffic with the largest declines in Oceana, Europe, Sub-Saharan Africa, and North America [129]. Notably, trade of aquatic products declined more steeply than other sectors, with a 9.5% relative drop in trade during the first lockdown periods of 2020, but fisheries trade appeared to recover by July and August 2020 [130] (Box 7).

Box 7. Global trade of aquatic products rebounds in August 2020.



The change in daily global total trade as a fraction of the average daily trade (over 2019). Blue = imports, red = exports, gray = import + exports. Sector 1: Agriculture; Sector 2: Fisheries; Sector 3: Mining and quarrying; Sector 4: Food and beverages; Sector 5: Textiles and wearing apparel; Sector 6: Wood and paper; Sector 7: Petroleum, chemical and non-metallic mineral products; Sector 8: Metal products; Sector 9: Electrical and machinery; Sector 10: Transport equipment; Sector 11: Other manufacturing.

Verschuur et al. (2021) Global economic impacts of COVID-19 lockdown measures stand out in high-frequency shipping data. PLOS ONE 16(4): e0248818.

Domestic and international aquatic food distribution was disrupted, redirected, or halted by sudden shifts in demand, supply, limits on the movement of goods and people [18,27,45,89,131–135]. Distributors faced border closures [27,136,137], movement restrictions [125,138–142], increased transportation costs [38,48,143,144], and problems in staffing vessels and ships [145]. In many countries there was reduced demand from buyers and traders [45,48,67,72,85,138,144,146–150]. Supply and trade

disruptions made it difficult for producers to introduce products to domestic and international markets [151]. In addition to the distribution of finished products, there were also severe disruptions related to the distribution of production inputs and raw materials for processing [44,67,90,152–154]. The export of high value live and fresh products was hardest hit by international travel restrictions which limited flights by commercial air carriers, while frozen and canned products shipped by cargo vessels were less affected as these products have longer shelf-life and were in demand at retail [18].

In response, distributors focused on different markets [33] and shortened supply chains [155,156]. Cargo ships engaged in "blank sailing" by reducing shipping capacity and skipped pickups at some ports or regions, allowing carriers to sustain freight rates at profitable levels [157]. Seaport adaptation depended upon the type of port and its role in the supply chain [158].

3.2.5 Retail, food service, and hospitality

Consumer demand shifted dramatically over the course of the pandemic; some businesses were able to withstand shocks posed by lockdowns and supply chain disruptions while others were less . At the start of the pandemic, aquatic food sales declined due to decreased consumer demand, disrupted supply [50], and market insecurity [41,60,122]. In-person food service was hardest hit by lockdowns [18]. The hospitality and tourism markets were also hurt by travel restrictions and decreased consumer mobility [76,83,101,121,135,159–163]. In particular, sales of live and fresh products to restaurants, hotels, and tourists were affected [156,164,165]. The over-dependence on tourism made some countries or areas more vulnerable to the pandemic [166], for example, Fiji and the Galapagos struggled because of a reliance on ecotourism as the main economic driver [160,167]. Retail outlets did well with increases in sales of all types of aquatic foods, and in particular frozen and canned products with longer shelf-life [52,75,168]. Strategies to attract more or different customers included local and direct marketing and e-commerce (i.e., mobile platforms, online sales, home delivery services) (Box 8) [33,70,87,115,164,169–172] .

Box 8. The rise of local and direct marketing.
Local and direct marketing increased in the United States and Canada as fishers looked for alternate ways to market their catch. The authors predicted a re-localization of aquatic foods and more "boat to fork"marketing. Through interviews, the researchers found that relationships among fishers and their supply chains and with consumers was key to being resilient. One participant noted, *"the direct relationship between the fishing family and the end consumer builds trust, builds flexibility on the part of the customer."* Access to diverse fisheries and fishing seasons, and control over prices, outlets to redistribute oversupply, access to financial capital, and media attention were also critical for supporting resilience.[170]

Stoll et al. (2021). Alternative seafood networks during COVID-19: Implications for resilience and sustainability. *Frontiers in Sustainable Food Systems*, 97.

3.2.6 Food environment

Food availability, accessibility, and diversity decreased for many households during the pandemic [148,169,173–175]. Consumers confronted food shortages for several food groups, including aquatic food, [64,176] due to closure of the food service sector, limited market hours, and socioeconomic factors [33,66,103,168,177–179]. The availability of food was also affected by border closures and transportation disruptions [27]. Low-income households in urban and low- and middle-income countries were most vulnerable to food insecurity [124,173,180–182].

The lockdown influenced food selection and acquisition [183,184]. Countries with a strong technology infrastructure introduced online grocery shopping platforms [185]. Online shopping and home deliveries allowed consumers to purchase food while in home confinement [186,187]. Consumers also greatly depended on digitized tools to obtain information about COVID-19 [188] and learn about food safety [189]. Food purchasing behaviors depended on the level of perceived stress and trust in various sources of information [190]. Cultural norms played an important role in determining how people adjusted their diet [191]. Closures of worship sites limited opportunities for gatherings and socialization around food [32,42]. For example, Chinese Lunar New Year celebrations, traditionally associated with the consumption of high-value aquatic food, were canceled [52]. Over time, retail sales rebounded as the industry adapted and consumer demand increased [60]. Consumers were able to access food through mobile vendors [122] and digital platforms. For example, online services such as Amazon Fresh found the need to sell fewer items on sale to attract and expand their customer base because the demand was so high [192].

3.2.7 Aquatic food prices

Food prices were volatile during the pandemic. During the early stages of the pandemic, consumer demand for fresh aquatic foods waned [51] in many countries, leading to reduced food purchases [27,60,172,193] and oversupply[140] as retailers and local fishers were forced to sell their products at much lower prices [96,114]. This may have been due to economic uncertainty, movement restrictions, and in some countries fear about fish potentially being contaminated by Covid-19. A sharp drop in tourism also contributed to this drop in some settings.

Later on, many households perceived a surge in food prices across major food groups, especially for aquatic foods [116]. Prices of aquatic foods increased due to input price disruptions [194], supply chain disruptions, and import bans [140,195]. Many consumers had lowered purchasing power compounding difficulties to afford fish [180,196] Decreases in the availability of imported fish and in

some countries growing demand for locally-sourced fish also contributed to rising prices[27]. Food prices increased globally, but the increase was greatest in low- and middle-income countries compared to high-income countries [180]. Consumer food prices for nutritious foods were also higher in countries hardest hit by the pandemic [13].

3.2.8 Household food security, diets and nutrition

3.2.8.1 Food security

Covid-19 and responses such as lockdowns induced an economic contraction (-3.5% in 2020) and unemployment worsened worldwide, which initially influenced the type of food people could afford and access and led to rising food insecurity [40,60,197]. There was a moderate to severe increase in world hunger from 2019 to 2020. Latin America and the Caribbean (9%) experienced the sharpest rise in food insecurity, followed by Africa (5.4%) and Asia (3.1%) [17]. North America and Europe, countries typically with the lowest prevalence of food insecurity, also experienced food shortages and scarcity during COVID-19 [17]. Existing stressors such as conflict, environmental degradation, refugees, and internally displaced populations compounded the effects of the pandemic [198–200].

Lower-income households attempted to maintain their livelihoods by accessing their savings and selling assets [201]. Selling of productive assets such as livestock was common [202]. Jobless and urban or migrant laborers returned to rural areas seeking alternative livelihoods [203]. Households responded by reducing spending and increasing household food production through home gardens [86]. Mental distress stemmed from social isolation [204], uncertainty about the virus, restrictions, and concerns about acquiring food [92,105,190,191,205–213]

3.2.8.2 Impacts of the lockdowns on diets

Our approach to searching the literature resulted in more studies focusing on dietary intake than on food security. Early on, the direct and indirect effects of COVID-19 and government disease control measures were widely expected to adversely affect the diets of populations, including impacts on transportation, production and trade of commodities, lockdowns, reduced market access, and lowered incomes. Studies in many countries explored the impact of lockdowns on diets, largely using cross-sectional studies and web-based convenience sampling approaches [15]. As such, the majority of studies did not collect longitudinal data of household diets across time. Most studies were conducted in high-income countries, and few were from low- and middle-income countries. Interestingly, while the majority of surveys reported greater consumption of dairy products, cereals, legumes, fruits, vegetables, processed foods, and alcoholic beverages, most studies described a decrease in the consumption of aquatic foods (70%) and meat (56%) [15]. While red meat intake varied globally with lower intake in Europe compared to Asia and South America, the decrease in aquatic food consumption was consistent across geographical regions.

3.2.8.3 Substitution of foods among low-income populations

In low-income countries and populations, some studies showed that households experienced more barriers to access higher quality food items such as fish, vegetables/fruits, and animal source foods.[144,148,214–216]. Early on, food insecure households consumed less fresh food and were unlikely to have sufficient food stored in their homes [214]. Due to financial hardships caused by the pandemic, they were more likely to rely on cheaper and less nutritious foods (i.e., processed foods and starchy staples), and reduce consumption of comparatively expensive food products such as fish and meat [217–219]. Such patterns echoed observations from prior economic crises [220]. Women and children were especially vulnerable to nutrient deficiencies [17]. Elderly people were also vulnerable to lower dietary diversity [221,222]; older adults had difficulty accessing a variety of foods given their frailty and lack of familiarity with technology. Households attempted to maintain the status quo of their dietary behavior by reducing other essential non-food expenditures, borrowing money, and selling household items to purchase food [223]. Examples of coping strategies used among households and small-scale fishers in Lake Victoria, Kenya are presented in Box 9.

