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Socio-structural drivers, fisheries footprints, and seafood consumption: A comparative international study, 1961-2012

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ABSTRACT

This study examines the socio-structural drivers that influence the fisheries footprint and seafood consumption of nations. We assess how levels of economic development, population size, and transformations in food-system dynamics, such as those associated with terrestrial protein production and consumption, account for variation in ecological impacts and seafood consumption over time. The fisheries footprint indicator allows for a broader, ecologically grounded analysis. The seafood consumption indicator is a more restrictive measure, focused solely on direct human consumption. Using fixed-effects regression for 162 nations over the 1961 to 2012 period, we find that population and affluence are central drivers of nations' fisheries footprint and seafood consumption. The results also indicate that diets within nations tend to become more protein intensive across different forms of animal protein. These findings suggest that modernization and changing dynamics of food systems have contributed to increased impacts on seafood consumption and, more generally, aquatic ecosystems.

1. Introduction

Nations and communities across the world depend on fisheries production as a source of protein and an economic livelihood. Over the past five decades, fisheries and aquaculture production grew steadily, and outpaced the growth of the world's population (FAO, 2014). While there is much debate regarding the accuracy of historic captures levels, according to the Food and Agriculture Organization of the United Nations (FAO), global fisheries captures have ranged between 87 and 93 million tons since the late 1980s (FAO, 2016; Pauly and Zeller, 2016). At the same time, aquaculture—commonly referred to as fish farming—has become one of the fastest growing sectors of the global food system, and in recent years produces about half of all seafood for human consumption. Reliance on aquaculture production will likely increase in coming decades. The World Bank (2013) predicts that, based on current trends, total production from aquatic systems will grow from 154 million tons in 2011 to 186 million tons by 2030, and that demand for fish oil (an integral input used in many aquaculture operations and increasingly as fertilizer for agriculture) will intensify as well.

The interplay between marine and social systems requires sociological analysis (Longo and Clark, 2016). An important task is to empirically account for and theoretically situate the growth and change in seafood systems. Further, we need to better comprehend the ecological implications of these processes of growth and change in relation to the global food system in general. This study enhances our understanding of these processes by utilizing an approach that ecologically situates human-societal, food system impacts. We combine data provided by established global organizations to analyze the socio-structural drivers of nations' fisheries footprints and consumption of seafood. As a component of the well-known ecological footprint measure developed by the Global Footprint Network, the fisheries footprint accounts for the marine area required to sustain current levels of seafood consumption within a nation. It is estimated by drawing on the calculation of net primary production—or the amount of solar energy converted into organic matter through photosynthesis—needed to support a fishery (Ewing et al., 2010; Imhoff et al., 2004; Pauly and Christiensen, 1995).

Prior sociological research indicates uncertainty regarding how political-economic factors may account for variation in overall impacts on fisheries (Jorgenson, Rice, and Crowe, 2005). The purpose of this study is thus to advance our understanding of how socio-structural processes influence changes in fisheries and, more generally, aquatic systems, over time. Toward this goal, we assess how levels of economic development, population size, and productive/consumptive dynamics in the food system—specifically terrestrially produced protein in meat and livestock systems—account for variation in the amount of coastal

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and marine ecosystem territory needed to sustain levels of seafood consumption. We employ fixed effects modeling techniques and national-level data ranging from 1961 to 2012 to estimate how these factors drive fisheries footprints and aggregate seafood consumption, and compare the overlap and differences between the distinct measures of human interaction with aquatic-based food systems. We contextualize the analysis using prominent theories in environmental sociology concerning modernization, political economy, and human ecology. To begin, we situate and describe the social and ecological circumstances associated with changes in aquatic-based production systems.

1.1. Social and environmental dimensions of modern fisheries

There is no area in the ocean system that remains unaffected by human activity, and multiple anthropogenic factors threaten the sustainability of large portions of marine systems (Halpern et al., 2008; Roberts, 2013). Withdrawals from fish stocks have already had wide-ranging effects on marine and other aquatic systems. Large-scale, increasingly efficient fishing methods put intense pressure on fish populations and have, at times, caused cyclical disruptions across food webs (Longo, 2010; Longo, Clausen, and Clark, 2015). These practices have amounted to a 20 percent decline in biologically sustainable fishing levels in marine fish stocks, below which the probability of stock degradation and collapse becomes increasingly likely, between 1974 and 2010 (FAO, 2014). Put another way, the crossing of what are considered sustainable thresholds is becoming more common. As a result of intensified production, the FAO (2016) considers about 31 percent of all fish stocks to be overfished, or exploited beyond what is considered biologically sustainable. Further, it was estimated that about 58 percent of fish stocks were fully exploited, meaning that most fished species are already at or near their maximum sustainable yield (FAO, 2016).[1]

In order to meet the growing demand for seafood in recent decades, aquaculture systems have become an important source of seafood production. Under the moniker of the "blue revolution," aquaculture technologies are seen as providing the capacity to continue growth in the seafood sector, while minimizing impacts on wild fish stocks (Sachs, 2007). Nevertheless, the growth of industrial aquaculture has been dependent upon substantial quantities of energy and fish-based feed inputs to sustain it, especially for high-trophic level species—or species higher in the aquatic food web—such as salmon (Longo, Clark, and York, 2013). The expansion of aquaculture production is thus not a simple fix to the ecological impact of the seafood industry.

