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Modernization, Political Economy, and Limits to Blue Growth: A Cross-National, Panel Regression Study (1975–2016)*

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Abstract Seafood production and trade have expanded dramatically over the last 40 years and comprise one of the fastest growing, and most environmentally impactful, sub-sectors of the global food system. While richer nations have increased their seafood consumption and displaced their environmental load, the marine environmental impact of fishery production has largely shifted to the waters of less-affluent nations. To sustain fishing economies and seafood security, in an era of increasing marine ecological precarity constitutes a major challenge for development and human well-being in the 21st century. Blue growth perspectives emphasize the transformative power of growth-oriented development. Such perspectives conflict with critical political economic theories of environment and food systems; notably, the treadmill of production and world food system scholarship. Using annual data from the Global Footprint Network, World Bank, UN FAO, and International Monetary Fund, this study applies methods in cross-national, panel regression analysis in order to ultimately pose some important challenges to modernist blue growth perspectives. The analysis suggests that economic growth and incorporation into the world market economy have led to unsustainable and inequitable outcomes regarding the marine ecological impact of fisheries.

Introduction

A growing body of critical food systems research concentrates on the socioecological dynamics of terrestrial-based agriculture. However, seafood—marine and freshwater fish, mollusks, crustaceans, and other forms of aquatic animals, hereon referred to as fish—comprise the fastest growing protein consumption commodity category in the world (Burwood-Taylor 2019). Similarly, aquaculture, or the controlled rearing

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of fish, is the fastest growing sub-sector of the world food system (FAO 2018b). While robust sociological studies of these issues are increasing, scholars of the global seafood system and fisheries advocate for studies that engage with social theory and historical context in order to explicate marine system change (Campling and Havice 2018; Campling, Havice, and Howard 2012).

The relative paucity of sociological study in this area stems in part from environmental sociology's historic, terracentric notion that the sea exists "out there," away and distinct from human society (Hannigan 2017; Longo and Clark and Longo 2016). Yet, human society's impact on various ocean sectors and ecologies is quite evident, as well as ocean sectors' and ecologies' impact on society. Contrary to antiquated ideas about the ocean's inexhaustibility, modern fishing has drastically reduced marine biomass and biodiversity, especially for higher trophic level, predatory fish (Christensen et al. 2014). Today, roughly 90 percent of all fish stocks are fished at or beyond their maximum sustainable yields (MSY) (FAO 2018a). While MSY is far from a perfect indicator of fisheries ecologies, this reality suggests that there is little room for material expansion in wild, capture fisheries sectors. Indeed, patterns indicate stagnation or decline across capture fisheries, and a new dependence on aquaculture to sustain consumption and profit in an era of depletion and stress (FAO 2018b; Longo et al. 2019). These trends have particularly impacted those living in coastal environments and marine-based economies of the global South, where export-oriented seafood production, seafood industrialization, and the decline of smaller scale, artisanal methods have occurred at high rates. Importantly, in this context, the viability of fisheries matters greatly for rural and coastal community food security and social reproduction (Bell et al. 2009). The analysis utilizes a metric that directly assesses the productive impact of fisheries development in the marine environments of less-affluent countries to assess the drivers of change in the material, productive bases of aquatic food systems.

The purpose of this study is to examine how political economic conditions associated with capitalist development such as—increased economic growth, trade, foreign investment, and financial development—have affected the material bases of the global seafood system, which increasingly are located in the waters of the global South. With growing concern over how to create a sustainable "Blue Economy," across ocean sectors, this study is especially relevant. In spite of growing scholarly pressure to incorporate sociocultural dimensions concerning equity and justice, recent empirical studies of Blue Economy discourse have reveal that business, innovation, profit accumulation, and growth-oriented frames are overwhelmingly prevalent (Silver et al. 2015; Voyer et al. 2018). Critics of the Blue Economy also reason that it constitutes a new institutional fix to reorient more ocean space to satisfy the accumulative demands of the world capitalist market economy (Brent, Barbesgaard, and Pedersen 2020; Winder and Le Heron 2017). Thus, there is need to investigate the extent to which blue growth assumptions are supported by historical evidence. Accordingly, the purpose of this study is to assess how world-capitalist, political economic imperatives have impacted the ecological bases of fisheries over time. To do so, the analysis utilizes an understudied, disaggregated component of the fisheries footprint metric—the fisheries footprint of production—to evaluate the ecological impact of nations' fisheries systems. By employing time series, panel regression approaches, this study provides historical, empirical context for evaluating contemporary blue growth assertions concerning development and marine sustainability.