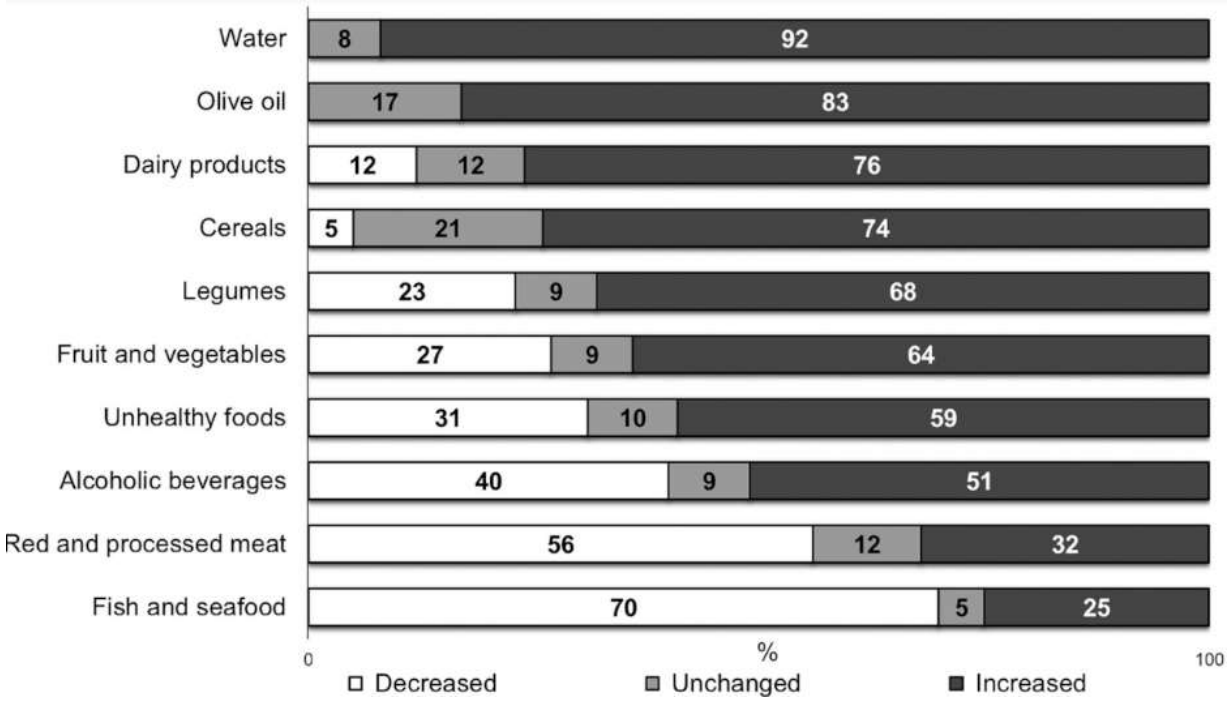
Box 9. Coping strategies for small-scale fishers around Lake Victoria, Kenya.
Households reported less fish consumption, higher prices for fish, and coped by switching to lower priced dried fish as a result of the COVID-19 pandemic. Interviews were conducted with 88 households in three small-scale fishing communities around Lake Victoria in March and June 2020. A third of households included fishers. Fewer fishers were active in June because of perceived health risks. Harvests were more often sold than eaten because of higher fish prices in June compared to March. While these high prices benefited fishers and traders, consumers were adversely affected. The authors note "*...small-scale fishers are often both sellers and buyers*" and their decisions are influenced by local purchasing power and global markets, which should be considered by policymakers responding to COVID-19. [196] Fiorella et al. (2021). Small-scale fishing households facing COVID-19: The case of Lake Victoria, Kenya. Fisheries Research, 237, 105856.

3.2.8.4 Shifts to aquatic food intake due to lockdowns

Most studies (70%) reported a decrease in aquatic food intake due to COVID-19 (Box 10). The negative shift in aquatic food consumption was greater compared to other food groups [15]. Many studies reported a decrease in meat and aquatic food intake due to the lack of availability, affordability, and in some cases a fear of viral transmission [15,148,224]. For example, in Bangladesh

fish intake was greatly reduced because of its higher price and replaced with cheaper staple grains and starchy foods [183,218]. In contrast, meat and aquatic food intake increased in Australia, which was thought to be due to government support to maintain consumer confidence in spending [225]. Shelf stable and frozen aquatic foods were preferred over fresh products because they could be stored for an extended period of time [183]. For example, sales of frozen fish in Italy increased by approximately 43% in March 2020 compared to March 2019 [226]. Stockpiling behavior increased because households shopped less frequently during COVID-19 [227] and feared future food shortages [228].

Box 10. Aquatic food intake decreased in 70% of studies, more than any other food category. [15]



Mignogna et al. (2022). Impact of Nationwide Lockdowns Resulting from the First Wave of the COVID-19 Pandemic on Food Intake, Eating Behaviors, and Diet Quality: A Systematic Review. *Advances in Nutrition*, *13*(2), 388-423.

3.2.9 Food safety

In June and July, 2020, several COVID-19 outbreaks in China were thought to have originated from imported aquatic food [229,230]. Reports of SARS-CoV-2 on imported aquatic foods [231–233]

continued to emerge in China through August and September, 2020. This led to questions about whether aquatic animals can become infected and transmit the virus to humans. Reviews of the topic found it was uncommon for respiratory viruses, and SARS-CoV-2 specifically, to be transmitted through foods, although one study noted that caution was appropriate in the early stages of the pandemic (Box 11) [63,234–238]. When examining routes of transmission, one study found that SARS-CoV-2 was less likely to infect fish than humans [239] and while coronaviruses in general were rare in aquatic animals [240], the family of coronaviruses that includes SARS only infects mammals [238].

Regardless of whether foodborne transmission of SARS-CoV-2 posed an elevated risk, more attention was paid to food safety both along the supply chain and in the home [189,237,241–245]. Households made a concerted effort to engage in food safety and hygienic practices [183,189,246–249], while food processors and retailers used basic measures like sanitization, health monitoring, and hand-washing to reduce transmission of the virus from worker to foods and keep workers safe [233,250]. Food control became more stringent for importing countries due to food safety concerns [67,251,252] and some countries shifted preferences for domestic sources [251]. The heightened focus on food safety and the safety of imported aquatic food is likely to continue in China and elsewhere.

Box 11. Expert insights on SARS-CoV-2 as a food safety risk.
"SARS-CoV-2 is not a foodborne virus and should not be managed as such. This virus can contaminate surfaces, including food handled by an infected person or coming in contact with contaminated material. Although SARS-CoV-2 has low stability on fomites at 21-23 °C (room temperature), it has been demonstrated that the virus can survive the time and temperatures associated with transportation and storage conditions associated with international food trade, thereby presenting a "non-traditional" transmission mechanism requiring enhanced screening protocols for the international seafood trade." [235] Godoy et al. (2021). SARS-CoV-2 transmission via aquatic food animal species or their products: A review. *Aquaculture, 536*, 736460.

3.2.10 Food loss and waste

COVID-19 had mixed effects on food loss and waste, with impacts varying based on the time period, stage of the supply chain, and population. During the initial lockdown period some consumers engaged in panic buying and stockpiled foods which caused food shortages [253] and overbuying that led to increased waste of perishable goods (Box 12) [254] . In other areas, consumers bought smaller quantities of food and paid more attention to them through proper handling and storage [197,207]. The majority of studies found that overall household food waste decreased during the pandemic [197,207,255–262]. Meat and aquatic food were the least wasted food

products in many countries, likely due to the closure of hospitality services, their higher cost, and less impulse buying of expensive foods [197,207,259,263,264].

COVID-19 brought about increased awareness for food waste so people had a stronger inclination to reduce waste [197,265–268]. Food waste was studied among different age groups and life stages. In some studies, young consumers were especially motivated to implement better food management practices and modify their behavior to reduce food waste [261,263]. In other studies, older populations, including those that worked less than full-time and had no children, were less likely to waste food [256,269]. Lower levels of food waste correlated with higher levels of cooking confidence, perceived time, and meal planning behaviors [256]. To reduce food waste, strategies were proposed to better save, store, and eat leftovers and dry fish as means of preservation [263,270].

Box 12. A shift in consumer food purchasing habits in Poland, implications for food waste.
In Poland, consumers' shopping behavior changed dramatically during the COVID-19 pandemic, as identified in a survey of 500 residents. Grocery store visits dropped, and more food was purchased on each trip. Over-purchasing was a significant source of food waste, particularly for perishable goods. Consumers planned their purchases more during the pandemic than before. Food was treated more carefully and consumers reported that less was wasted. Future studies are needed to understand if these short-term beliefs and behaviors are retained in the future [254]. Nicewicz, R., & Bilska, B. (2021). Analysis of Changes in Shopping Habits and Causes of Food Waste among Consumers Before and During the COVID-19 Pandemic in Poland. *Environmental Protection and Natural Resources*, *32*(3), 8-19.

There was increased food loss in some LMICs due to lower demand and perishability, limited transport, storage capacity, and retail food price volatility [271]. The drop in demand also generated aquatic food loss at the production, storage, transport, and trade [85,138,272]. Significant losses were seen, especially in areas where access to processing and storage infrastructure was poor [82].

3.2.11 Environmental impacts

The pandemic had a complex mixture of positive and negative effects on aquatic environments (Box 13). The largest benefits to aquatic environments came in the early phases of the pandemic stemming from a sharp decrease in human activity and mobility. This caused short-term reductions in fossil fuel use, industrial pollution, and humans' presence in the environment [273–275]. As a result, there was a reduction in air and water pollution [275–277], and improvements in surface and coastal water quality [278–281]. For example, the Chilika Lagoon in India, Asia's largest brackish water lagoon, had a 64% decrease in total petroleum hydrocarbon levels from reduced

use of fishing and tourism boats, which allowed regulators to set a new (lower) baseline for water quality [282]. There were reductions in underwater noise from vessel engines, which enhanced aquatic animals' ability to communicate and improved their overall health [283]Reduced human pressure increased observations of aquatic animals near coasts [284,285].

The impacts to fisheries were mixed and varied across regions and over time. In the first few weeks and months of the pandemic fishing pressure was greatly reduced; one global estimate found ocean fishing was reduced by 12% [274]. Travel restrictions also reduced recreational and charter fishing in many parts of the world [284,286–288]. As local and global economies became stressed, subsistence fishing (i.e. fishing for home/own consumption) increased in many places to support livelihoods and food security [42,83]. Lockdowns and movement control orders reduced fisheries monitoring efforts, which hampered fisheries stock assessments [289], prevention of illegal, unreported and unregulated (IUU) fishing [290], and ongoing conservation efforts [273]. The extent to which the pandemic will create long-term positive or negative outcomes for fisheries, aquatic habitats, and biodiversity may take years to assess [274].

Box 13. Did the COVID-19 pandemic help or hurt aquatic environments and fisheries?
The COVID-19 pandemic provided a rare natural experiment to see how ecosystems and wildlife responded to a world with less human activity. Using an analysis of global human mobility and 877 observations from over 51 countries, Bates and colleagues found a mixture of positive and negative effects on wildlife around the world. They note that this finding is *"inconsistent with the prevailing view of humans as primarily harming biodiversity."* Responses were at times unexpected, such as the absence of humans hurting animals. This type of finding the authors describe "*highlights the dual role that humans play in threatening and protecting species and ecosystems*" [274]. Cooke and colleagues explored impacts on freshwater fish. They found potential benefits to fish populations from what they describe as a *"...a global 'pause' in economic development and declines in human disturbance."* [273] They caution that while there may be short-term gains, the relatively short pandemic lockdown period may not have sustained long-term changes on freshwater fish. There were also negative effects on fisheries from decreased monitoring, enforcement to control illegal fishing and pausing efforts to study, conserve, and restore aquatic environments. Bates et al. (2021). Global COVID-19 lockdown highlights humans as both threats and custodians of the environment. *Biological Conservation*, *263*, 109175. Cooke et al. (2021). A global perspective on the influence of the COVID-19 pandemic on freshwater fish biodiversity. *Biological Conservation*, *253*, 108932.

