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Shocks to fish production: Identification, trends, and consequences

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ABSTRACT

Sudden disruptions, or shocks, to food production can adversely impact access to and trade of food commodities. Seafood is the most traded food commodity and is globally important to human nutrition. The seafood production and trade system is exposed to a variety of disruptions including fishery collapses, natural disasters, oil spills, policy changes, and aquaculture disease outbreaks, aquafeed resource access and price spikes. The patterns and trends of these shocks to fisheries and aquaculture are poorly characterized and this limits the ability to generalize or predict responses to political, economic, and environmental changes. We applied a statistical shock detection approach to historic fisheries and aquaculture data to identify shocks over the period 1976–2011. A complementary case study approach was used to identify possible key social and political dynamics related to these shocks. The lack of a trend in the frequency or magnitude of the identified shocks and the range of identified causes suggest shocks are a common feature of these systems which occur due to a variety, and often multiple and simultaneous, causes. Shocks occurred most frequently in the Caribbean and Central America, the Middle East and North Africa, and South America, while the largest magnitude shocks occurred in Asia, Europe, and Africa. Shocks also occurred more frequently in aquaculture systems than in capture systems, particularly in recent years. In response to shocks, countries tend to increase imports and experience decreases in supply. The specific combination of changes in trade and supply are context specific, which is highlighted through four case studies. Historical examples of shocks considered in this study can inform policy for responding to shocks and identify potential risks and opportunities to build resilience in the global food system.

1. Introduction

Sudden and unexpected changes, or shocks, in food production and distribution systems can limit access to food and adversely impact local nutrition and food security. Such events can initiate a cascade of effects through the interlinked social-ecological food system. The ability to respond and adapt to such disruptions while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks describes the system's resilience (Walker et al., 2004). Food systems with low resilience have limited responses and capacity for adaptation to disruptions through mechanisms like trade, alternative food sources, backup distribution, or emergency supplies, causing food shortages of varying degrees of intensity and duration (Schipanski et al., 2016). Even when food production shortages are temporary, periods where essential nutrients are lacking can adversely impact the health of vulnerable populations such as pregnant women, children, and the ill (Block et al., 2004). For example, the drought in the Horn of Africa in 2011 contributed to the food insecurity and malnutrition of over 11 million people, with one in three children suffering from food shortages, widespread decreases in farmer and agribusiness worker incomes, and increased unemployment (UNEP, 2011). Income and asset loss and unemployment throughout the food production chain have lasting impacts for poor families and perpetuate poverty traps (Cuny and Hill, 1999). Therefore, characterizing the nature and frequency of disruptions, or shocks, to food systems is important to understanding the factors contributing to global food security. Ideally, this insight can

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be leveraged to prevent or mitigate the effects of future shocks and build food system resilience.

Shocks to food production can limit local access to food, but can also propagate through the international trade network, impacting prices and availability globally. The dynamics of this type of shock propagation have recently been explored through network models (Gephart et al., 2016; Tamea et al., 2016; Marchand et al., 2016). The 2008 grain crisis provides an example of a shock spreading through the trade network (Puma et al., 2015; Bren d'Amour et al., 2016). During this event, grain prices spiked due to increased demand for biofuels, higher oil prices, decreasing grain stocks, and the weakened US dollar (Headey, 2011). Rising wheat prices led India, the second largest rice producer, to ban exports of non-Basmati rice in 2007, which subsequently led other rice exporting countries, including China, Vietnam, and Egypt, to introduce export bans (Christiaensen, 2009). Some major importers, including the Philippines, responded by purchasing additional rice at increasing prices. Hoarding then further drove up the global price of rice (Christiaensen, 2009). By the end of the crisis, the World Bank reported over 130 million people were driven into poverty and the FAO estimated that an additional 75 million people became malnourished (Headey, 2011). This case illustrates the potential for multiple stressors (e.g. increasing biofuel demand and oil prices, changes in grain stock policies, and financial crises) to cause shocks which propagate on large spatial scales, and also illustrates how different sectors are increasingly interconnected (Homer-Dixon et al., 2015). A greater proportion of food is being traded internationally between more countries than ever before, and this increases the potential for shocks to local food systems to propagate into global crises (D'Odorico et al., 2014; Bren d'Amour et al., 2016).