Fisheries and Seafood Systems Background

A substantial portion of the world ocean is now subject to industrial scale harvest of fish, leaving increasing amounts of ocean space vulnerable to intensive, industrial extraction that threatens biodiversity and marine ecosystem stability (Amoroso et al. 2018; Kroodsma et al. 2018). Widespread industrial fishing practices led to an aggregate increase in fish captures over the 20th and into the 21st century; however, this aggregate growth in capture corresponds with a flattening or stagnation of wild capture fish in the 1980s (Mansfield 2011). In the global North, many, including the European Union, are skeptical that sustainable capture fisheries constitute a viable, growth-oriented project (Boonstra et al. 2018). As such, over the last several decades, export-oriented development in global South nations has sustained global North consumption of seafood (Mansfield 2011). In like manner, intensified regulation in global North marine spaces corresponds with southward shifts in fishing activity (Worm et al. 2009). Much of this activity supports the massive global seafood trade, upon which nations in Asia, Oceania, Latin America, and (to a somewhat lesser extent) Africa have served as net exporters of seafood over the last several decades (Bellman, Tipping, and Sumaila 2015).

To support this uneven relation, international law codifies intensive fishing practices. Article 62 of the UN Law of the Sea compels nations to 'optimum utilization' of fish resources, or lose fishing rights to distant water, highly capitalized fleets (Campling and Colas 2021). Indeed, global North nations and firms finance a great deal of export-oriented fishery production within the exclusive zones of less affluent countries (McCauley et al. 2018). In terms of fishery employment, labor in the global North has become scarcer and more specialized, with many generational fisheries losing viability due to aforementioned, external socioeconomic trends (Clark 2020; Howard 2017). Consequently, a vast majority of people employed in fisheries live and work in global South nations (FAO 2018a; World Bank 2012). Much of this work is vulnerable to severe exploitation, with ecological degradation and resultant productive inefficiencies driving down profits and, with them, the cost of labor (EJF 2019).

Theoretical Background

Blue Growth and Modernization

Ecological modernization scholars have long posited that advancing economic affluence or economic growth, commonly operationalized as per capita GDP, should lead to long-term net improvements in environmental sustainability metrics (Mol and Sonnenfeld 2000; Mol and Spaargaren 2000; Spaargaren and Mol 1992; Sarkodie and Strezov 2019). Alongside growth, ecological modernization scholars have emphasized the importance of trade and integration into the capitalist world economy as rationalizing, regulatory forces of environmental protection (Mol 2002, 2006). Moreover, ecological modernization scholars have generally articulated an optimistic lens in their characterization of marketization, or the "economization of ecology," alongside a view of the capitalist world economy as a system capable of incorporating ecological concern via green, cooperative trade, and investment (Jänicke and Lindemann 2010; Mol 2010).

The tenets and claims of ecological modernization have long been litigated and debated in the fields of environmental sociology and environmental political economy, with some indication that its application is diminishing in scope and frequency within sociology (Clark et al. 2021). However, perspectives that articulate optimism about the capacity of already existing structures and institutions to facilitate economistic solutions to marine environmental troubles are quite common in fisheries economics, gray literatures, and sustainability theory (Longo and Clark 2016). In the literature on fisheries captures and marine ecological footprints, some interpret initial stagnation and decline of capture fisheries, but long-term stabilization of capture rates, as evidence that a managed growth model can produce some degree of sustainability in global fisheries (Rashdan et al. 2021). Some recent studies find evidence to support a decoupling between economic and environmental impact, or Environmental Kuznets Curve, in fisheries when controlling for measures of trade and investment freedom or when focusing on certain fishing zones in China and some Asian countries (Karimi et al. 2021; Kong, Cui, and Xi 2021; Wang et al. 2019).