Environmental pollution from medical waste received considerable attention in the literature. One study estimated 8 million tonnes of medical waste was created in response to the pandemic and 25,000 tonnes have entered the ocean [291]. Surgical face masks compromised a large share of litter collected along water bodies in Kenya [292], Ethiopia [293], Bangladesh [294], and Morocco [295]. Medical waste and plastic pollution can cause risk for human and aquatic animal health [296,297]. There were calls in the literature for more environmental awareness, informational campaigns, as well as government restrictions, monitoring, and technology to decrease medical waste pollution [298–300].

3.3 Recommendations

The COVID-19 pandemic required immediate action by groups, institutions and governments to protect the most vulnerable and keep core functioning of the food system intact. This section summarizes the recommendations provided in the literature about how to cope and respond to the pandemic, learn and adapt, and become more resilient to future shocks and stressors. Three quarters of the reviewed studies (500 of 671 studies) contained recommendations. The recommendations are grouped into categories based on the food system framework (Figure 1). These categories include topics such as research and technology, governance, social protections, risk mitigation, education and behavior change, and information access. Many recommendations highlight opportunities for action or influence over the food system, external drivers and outcomes. Some solutions are context or region-specific but most are broadly applicable to the fisheries and aquaculture sectors and their value chains.

3.3.1 Research and technology development

This section describes the recommendations related to research, development, and technology in the fisheries and aquaculture sectors. There were 210 studies in the literature review that included recommendations in this topic area. Three sub-topics emerged as important: digital transformation of aquatic food value chains, recognizing the digital divide and not leaving individuals and groups behind, and conducting interdisciplinary research.

3.3.1.1 Use digital transformation to bolster aquatic food value chains

Digital platforms can be leveraged in many ways to support the aquatic food value chain [32,301,302]. Technology can streamline production by shortening the supply chain [45], maintain the freshness of food, and improve storage capacity [303]. Fishers can utilize electronic commerce for direct commercialization and online sales [103], allowing them to diversify their customer base [213]. Digital communication platforms such as personal electronics can be used for teleworking, remote meetings, and online training [60,304]. They can also give seafarers a way to communicate with their family and friends [113]. Geospatial technology facilitates aquatic food trade and provides better oversight of fishing activities [33,99].

3.3.1.2 Provide non-digital options for those with limited access to technology

The use of technology is not always feasible, especially for individuals from lower socioeconomic backgrounds. Some households cannot afford internet service or digital devices. Others may not know how to use technology. The older generation may feel left behind if they are unable to keep-up with younger tech-enabled business models [305]. Digital transformation should recognize this divide and have alternative non-digital resources ready and available for those with limited access to technology (Box 14) [306] .

Box 14. The digital divide in small-scale fisheries in Mexico.
Technology was used by small-scale fishers to sell what they caught and stay connected during the pandemic, but some did not adapt to life in the digital world, as found by Lopez-Ercilla and colleagues in a study of Mexico's small-scale fishers. Many communities closed off from the outside world at the start of the COVID-19 pandemic. "*We stopped everything. We closed the processing plant and halted production*" said a 51 year old small-scale fisher, one of almost 400 small-scale fishers interviewed. Market closures and price drops were widely noted from March to June 2020 and when markets reopened in November, fishing activity and prices were still lower than normal. Fishers adapted by catching low value species, selling to direct markets, and using technology for e-commerce. Study authors found unequal access, ability, and comfort using technology. This "digital divide" among small-scale fishers created inequity that was greatest for women and the elderly. Study authors concluded that recovery efforts must include digital and non-digital strategies to make sure groups are not left behind [41]. Lopez-Ercilla et al. (2021). The voice of Mexican small-scale fishers in times of COVID-19: Impacts, responses, and digital divide. *Marine Policy*, *131*, 104606

3.3.1.3 Build interdisciplinary and inclusive research capacity

In answering research questions, multidisciplinary collaboration and "One Health" principles are recommended to ensure human, animal, and environmental health questions are addressed [63,82]. For example, multidisciplinary collaboration can be beneficial to study COVID-19's long-term impacts on the environment, particularly in areas where fish stocks are declining [307]. This may include research on the trophic transfer of microplastics [308], ecotoxicity caused by pharmaceuticals, sustainable waste disposal methods, and transmission of COVID-19 in wildlife species [39,49,309,310]. Collaboration across diverse stakeholder groups [311] also allows for better information dissemination and knowledge sharing [312,233]. In conducting research, vulnerable populations, such as women [80], children [216,223], the elderly [221], and indigenous groups [313] deserve more representation in public health research [82]. Research can facilitate inclusion, equity, and mutual learning [140] if it involves marginalized groups such as small-scale farmers, and is conducted in a sensitive and ethical fashion.

3.3.2 Infrastructure, policy, and governance

Recommendations related to infrastructure, policy, and governance in the fisheries and aquaculture sectors were discussed in 291 studies. Articles provided a range of recommendations grouped into three sub-topics: strengthening local food systems, economic aid for small scale fishers, and governance reform.

3.3.2.1 Strengthen local food systems

Local food systems support self-sufficiency. Investing in the local infrastructure [170], hiring from within the community [314], and encouraging the public to purchase domestic food are ways to strengthen the local economy [315]. National platforms increase self-production and bolster food security within domestic markets [172], decreasing reliance on foreign markets [92,187,316]. Shorter food supply chains and marketing channels can also improve the quality and safety standards on aquatic food products, fortify relationships between fishery associations, and promote local aquatic food consumption and sales [44,290]. Governments can bolster local sales by facilitating the distribution of direct sales [43] and expanding the purchase of aquatic food for institutional use [132] and food aid.

3.3.2.2 Increase economic aid and social assistance for small-scale fisheries

Financial assistance and social support can alleviate the socio-economic impact of COVID-19 restrictions and increase the likelihood for aquatic food businesses to survive [35,47,317]. Governments can organize donations and stimulus packages to support workers in need, prioritizing the specific needs of those most vulnerable to exploitation [35]. Governments can also create alternative income generating opportunities for fishers to avoid unemployment [318]. Aquatic food workers can be designated as essential workers, which can provide fairer and safer working conditions [185,198,307,319,320]. While many essential workers still lack protections [321], they have an easier time obtaining expedited visa services for foreign labor, compensation if prevented from fishing, and access to microfinance programs [98].

3.3.2.3 Reform fisheries and aquaculture governance

Better communication, risk-based management, and environmental traceability can strengthen fisheries and aquaculture governance. First, the public should have the means to communicate with their state and local authorities [322]. Mutual knowledge exchange between government and fisheries professionals facilitates effective and timely decision making along the aquatic food value chains [140,51,100,152]. A local liaising representative may be appointed to facilitate this exchange. Leaders can also coordinate communication among different stakeholders [323] to manage logistics, rapidly mobilize support [42], and keep food supply chains open [324]. Second, the government can support corporate actions involving better risk-based management strategies [32]. Regulatory requirements can be streamlined and simplified for fishermen [170]. For example, relaxing restrictions can facilitate access to farm inputs and allow producers to keep their businesses open [152]. Third, ecosystem governance [60] such as eco-labelling can promote fisheries

and aquaculture practices that are sustainable for the environment [314,325]. The government can also implement waste recycling solutions that minimize environmental pollution and conserve natural resources [326,327].

3.3.3 Social protection and human capital

This section describes the recommendations related to social protections and human capital. There were 168 studies in the literature review that included recommendations in this topic area. Key sub-topics include ways to prioritize vulnerable groups, support both physical and mental health, and strengthen affordable finance options.

3.3.3.1 Prioritize vulnerable groups in social protection programs

Access to social protection measures can promote family health and wellbeing, especially for marginalized groups [32]. Social protection programs are often the first line of defense for vulnerable groups such as women, children, the elderly, and ethnic minorities. Female fish workers play a crucial role in small-scale fishing communities and are in need of support [41,105,328]. Children are vulnerable and often depend on social protection programs and school lunches to keep hunger at bay [216]. The elderly are disadvantaged due to mobility limitations, physical and mental impairments, and higher risk of mortality from COVID-19. They may also have limited knowledge and access to technological devices, needing support ordering food online [329]. Ethnic minorities often come from lower socioeconomic backgrounds and are at greater risk for unhealthy behaviors [330]. Migrant and non-status workers deserve better access to social protection including fair pay, adequate working environments, and paid sick leave [319].

3.3.3.2 Establish support systems for physical and mental health

Healthcare services are needed for formal and informal fishers to cope with unprecedented disruptions [139,217,331,332]. Social protection programs such as vouchers and cash transfers can promote behavior change towards healthier and sustainable diets [,217,333–335] by incentivizing families to plan meals, shop with a list, and consume local and seasonal products. Furthermore, mental health resources can help fish workers deal with work-related stressors [43] and pandemic-related anxiety [336]; crisis consultations with a mental healthcare provider promotes a healthy mindset [337] at work, reduces accidents, and minimizes burnout.

3.3.3.3 Alleviate financial burdens and expand affordable finance options

Access to emergency low-cost loans, economic relief packages, and food purchasing capacity can lessen the financial burden for fish workers [42,65,83,144]. Financial assistance can also be in the form of insurance opportunities [338], debt relief programs [339], and postponing the collection of annual fishing license fees [60]. Index-based insurance systems are especially helpful when payouts are based on a predetermined index (i.e., weather events) for loss of assets and investments [323]. Governments can also provide financial support through aid, subsidies, tax relief, and distribution of food [63,84]. The incomes for households with more severe restrictions should be

supplemented to ensure they have purchasing power to obtain an adequate supply of nutritious foods [201]. Collectively, these efforts serve as a buffer for small-scale farmers and fishers to cope with the pandemic. Fish workers that have stronger institutional and financial support are also more willing to take risks and test innovative ideas [340].

3.3.4 Risk mitigation and adaptation

Risk mitigation and adaptation recommendations were discussed in 141 studies in the literature review. The most important sub-topics were supporting diversification in aquatic value chains, ensuring worker safety, and mitigating environmental impacts of the pandemic.

3.3.4.1 Support diversification in the aquatic value chain

Diversified farms, food supply chains, and trade networks provide many options for food security. Having a variety of distribution channels makes artisanal fishers and small holders more resilient to stresses and shocks [18]. Import and export market diversification guards against trade disruptions and market closures [213]. People have a wider range of geographical locations that they can access supply inputs and aquatic food [316]. Alternative aquatic food networks and distribution channels can improve producer-consumer relationships and create alternative avenues for producers to market their products [140,153], creating a safety net for producers, traders, and retailers [341].

3.3.4.2 Ensure the safety of fish workers

Security protocols such as wearing PPE, handwashing, and frequent cleaning of contaminated surfaces are effective strategies to minimize COVID-19 transmission when handling and cooking aquatic foods [102,310,39,233,234]. An adequate supply of COVID-19 vaccines [59,342] and testing kits also minimizes transmission risks for high-risk workers along aquatic food supply chains [134,229]. Strict hygiene and sanitation practices also reduces the risk for zoonoses transmission at fish markets [28]. Specifically, wildlife trade bans, better animal husbandry practices, regular inspections, and quarantine measures can provide better traceability and surveillance to prevent viral transmission between people and animals [230,231,343,310].