While droughts and the 2008 grain crisis illustrate the consequences of shocks to agricultural production systems, shocks in fisheries systems are poorly characterized because temporal analyses have tended to focus on long-term trends rather than sudden drops and their resulting impacts. However, the effect of shocks is relevant to seafood production because seafood is among the most highly traded food commodities and is impacted by multiple potential shocks including fishery collapses, natural disasters, oil spills, policy changes, and aquaculture disease outbreaks (Gephart and Pace, 2015). Further, seafood is the source of almost 20% of animal protein consumed globally and an essential source of micronutrients in many coastal developing nations (FAO, 2014; Beveridge et al., 2013). As a result, it is important to identify historical cases of shocks to seafood systems to assess their causes and impacts on trade and domestic seafood supply.

There are a variety factors that could contribute to either more or fewer shocks over time or in particular regions or systems (Table 1). Increasing exploitation, intensification and connectivity of aquaculture, and natural or environmental disasters could contribute to more shocks while improved capture fishery management or infrastructure, proactive avoidance measures, or stocks collapsing prior to the study period could contribute to fewer shocks (Table 1). Other factors could contribute to either more or fewer shocks depending on the particular case, such as the increasing connectivity of the global market (which could increase pressure on fisheries or provide a buffer) or increased stock data availability (which could allow for increased intensification or improved management). Climate change also serves as a backdrop to these factors, by potentially making fishery systems more susceptible to shocks, by driving a redistribution of marine catches, and by causing more frequent extreme weather disruptions (Cheung et al., 2013; IPCC, 2014; Gattuso et al., 2015). A pattern in historical shocks would identify potential vulnerabilities in the seafood production system. This creates opportunities to manage measurable risks and supports the need to create buffers to hedge against shocks arising from true uncertainty in these complex systems—i.e. from unknown events impossible to predict (Sumaila, 1998; Lauck et al., 1998). Further, patterns in the impact of shocks on trade and supply inform whether and when a regional shock will have distant impacts through international trade or may impact local human nutrition.

While shocks have been defined and identified in specific systems with known causes or based on long time series, these methods cannot be applied in general when the shock cause is unknown and long time series data are unavailable. This is particularly problematic for food production systems, including fisheries, which are exposed to multiple environmental, policy, and economic shocks. One approach is to use expert or local knowledge to identify events considered shocks to particular systems. While this approach is valuable for studying individual systems, it is difficult to standardize the definition of a shock across systems and may be biased against shocks that are not widely reported on or those which occurred in distant memory. As a result, a data-driven approach can complement system knowledge to identify shocks across systems and over time.

Here we apply a statistical shock identification approach to national fisheries production time series to answer the following questions: 1) have the frequency or intensity of shocks increased; 2) do regions or production systems (capture versus aquaculture) have more, larger, or longer shocks; and 3) how are shocks divided among decreased exports, increased imports, and changes in domestic supply? We discuss four case studies in detail to illustrate the specific trade and seafood supply impacts of shocks which arise from different causes and occur within different contexts.

2. Methods

Shocks can be identified through qualitative approaches based on literature, news reports, and expert knowledge, or through quantitative approaches based on outliers or system-specific definitions. For example, both heat waves and floods are defined as extremes relative to the historical distribution of events, while droughts are identified by indices comparing supply and demand for soil moisture (e.g. the Palmer drought index). However, these methods typically require long time series to generate a distribution or are only relevant for specific types of shocks in a given system. While qualitative approaches are useful for studying individual systems, potential reporting biases, such as less

Table 1
Possible reasons to expect an increase or decrease in the frequency or intensity of shocks in fisheries and aquaculture time series.

Reasons for more shocks	Reasons for fewer shocks
Increasing exploitation	Stocks already collapsed
Increasing intensification and connectivity of aquaculture	Proactive avoidance measures
Increasing natural or environmental disasters	Improved infrastructure
Restrictions to improve capture fishery management	Improved capture fishery management in the past
Increasing connectivity of the global market	Increasing connectivity of the global market
Increased stock data connection and availability	Increased stock data connection and availability