While these findings and interpretations constitute one aspect of the scholarly discourse, optimism surrounding economic growth and the ecologically rational capacity of markets abound in gray literatures and discourse on marine sustainability. Recent empirical studies of blue economy conferences and written documents reveal that, overwhelmingly, actors and documents emphasize economistic logics when conceptualizing marine sustainability. Voyer et al. (2018) reported that their analysis of blue economy planning documents revealed that 78 percent of such documents referenced economic growth. Similarly, frames of "good business" and "innovation" are dominant, reoccurring thematic frames in blue economy documents and conferences (2018). These emphases constitute a "blue growth" discourse, which typically emphasizes the necessary co-existence between marine environmental protection and normative, capitalistic growth-oriented development (Boonstra et al. 2018). Indeed, some posit that growth and capital-intensive development are essential for sustainable fisheries sector development, as industrial aquaculture will require offshore marine ranching and capital-intensive, high-density farming of marine species in closed systems (Hilborn 2017; Swain 2017).

Overall, the growth of a capitalist world-economy (and the inclusion of new spaces within it) is, at least, an implicit objective of blue growth discourse. Familiar mechanisms of global capitalist development—like liberalized trade and foreign investment—can improve (it is posited) environmental indicators by providing economic incentive to maintain ecosystem services, as well as the economic capital needed to invest in more efficient technologies, like aquaculture or bycatch reduction technologies (Asian Development Bank 2018; UNCTAD 2004). In fisheries, such mechanisms are also necessary to support the coordinated monitoring of global seafood supply chains, largely stimulated by affluent, environmentally conscientious consumer demand in the global North (Doddema et al. 2020; Oosterveer and Spaargaren 2011).

A key element in blue growth discourse also concerns finance, often dubbed "blue finance." Citing growing social and environmental concern among leading international finance organizations and banks, Golden et al. (2017) argue that the continuing surge of ocean sector capital investment is reason for optimism. In 2018, Seychelles developed the world's first "blue bond," financed to fund marine protected areas and fisheries conservation efforts (World Bank 2017). Such efforts have generated great excitement for the creation of blue carbon markets, marine protected areas funded by debt for nature swaps, and, generally, a more innovative role for financing protection of marine spaces (Childs and Hicks 2019; Wabnitz and Blasiak 2019). At present, major international lending institutions and private financiers have made extensive rhetorical and material commitments to finance blue growth projects, including a $6.4 billion blue growth portfolio administered by the World Bank and a $5 billion investment commitment in the form of blue bonds from the Asian Development Bank (Mallin and Barbesgaard 2020). Generally speaking, this enthusiasm articulates a tremendous amount of optimism in the power of foreign investment and the global finance to steer marine sector development in a more sustainable fashion. In like manner, resource and fisheries economists generally regard trade openness as a necessary condition for resource conservation (Goldin and Mariathasan 2014; Chen 2021). In addition, trade relationships are said to build institutional support and trust necessary for cooperative management and regulation for fisheries and blue economy sectors (Burgess et al. 2018).

Thus, incorporation into the global market, specifically the liberalization of trade and national finance systems, is strongly encouraged by advocates of modern blue growth. Such development discourse typically focuses on poorer or so-called developing states, small island nations, and small-scale fisheries in the global South (Silver et al. 2015). An increasing amount of scholarship critically assesses the assumptions of blue growth and works to steer blue economy framing in directions that prioritize equity and advocate for more direct, or non-market, policy solutions to socioecological problems (Bennett et al. 2019; Cisneros-Montemayor et al. 2021). Also, there exists growing scholarly critique that advances blue degrowth, as well as policies and development paradigms that advocate for the rights of small-scale and indigenous fishing communities (WFFP 2017). Nevertheless, a dominant thread across much blue economy discourse advances notions of ecologically rational blue growth. This study investigates the extent to which optimism in these market forces is historically justified in marine fisheries environments.