3.3.4.3 Mitigate COVID-19 related impacts on aquatic environments

Efforts to protect aquatic ecosystems are necessary to maintain the viability of fisheries and natural resources. Location-specific environmental surveillance, control of discharge pollutants, and management of anthropogenic activities can mitigate biodiversity loss and ensure the long-term restoration of air and water quality [344, 345,346,347,154,348]. Ecosystem approaches may include the use of biodegradable PPEs [326,327,349–351], stringent debris reduction policies, and the installation of more waste disposal bins [352].

3.3.5 Capacity, education, and behavior change

Recommendations related to the topics of capacity building, education and behavior change were mentioned in 150 studies in the literature review. The sub-topics include strengthening the capacity of women, promoting healthy lifestyles and diets during lockdown periods, and supporting holistic and multidisciplinary programs.

3.3.5.1 Strengthen the capacity of women in the fishing sector

Gender-transformative approaches should be utilized to provide women with equitable access to resources, benefits, and opportunities [353]. Fisherwomen, including many in the small-scale sector, deserve support [63,80] to participate in leadership and decision making [80,328]. Women appraise the impacts and hardships of COVID-19 realistically, making them transformational leaders [328]. Teaching technical and entrepreneurial skills are other ways to empower women. An enabling environment for small-scale female farmers [307,354] improves food security, household welfare, [90] and reduces gender-based violence [272].

3.3.5.2 Promote healthy lifestyle behaviors and diets during the lockdown period

Governments should promote healthy lifestyle behaviors, which can boost immunity, prevent long-term adverse health effects, and improve overall well-being. Health education is particularly important during lockdown periods due to increased stress, unhealthy eating, and sedentary behavior. For example, households should be educated and encouraged to consume a variety of nutritious foods in moderate portions [217,355–357,358], stay physically active [330,359,360], and develop healthy sleeping habits [361].

3.3.5.3 Develop holistic, multidisciplinary programs

Multidisciplinary perspectives are important for biodiversity conservation, ecosystem management [312], and animal disease control [237,310,342]. For example, veterinarians play a role in keeping aquatic and terrestrial animals healthy and developing biosecurity measures for food animal farms and markets [310]. A more holistic perspective can also help with biodiversity and ecosystem management [312]. Collaboration between different disciplines ensures that a wider range of ideas are brought to the table and human, animal, and environmental health are fairly represented [63,82,18,362].

3.3.6 Information access and connectivity

This section describes the recommendations related to information access and connectivity within the fisheries and aquaculture sectors. Articles provided a range of recommendations grouped into three main sub-topics: strengthening regional and international food systems, the availability of public information, and the use of technology to share information and build connections.

3.3.6.1 Strengthen regional and international food systems

During the COVID-19 pandemic, partnerships across regional and international groups allowed for better information dissemination and knowledge sharing on food-related trade measures [42,95,264,311,312]. The involvement of diverse stakeholders enriches policy formulation and management, allowing communities to best overcome shocks caused by the pandemic [135]. Collaboration and cooperation among fishers strengthens social capital, generates innovation, and promotes fishers to broaden their network and professional associations [44].

3.3.6.2 Make public information accessible, transparent, and reliable

Appropriate and reliable information, especially medical information, is a human right that fishing communities deserve [39]. Information sharing among the scientific community builds institutional capacity [172] to overcome pandemic-related fisheries monitoring challenges [289], mitigates viral spread [363], and minimizes COVID-19 impacts on aquatic wildlife [364]. Education on how not to get infected and working with fishers to develop shared protocols are imperative to protect fishers, especially from isolated communities [39]. Transparency in harvest and distribution is critical in addressing illegal, unreported, and unregulated fishing, corruption, and poor fisheries management [365].

3.3.6.3 Use technology to share information and build connections

Technology allows for efficient information dissemination and knowledge sharing, which strengthens connections between stakeholders along the aquatic value chain [39]. This is particularly important in isolated communities with limited access to information. Access to reliable and fast internet and telecommunication systems can improve traceability of marine products and enable seafarers to better access information [337]. Web-based management and digital commerce can strengthen the supply chain [71]. Digital tools can be adapted to meet local needs to encourage community engagement [366].

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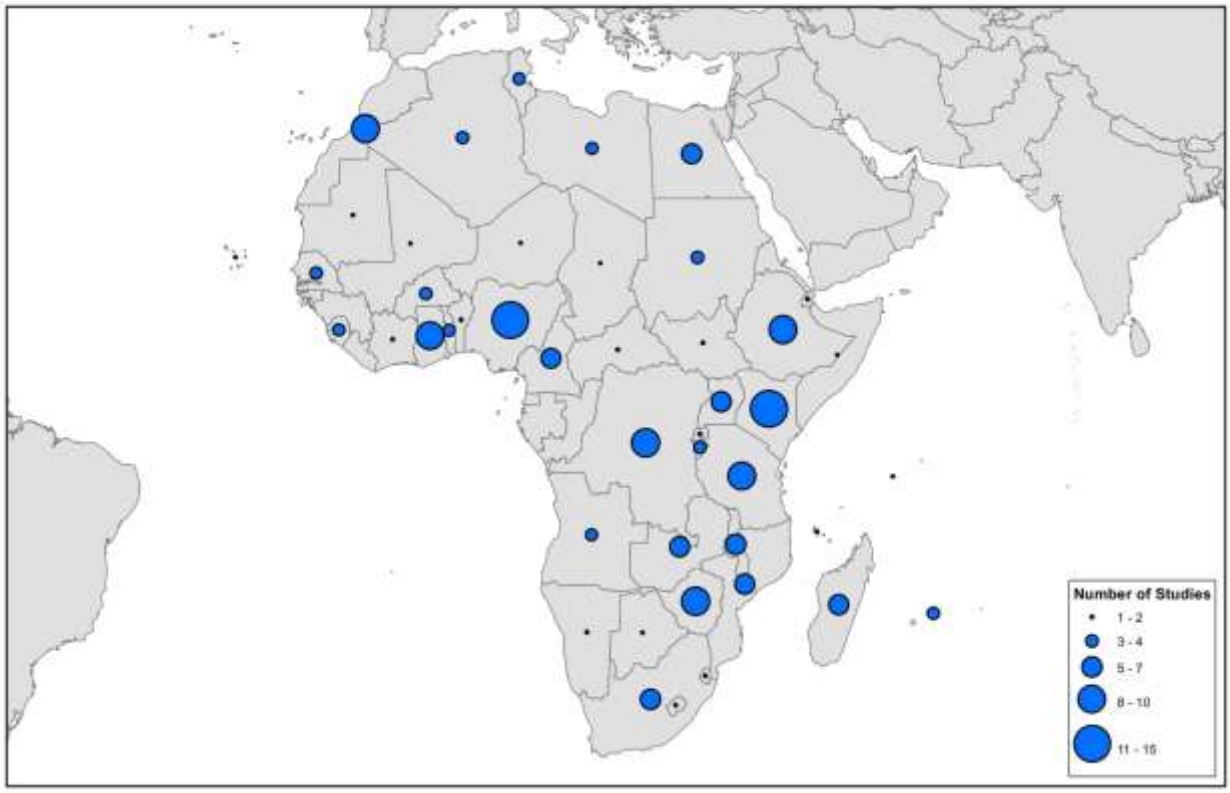
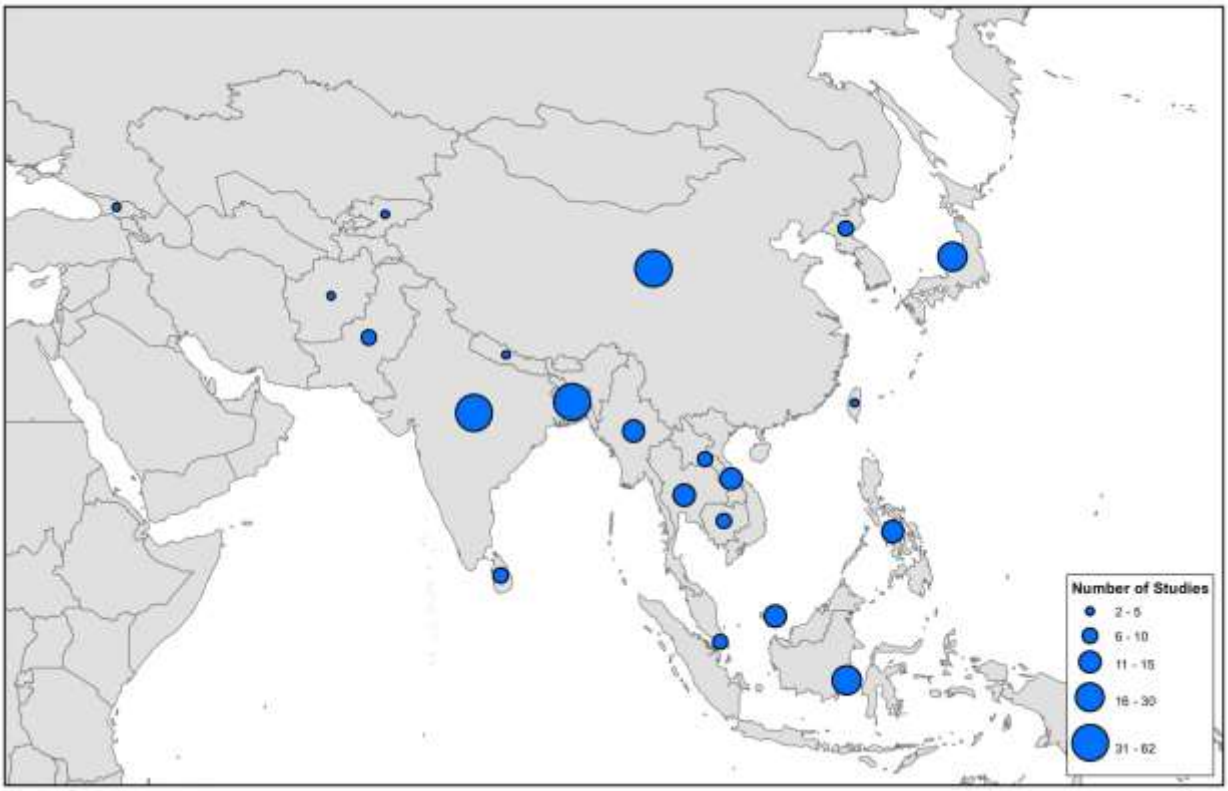
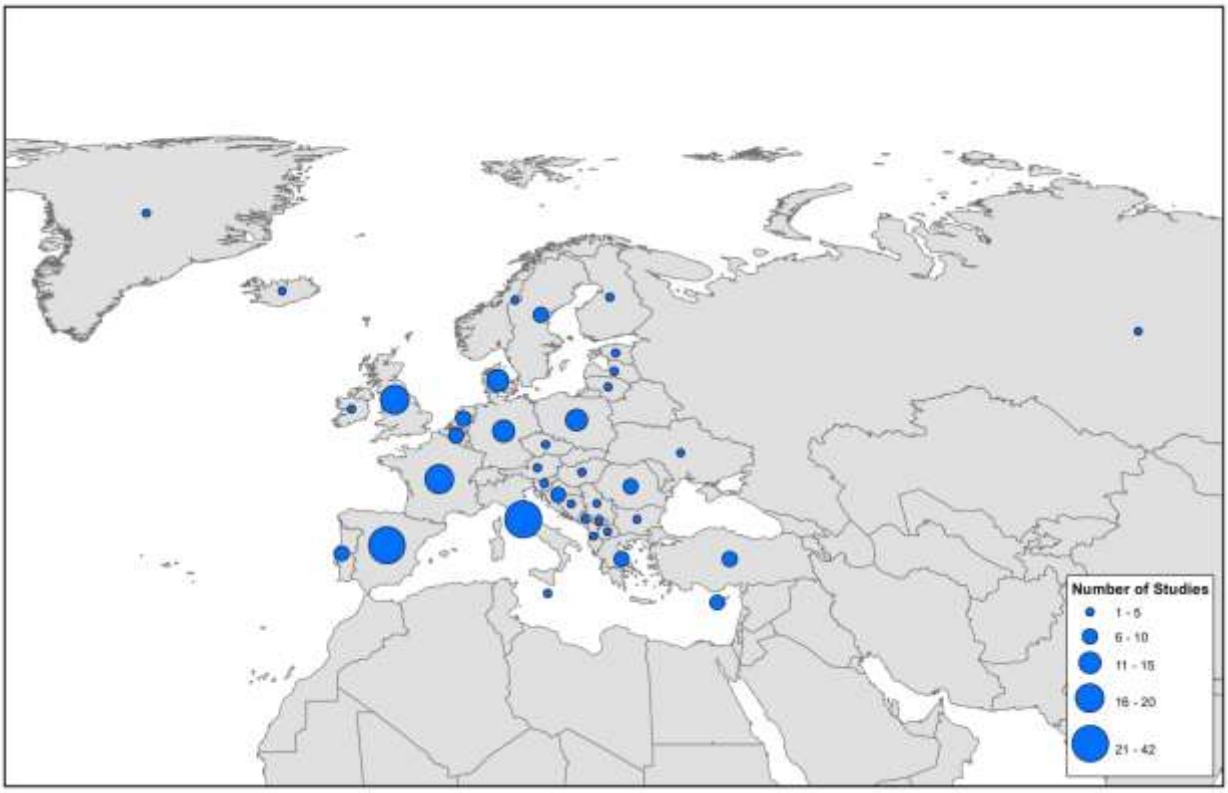
5 Supplemental Material