Large-scale marine degradation poses serious problems for social systems. For example, declines in marine biodiversity can result in reduced water filtration and declining quality of coral reefs—both of which can protect humans from exposure to toxins and intensified coastal storms (Hiddink et al., 2008). Because stress on one species at various trophic levels can have cascading effects on fish throughout the system, once stable protein supplies are now in jeopardy (Holmlund and Hammer, 1999). When these ecosystems are degraded, human communities that rely on fisheries resources as important sources of nutrition become increasingly vulnerable. These socioecological changes present an acute concern in parts of the Global South, particularly in regions that rely on small-scale or artisanal fishing operations as an important source of food and economic livelihood (Islam, 2014).

[1] There have been ongoing debates among fisheries scientists and managers regarding the efficacy of the concept of maximum sustainable yield (see Longo, Clausen, and Clark, 2015). If a fishery moves beyond what the FAO term fully exploited, the fishery can become overexploited—or fished at a level that threatens reproductive cycles and, accordingly, the future stock levels. These estimations change to some small degree across years, and the FAO continuously modifies their terminology and assessments. However, the overarching themes across recent FAO reports are, one, that there is little room for expansion in most fisheries and, two, that a sizeable portion of fish stocks are already fished at rates that are not sustainable.

Changing global markets and ecological conditions have also resulted in the use of slave labor in some fisheries, for example in Southeast Asia and West Africa (Bales, 2016; ILO, 2013). Fish production systems greatly impact the overall health and sustainability of aquatic systems, and these changes in marine systems pose unique and serious challenges for human society.

1.2. Human ecology, modernization, and the treadmill of production

Our environmental sociological framework is grounded in the recognition that socio-structural dynamics of human systems affect ecosystems, and vice versa (Catton, 1994; Duncan, 1959). This type of human ecology perspective, which investigates socio-structural interactions with ecological systems, is applicable to understanding human impact on aquatic systems, food systems, and other environmental systems. Research drawing on this approach indicates that a society's population dynamics, level of material affluence, and technical development are central drivers of environmental impact (Carolan, 2011; Dietz, Kalof, and Frisch, 1996; Dietz and Jorgenson, 2013; Stern et al., 1997; York and Gossard, 2004; York, Rosa, and Dietz, 2003a).

Researchers in the natural sciences have also begun to incorporate interrelated dynamics of social and natural systems into their indicators of ecological sustainability, and this process has further paved the way for advances in social science research (Liu et al., 2015). By unpacking anthropogenic environmental resource consumption, the Global Footprint Network provides a metric that details how much nature—measured in land and resources—human societies require to maintain their levels of consumption. This metric is known as the ecological footprint (Wackernagel et al., 1999). It tracks the societal supply and demand of productive area for six different categories of natural resource consumption (Global Footprint Network, 2017a). In this study, we examine an aspect of the ecological footprint, the fisheries footprint, and a conventional measure of seafood consumption, described in more detail below. Other social science research has utilized the ecological footprint to assess the socio-structural causes of environmental degradation (e.g., Jorgenson, 2003; Jorgenson and Clark, 2009, 2011; York et al., 2003a). Additionally, research on protein consumption and the environment has used the more conventional measure of consumption to estimate the level of impact on an ecological system (York and Gossard, 2004).

Human ecology scholars have made much progress in parameterizing and analyzing how dynamics of social processes and organization affect the environment. Research in structural human ecology emphasizes factors related to affluence, population, and technology in order to account for variation in environmental impacts. Advancing this approach, researchers have developed and applied the STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) model to predict and account for variation in several indicators of environmental impacts, such as carbon dioxide emissions and the ecological footprint of nations (e.g., Jorgenson and Clark, 2010, 2012; York et al., 2003a; York, Rosa, and Dietz, 2003b). We employ this method in developing our own analyses (described in subsequent sections), in order to assess how human socio-structural processes interact with and account for the level of impact on nations' fisheries footprint and seafood consumption.

In the examination of natural resources and food systems, sociological research has often employed theories of modernization to explain social and environmental change. Modernization approaches often emphasize the beneficial role of economic development and technological capacity in regard to influencing food consumption patterns and ecological impacts (Huber, 2000; Mol and Spaargaren, 2000; Spaargaren, Oosterveer, and Loeber, 2012). In environmental sociology, ecological modernization theorists conceptualize modernity as a source of environmental improvements. Borrowing from development theory and neoclassical economics, these scholars posit that continued advancement of liberal democracies, market development, and