Critical Political Economy

Growth and the Treadmill of Production

Environmental sociological scholarship of economic growth and the world system has long argued that economic growth under a capitalist economy requires increased ecosystem withdrawals to satisfy growth imperatives (Gould, Pellow, and Schnaiberg 2004; Schnaiberg 1980). Ever increasing withdrawals are, over time, required to satisfy the expansive demands of abstract, quantitatively limitless capital accumulation

(Foster 2005). This tendency, or growth imperative, serves as a structural impediment to many positive, growth-oriented processes—like the development of more efficient technologies. For example, treadmill scholars (and eco-Marxists who have extended on the framework) acknowledge the tendency of global capital to finance productive efficiencies, but note that improved productive efficiencies typically do not result in long-term net declines of ecological impact—a phenomenon known as the Jevons paradox (Clark and Foster 2001; Longo, Clausen, and Clark 2015; York and McGee 2016). Indeed, increased investment in production may further stimulate treadmill pressures to withdraw more net environmental resources in order to recoup the costs of productive innovation (Gould et al. 2004). Following these theories, contemporary quantitative, sociological studies on fisheries illustrates that aquaculture development has not evenly displaced the environmental impacts of wild capture fisheries, as there still exists immense economic pressure to extract species from wild environments (Longo et al. 2019; 2013).

In recent years, quantitative environmental sociologists of the world system have produced a bevy of analysis concerning the effects of growth on various environmental impact indicators. These studies often emphasize the varying effects of growth and development at different levels of national affluence (Huang 2018). For example, Thombs (2018) demonstrates that the effects of economic growth and trade openness on measures of carbon dioxide emissions have intensified unevenly across the world economy, with their deleterious effects increasing in less-affluent nations. Similarly, renewable energy consumption has little influence on carbon emissions or CO_2 emissions per unit of GDP in high income nations (Thombs 2017). Recent research also indicates that export flows to affluent nations correspond with increased carbon emissions in developing nations (Huang 2018). Processes in support of growth, like longer working hours, also are shown to correspond with increases in environmental impact indicators in both rich and less-affluent nations (Fitzgerald, Jorgenson, Clark 2015; Fitzgerald, Schor, and Jorgenson 2018). TOP-oriented scholarship on food system indicators like pesticides, seafood consumption, and fisheries consumption footprint also provide evidence to support the TOP's foundational arguments on growth in the context of a hierarchical, uneven world system (Clark et al. 2018; Clark and Longo 2019; Hedlund et al. 2020).

Food Systems and World Capitalist Development

While growth and therefore treadmill dynamics are certainly key for understanding agrarian environmental impacts, it is also necessary to consider the political economic structuring of the modern world food system and its relation to fisheries. Specifically, for the purposes of this study, it is necessary to consider how agrarian, political economic scholarship conceptualizes the socioecological importance of trade relations, foreign investment, and financial development. To begin, the contemporary neoliberal world food system, or regime, came into existence in the 1980s. This emergent regime is oriented around global South nations commodifying their agri-food systems toward export-oriented development of perceived luxury products, such as seafood (McMichael 2012a). This reorientation of food production and trade corresponded with structural adjustment programs, advocated by global North institutions such as the International Monetary Fund (IMF). These institutional processes aimed to restructure the national economies of many less-affluent nations in order to encourage privatization of finance systems and to remove controls on international financial investment in the hopes to attract monetary support from foreign capital (Holt-Giménez 2017). This development marked a shift "from aid to trade," as it encouraged (or coerced) poorer and less affluent nations to deregulate their agri-food systems, open borders for international finance, and modernize their agri-food production in service of global North firms and consumers (Goodman and Watts 1997; Longo and York 2008). Thus, the modern agri-food system is characterized by export-oriented production of luxury products from poorer countries, the liberalization of national finance systems, and capital investment aimed at agricultural industrialization in the global South.