The records identified in this literature review are available in a public data repository. References grouped by region and can be downloaded via the following link: https://github.com/dave-love/fao_literature

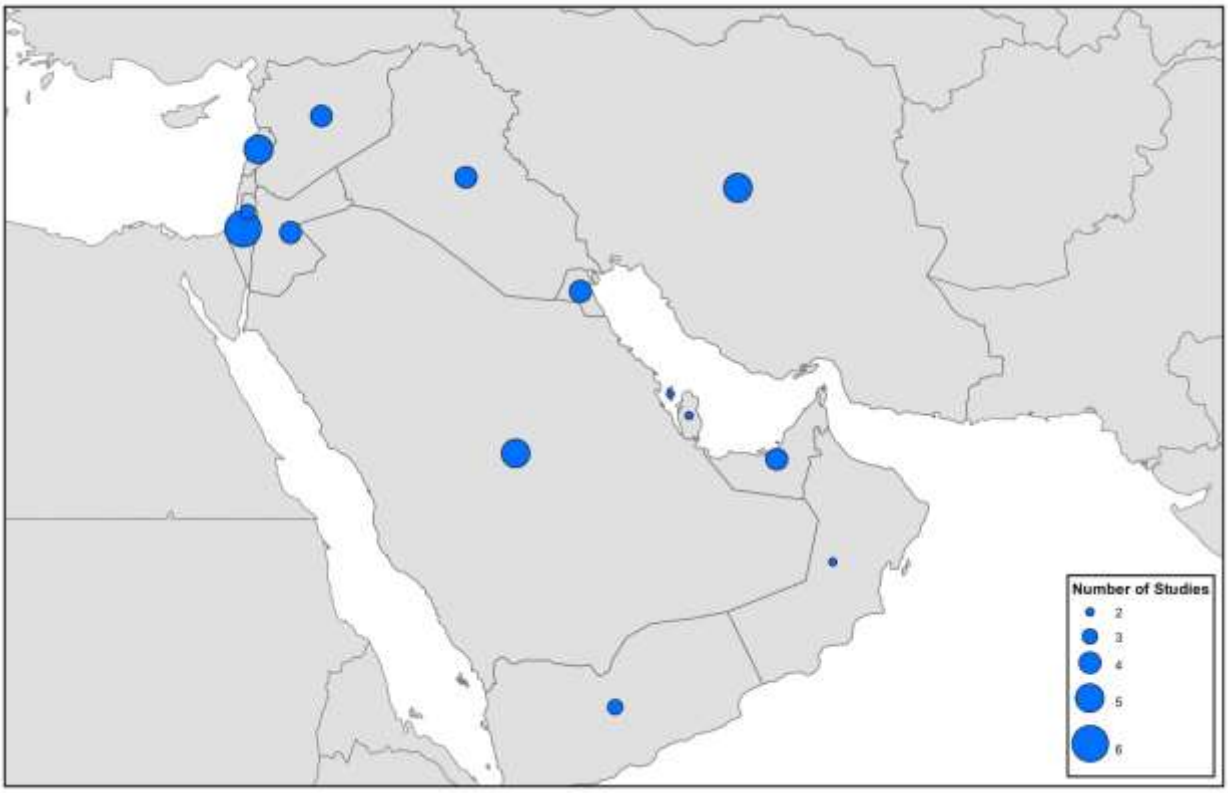
Regional maps of countries included in the literature review:



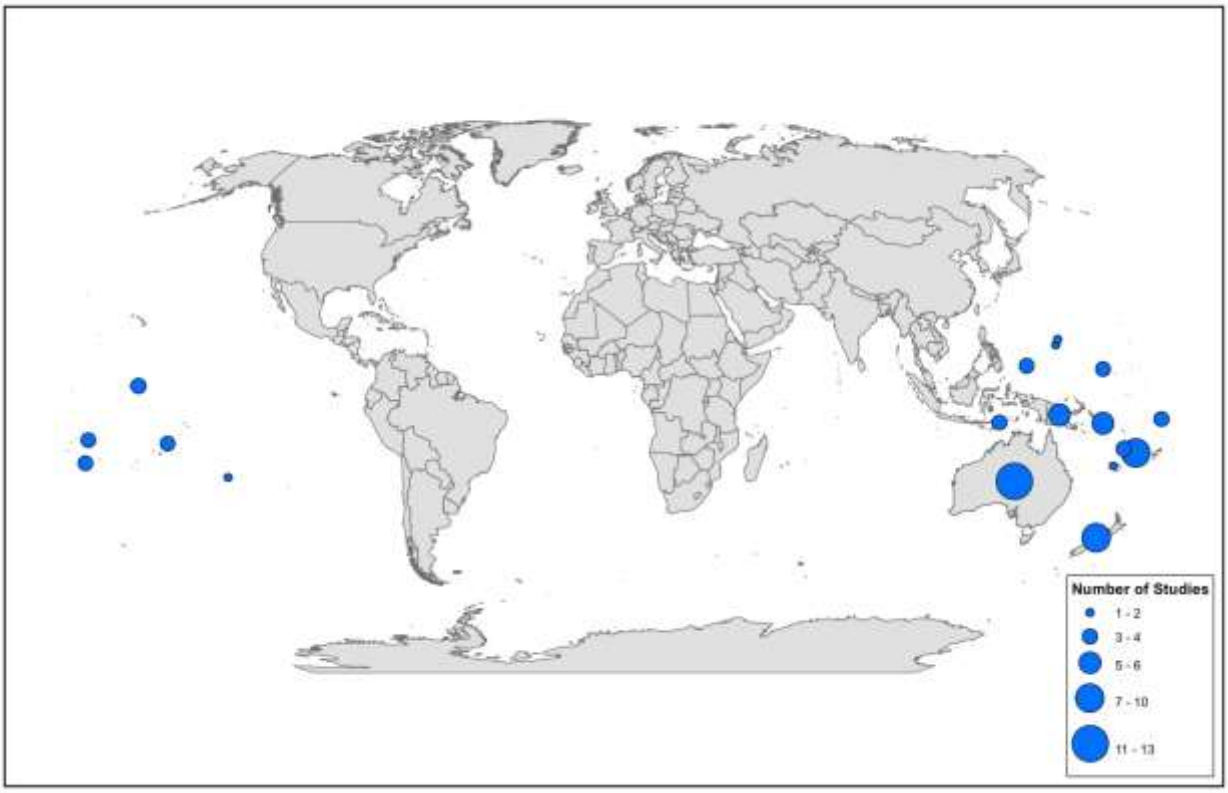

Number of Studies
2 - 5
6 - 10
11 - 15
16 - 30
31 - 62


Number of Studies
1 - 5
6 - 10
11 - 15
16 - 20
21 - 42


Number of Studies
1 - 3
4 - 6
7 - 10
11 - 15
16 - 20

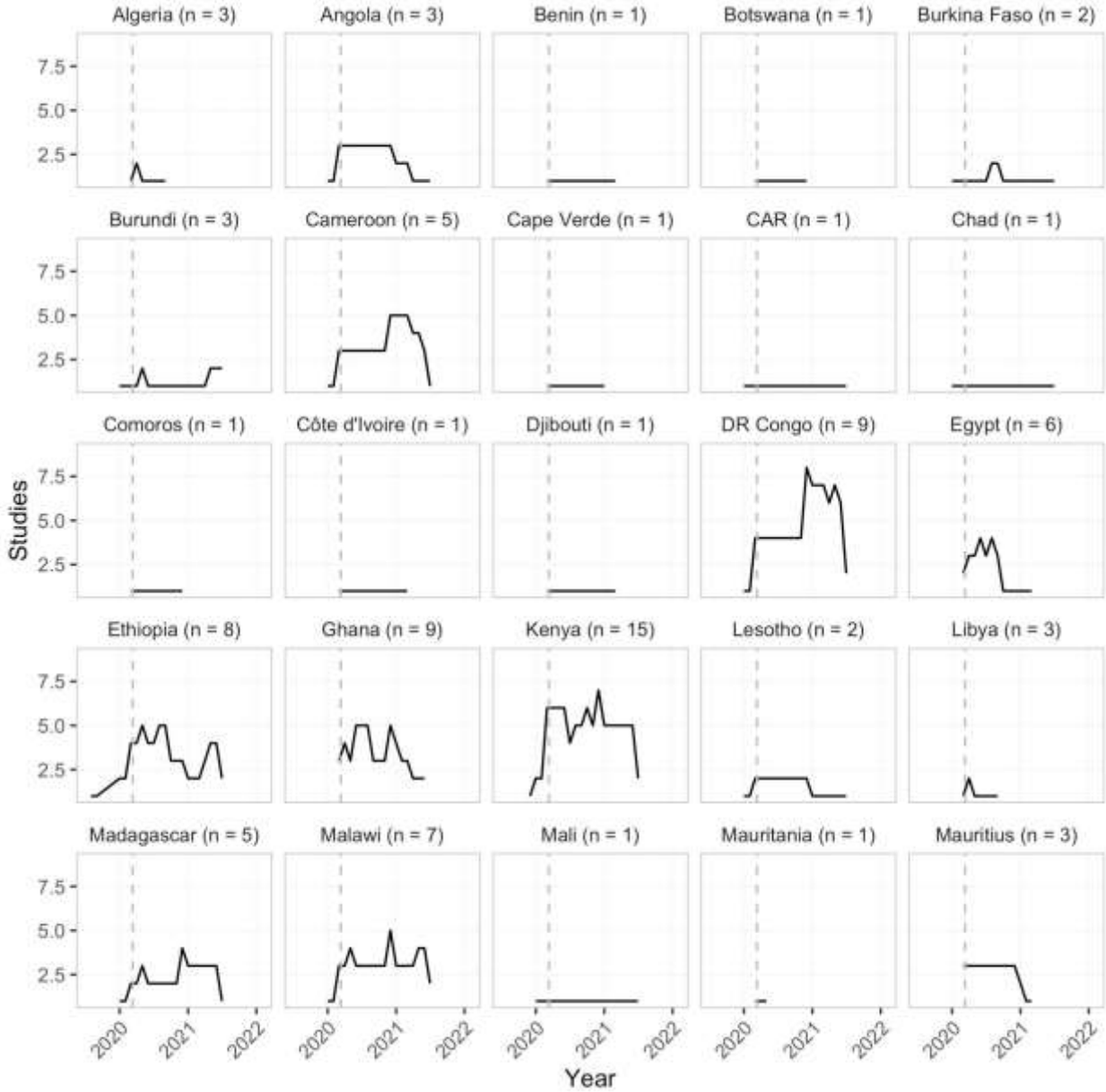

Number of Studies
2
3
4
5
6

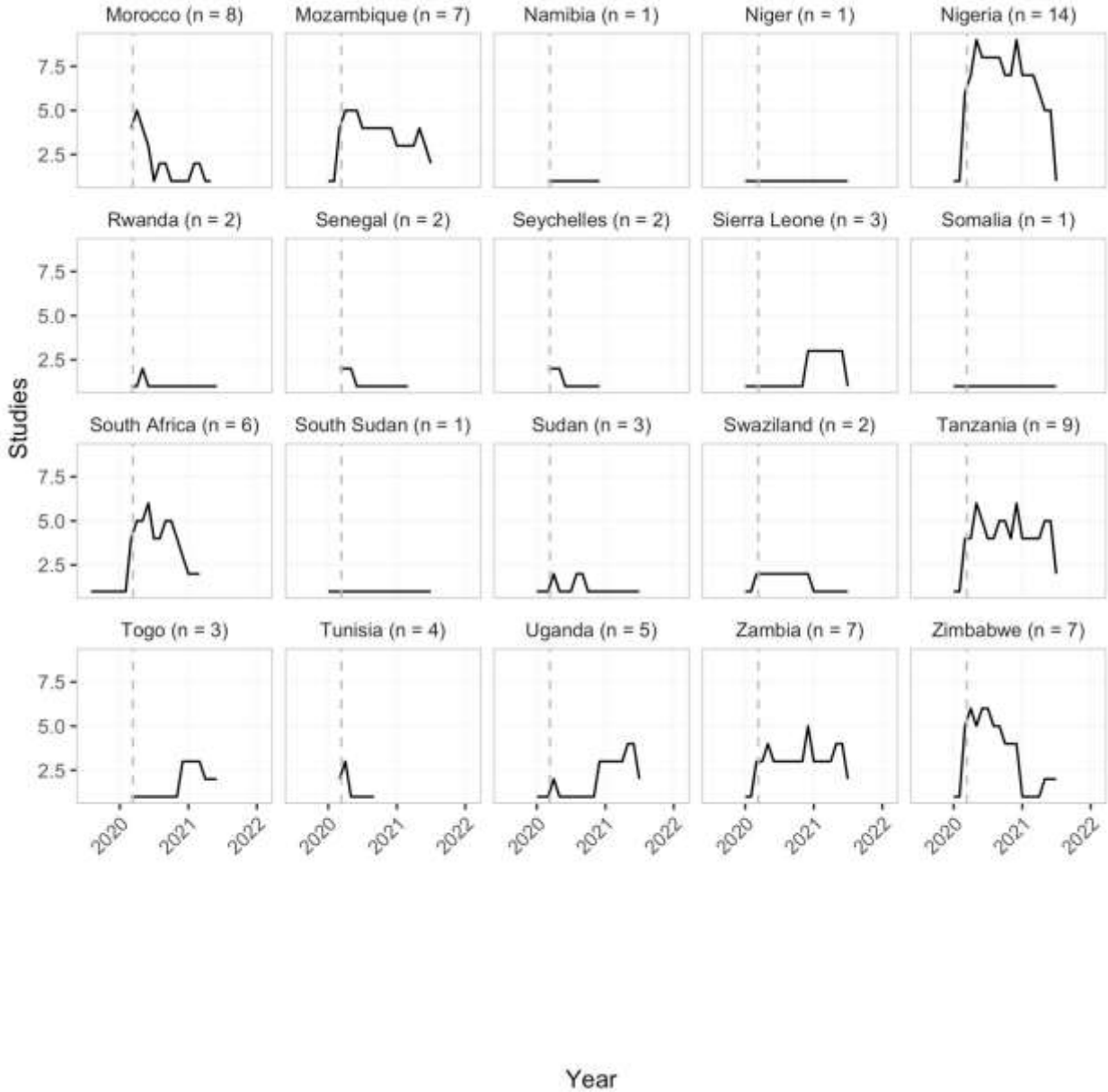

Number of Studies
2
18
19
53


Number of Studies
1 - 2
3 - 4
5 - 6
7 - 10
11 - 13

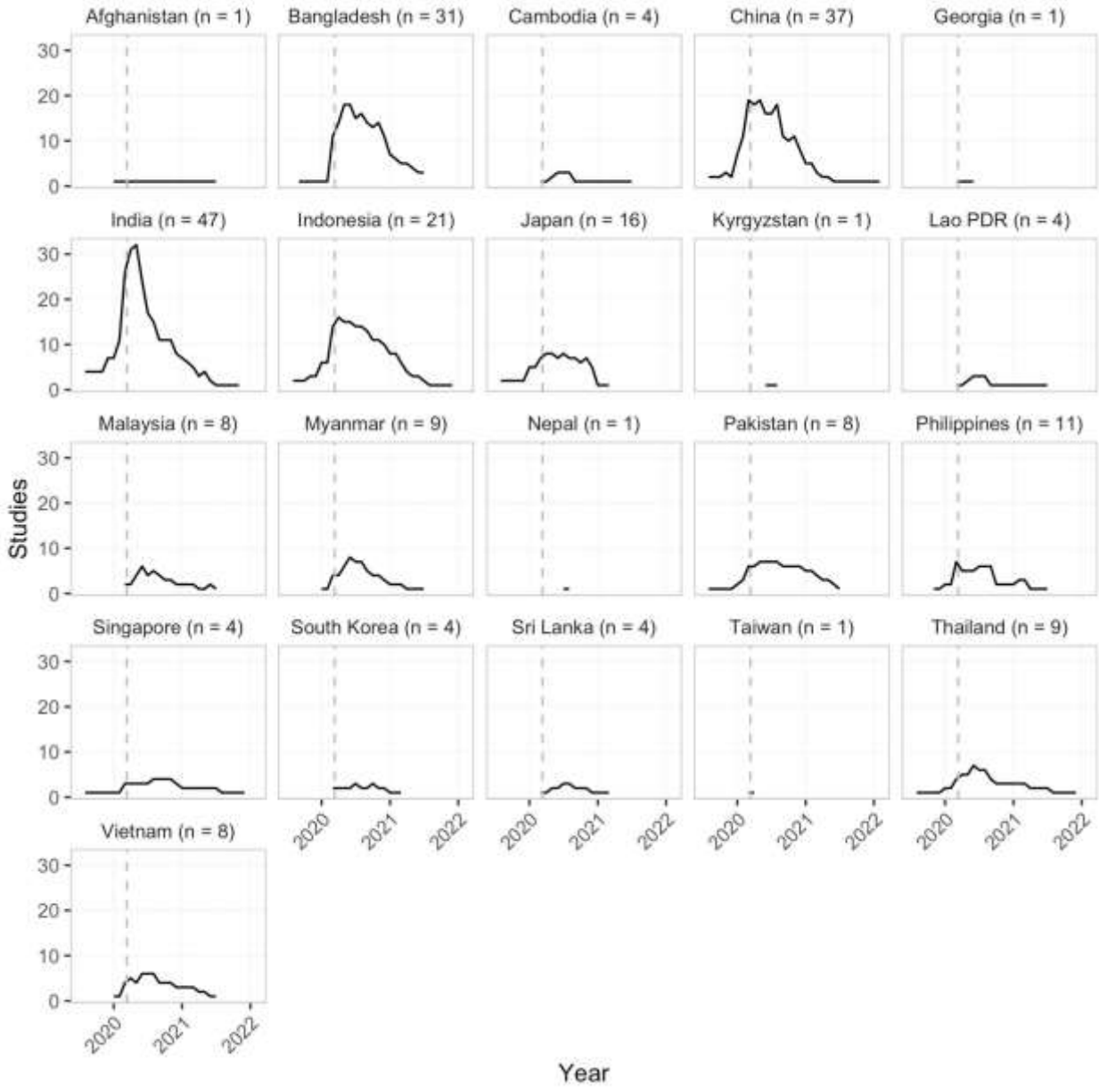
Study dates by region. The number of studies per month, based on the time periods that study data were collected and analyzed. Reviews and commentaries are excluded from these plots.

Africa

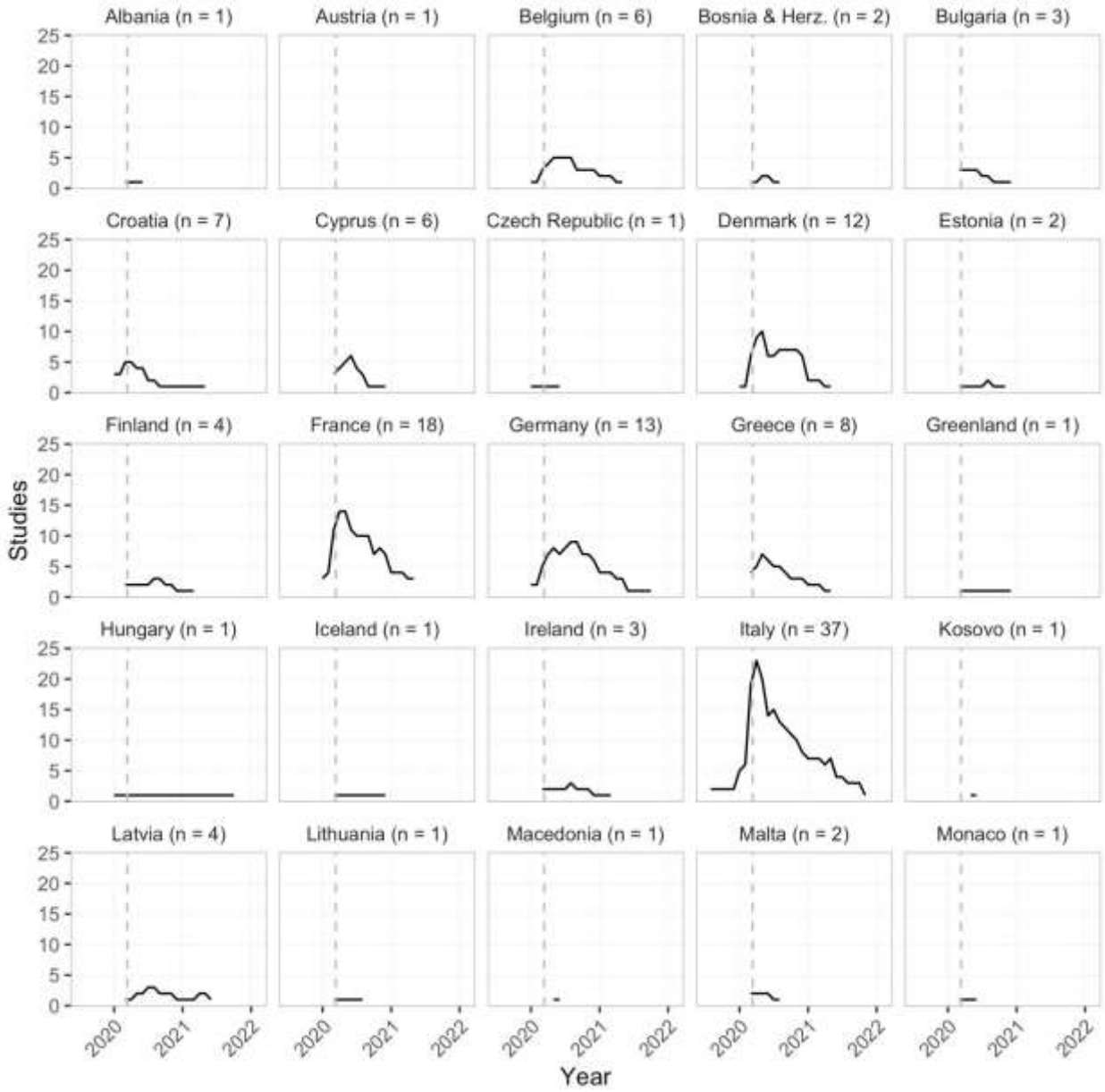


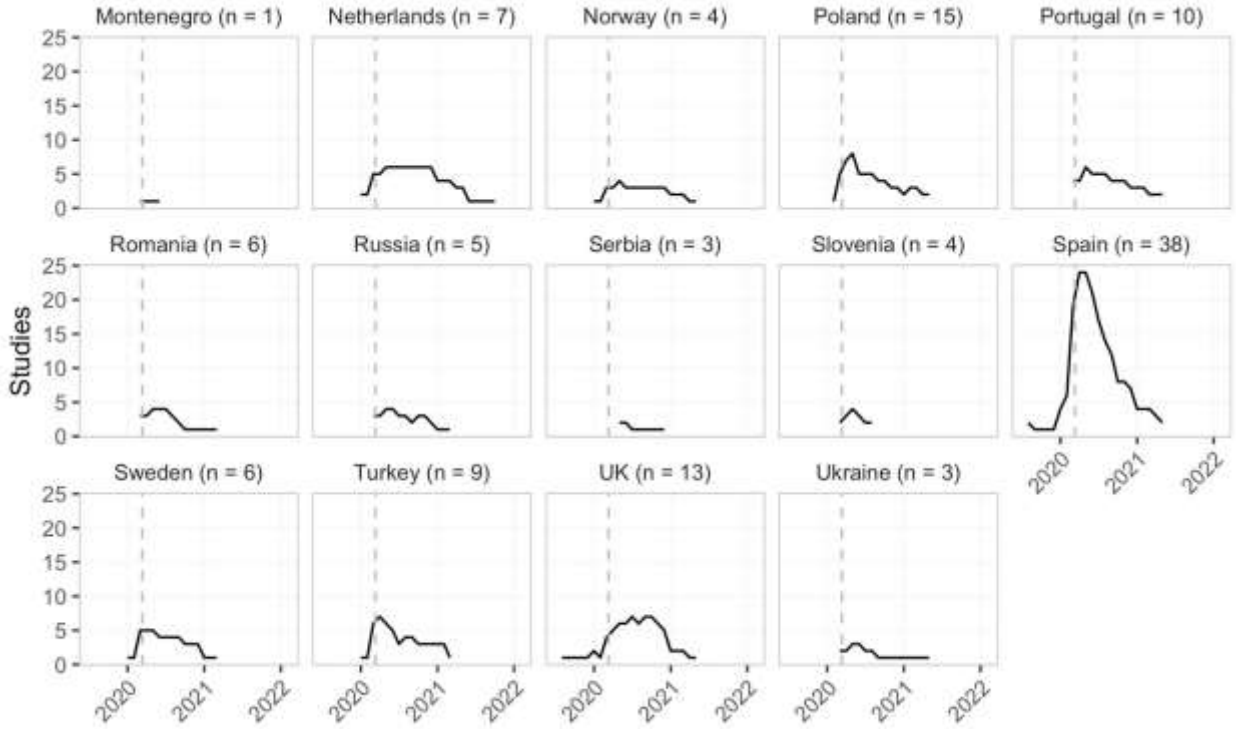

Morocco (n = 8)
Mozambique (n = 7)
Namibia (n = 1)
Niger (n = 1)
Nigeria (n = 14)
Rwanda (n = 2)
Senegal (n = 2)
Seychelles (n = 2)
Sierra Leone (n = 3)
Somalia (n = 1)
South Africa (n = 6)
South Sudan (n = 1)
Sudan (n = 3)
Swaziland (n = 2)
Tanzania (n = 9)
Togo (n = 3)
Tunisia (n = 4)
Uganda (n = 5)
Zambia (n = 7)
Zimbabwe (n = 7)
Studies
7.5
5.0
2.5
2020
2021
2022
Year

Asia

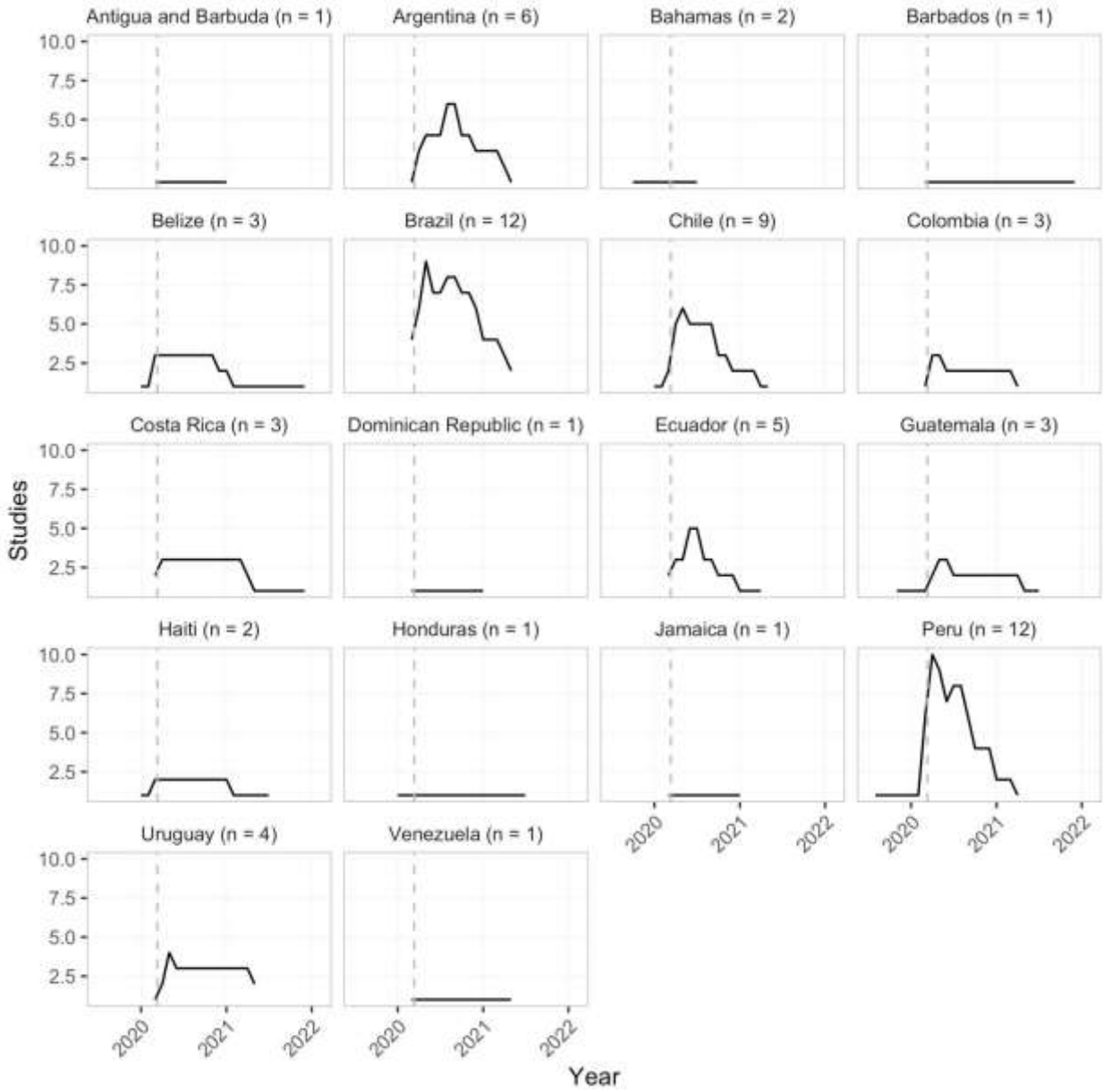

Afghanistan (n = 1)
Bangladesh (n = 31)
Cambodia (n = 4)
China (n = 37)
Georgia (n = 1)
India (n = 47)
Indonesia (n = 21)
Japan (n = 16)
Kyrgyzstan (n = 1)
Lao PDR (n = 4)
Malaysia (n = 8)
Myanmar (n = 9)
Nepal (n = 1)
Pakistan (n = 8)
Philippines (n = 11)
Singapore (n = 4)
South Korea (n = 4)
Sri Lanka (n = 4)
Taiwan (n = 1)
Thailand (n = 9)
Vietnam (n = 8)
Studies
0
10
20
30
2020
2021
2022
Year