Importantly, scholars characterize these mechanisms as tools to maintain uneven capital accumulation and outsource the treadmill's more ecologically deleterious effects. Environmental sociological scholarship on world system dynamics has considered foreign direct investment as a mechanism for fostering dependency, which enables richer nations to outsource their more ecologically intensive production to poorer, less powerful nations (Dorninger et al. 2020; Givens and Huang 2021; Jorgenson 2012; York 2008). In marine and terrestrial food systems, critical world food system scholars argue that foreign investment is an important driver of corporate land, water, and ocean expropriation as well as the development of intensive agri-industrial technologies (Barbesgaard 2019; Magdoff 2012). Regarding finance, some emphasize that financial development, characterized by private equity take overs, mergers and acquisitions, and the increasing rate investment in land, is the characteristic feature of the modern food system (Schmidt 2015). Such processes can lead to increased price volatility, alienation of labor, and—importantly—pressure to degrade environments (Burch and Lawrence 2009; Isakson 2014; Magdoff 2012). In fisheries studies, there is a growing concern that the rising of power of finance across the global food system may contribute to processes linked to ocean grabbing, inequitable market management schemes, and intensive aquaculture development (Carothers and Chambers 2012; Fururset 2016; Knott and Neis 2017).

Again, the aim of such development, especially within less-affluent or so-called developing states, has generally been organized around export-oriented production of luxury commodities (McMichael 2012b). Indeed, food production in less-affluent nations typically involves selling to global North based food distributors and retailers who control food value chains and, thus, the majority of profits (Holt-Giménez 2017; Otero et al. 2013). More broadly, prior research suggests that international trade dynamics, in terms of quantity and direction, are important for understanding change in environmental impact indicators (Besek and McGee 2014; Rice 2007). In aquatic food systems, case study-level research illustrates how modernization of national food systems and neoliberal pressures can amplify socioecological stress in fisheries (Howard 2017; Longo et al. 2015).

Overall, the stark theoretical differences across blue growth, modernization perspectives and critical perspectives on growth and agrarian development point to the need for empirical clarification. First, it is unclear if 21st century marine development should promote a growth-driven logic to achieve sustainable fisheries. Second, it is also unknown how the incorporation of nations' marine food systems into the world economy has affected the material bases of aquatic food systems over time. As discussed, blue growth discourses conceptualize on-going economic growth, financial development, increased trade relations, and capital investment as necessary mechanisms to support sustainable marine development. The forthcoming analysis seeks to situate how these mechanisms correspond with a key, understudied metric of fisheries sustainability: the fishery footprint of production. The methods, described in the subsequent section, develop models that can provide some evidence relevant to these pertinent questions.

Methods

Justifying Sample and Time Frame

The sample focuses on development in the fisheries of less-affluent nations. Delineating nations according to level of national affluence, or per capita income is a common practice in panel analyses at the nation state level (Clark and Longo 2019; Hao 2020; Jorgenson 2016; Shandra et al. 2009; Thombs 2018). The study chooses to specifically examine less-affluent nations for several reasons. First, according to world food system scholarship generally and on fisheries, as discussed above, export-oriented development and world (food) system incorporation is occurring extensively in poorer and middle-income countries. Second, extensive analyses of marine sector planning demonstrate that blue growth discourses are frequently applied to less affluent nations, especially in fisheries (Boonstra et al. 2019; Silver et al. 2015). Three, ecologically intensive fishery development has shifted away from the world's richest countries. As Figure 1 illustrates, this shift has occurred in spite of the fact that richer nations have dramatically increased their consumption of seafood.

This patterned development represents what Jorgenson (2016) refers to as environmental load displacement, or the phenomenon through which richer countries expand their consumption of material resources without degrading their own environments (see also Givens and Huang 2021). Here, the decline in fishery footprint of production signifies that the ecological impact of richer nations' fisheries production has fallen over time. Seafood consumption in affluent nations exceeded footprint of production in the 1980s, a period of intensified export-oriented development and neoliberalization in much of the global South's national food systems.