Europe

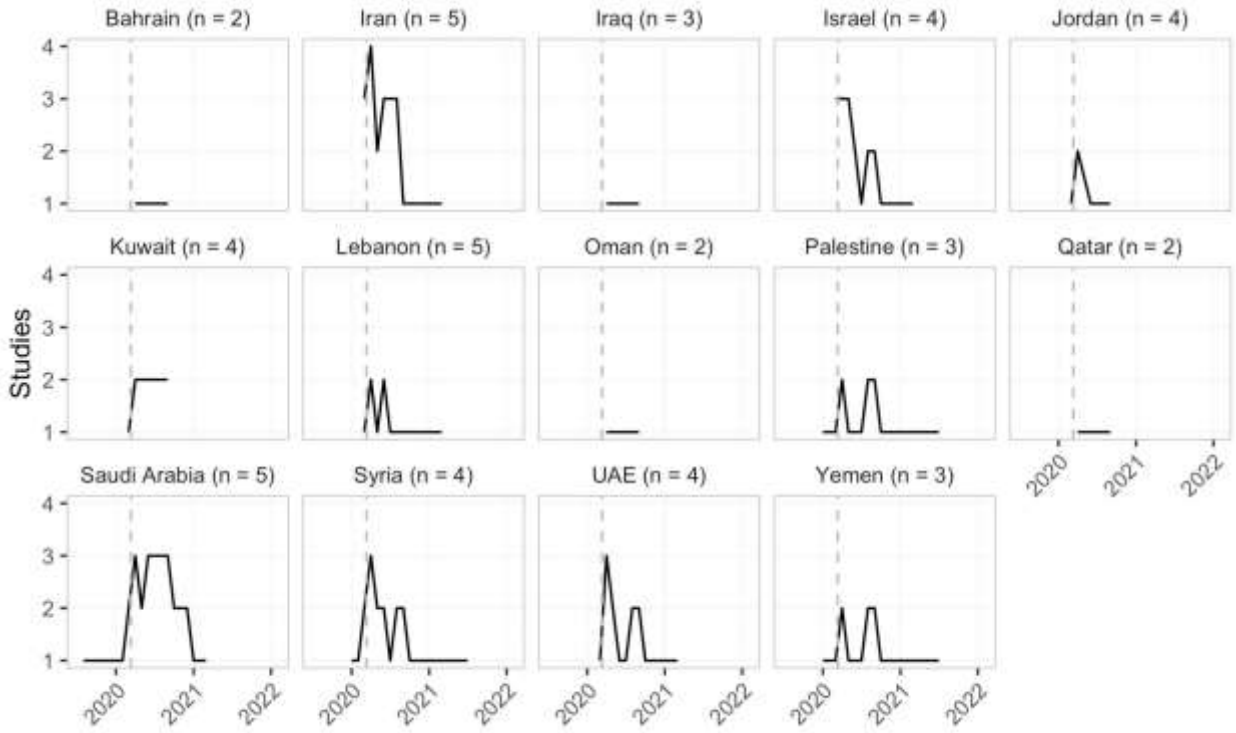

Albania (n = 1)
Austria (n = 1)
Belgium (n = 6)
Bosnia & Herz. (n = 2)
Bulgaria (n = 3)
Croatia (n = 7)
Cyprus (n = 6)
Czech Republic (n = 1)
Denmark (n = 12)
Estonia (n = 2)
Finland (n = 4)
France (n = 18)
Germany (n = 13)
Greece (n = 8)
Greenland (n = 1)
Hungary (n = 1)
Iceland (n = 1)
Ireland (n = 3)
Italy (n = 37)
Kosovo (n = 1)
Latvia (n = 4)
Lithuania (n = 1)
Macedonia (n = 1)
Malta (n = 2)
Monaco (n = 1)
Studies
Year
0
5
10
15
20
25
2020
2021
2022


Montenegro (n = 1)
Netherlands (n = 7)
Norway (n = 4)
Poland (n = 15)
Portugal (n = 10)
Romania (n = 6)
Russia (n = 5)
Serbia (n = 3)
Slovenia (n = 4)
Spain (n = 38)
Sweden (n = 6)
Turkey (n = 9)
UK (n = 13)
Ukraine (n = 3)
Studies
0
5
10
15
20
25
2020
2021
2022

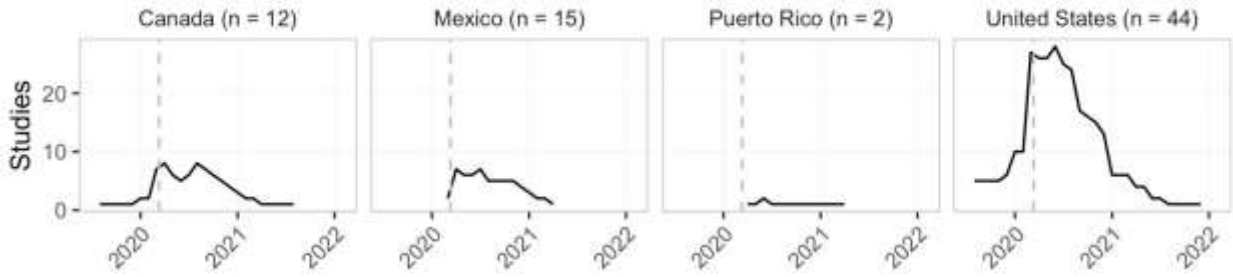
Latin America and Caribbean



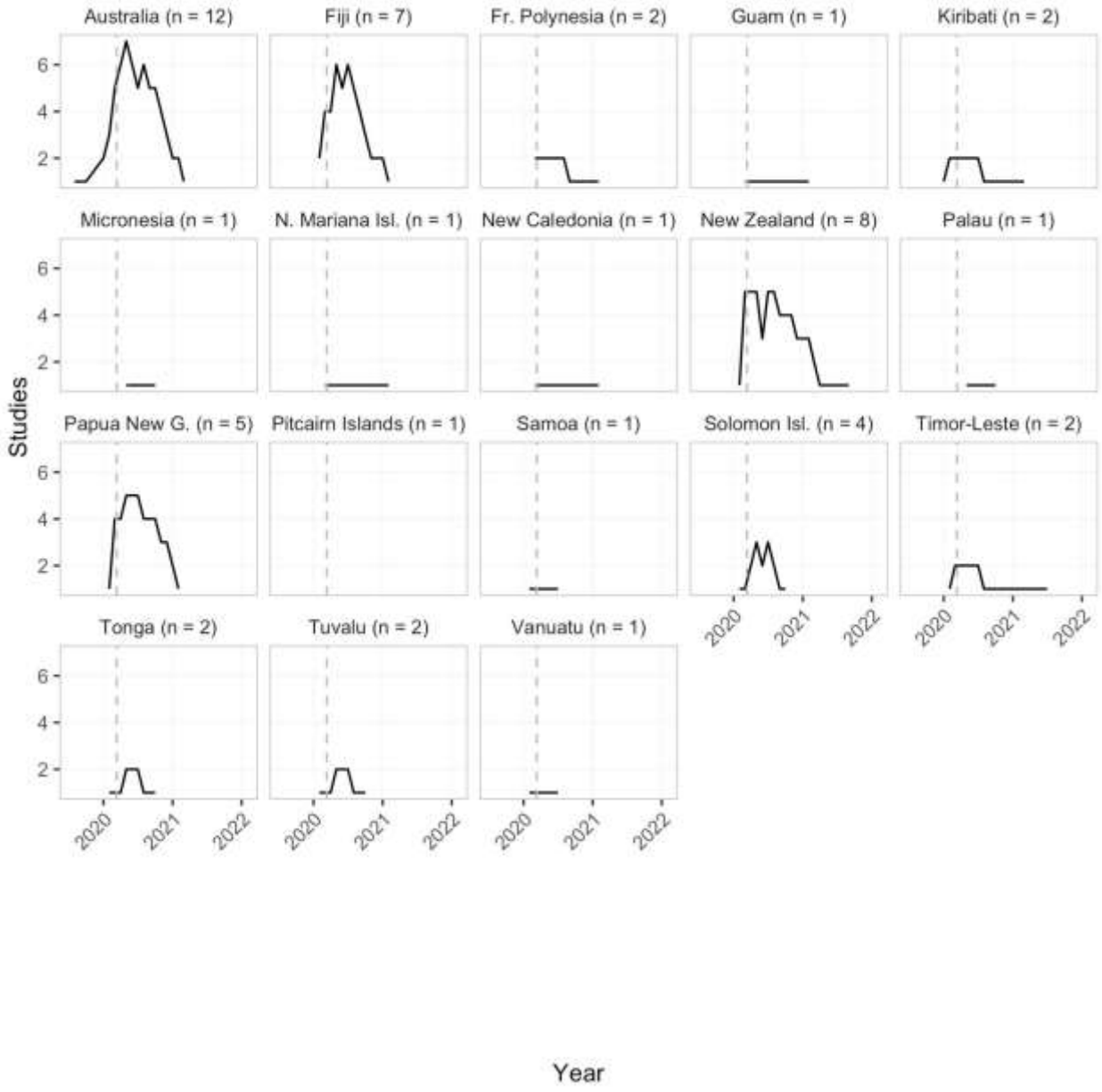
Middle East


Bahrain (n = 2)
Iran (n = 5)
Iraq (n = 3)
Israel (n = 4)
Jordan (n = 4)
Kuwait (n = 4)
Lebanon (n = 5)
Oman (n = 2)
Palestine (n = 3)
Qatar (n = 2)
Saudi Arabia (n = 5)
Syria (n = 4)
UAE (n = 4)
Yemen (n = 3)
Studies
1
2
3
4
2020
2021
2022

North America



Oceania


Australia (n = 12)
Fiji (n = 7)
Fr. Polynesia (n = 2)
Guam (n = 1)
Kiribati (n = 2)
Micronesia (n = 1)
N. Mariana Isl. (n = 1)
New Caledonia (n = 1)
New Zealand (n = 8)
Palau (n = 1)
Papua New G. (n = 5)
Pitcairn Islands (n = 1)
Samoa (n = 1)
Solomon Isl. (n = 4)
Timor-Leste (n = 2)
Tonga (n = 2)
Tuvalu (n = 2)
Vanuatu (n = 1)
Studies
Year
2
4
6
2020
2021
2022