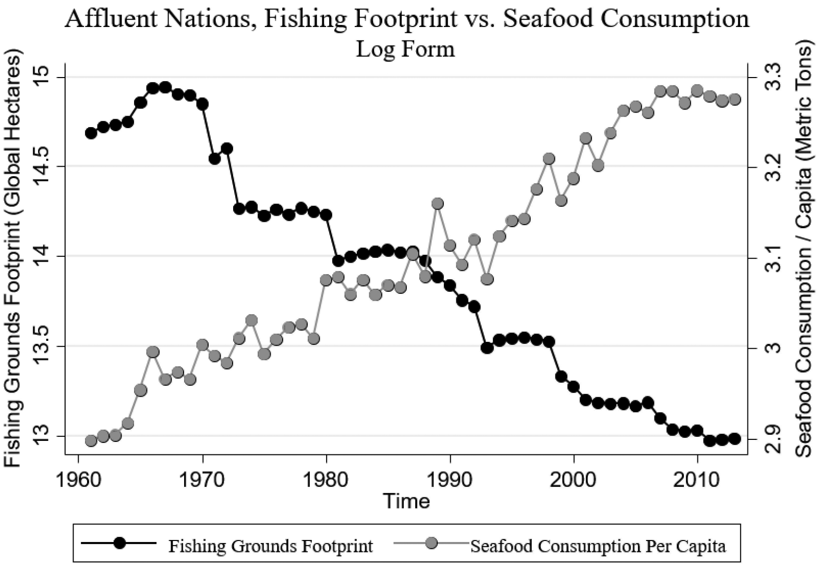

Figure 1. Fishing Grounds Footprint of Production vs. Seafood Consumption, Affluent Nations. 1960-2016.

Since then, global North seafood consumption has become ever more dependent upon the marine resources and fishery development of less-affluent countries (Smith et al. 2011). Indeed, in less-affluent countries, fishery footprint of production tripled in size between 1975 and 2015 (Global Footprint Network 2020). Thus, it makes sense to focus on marine fishery impact in less-affluent nations over this period. The models in this study therefore draw data from less affluent nations, at annual observations, for years 1975 through 2016, or the most recent year that disaggregated footprint data are available as of writing.

Similar to prior research, less-affluent nations are defined as nations that do not fall into the World Bank's high-income category, historically and into the present day (Jorgenson and Clark 2012). This approach allows for the analysis of over 100 total nations over time.

Data & Variables

Data werecollected from the Global Footprint Network, International Monetary Fund, World Bank, and Food and Agricultural Organization (FAO) of the United Nations. Table 1 lists all variables utilized in the

Table 1. Variables Utilized in Models

Variable Name	Source	Type of Variable	Description
Footprint of Fishery Production	Global Footprint Network	Continuous, DV	Global Hectares
Total Population	World Bank	Continuous	De facto, total residents
Per Capita GDP	World Bank	Continuous	2010 Constant Dollars, Divided by Midyear Population
GDP Quadratic	World Bank	Continuous	$(GDP/Capita)^2$
Urban Population, Percent of Total Population	World Bank	Continuous	Number of Persons in Urban Zone, percent of 100 Persons
Non-dependent age population	World Bank	Continuous	Percent of Total Population between Age 15 and 64
Seafood Exports	FAO Food Balances	Continuous	Total Fish/Seafood, Metric Tons
Direction of Trade Statistics	IMF	Continuous	Constant $ Value, Exports to Wealthy Nations
Financial Development	IMF	Categorical	Based on Financial Development Index Score
Foreign Direct Investment (FDI) Dependence	World Bank	Continuous	FDI Inflow, % of GDP

study and includes their sources, with the exceptions of financial development level and the GDP quadratic, all variables are log transformed to adjust for skewness and to allow for straightforward interpretations of variables based on percentage change (York, Rosa, and Dietz 2003).

The dependent variable, fisheries footprint of production, quantifies the amount of marine territory, measured in hectares, required to sustain a nation's harvested species (Borucke et al. 2013). It is thus a measure of the ecological impact of national-level fisheries production. The fisheries footprint of production considers not only the amount of fish harvested within a country, but also includes ecosystem considerations of the species harvested (Ewing et al. 2019). Specifically, the calculation for fishing grounds footprint is based on the primary production requirement (PPR) needed to sustain a harvested aquatic species. This equation is here:

$$\mathrm{PPR} = \mathrm{CC} \cdot \mathrm{DR} \cdot (1 / \mathrm{TE})^{(\mathrm{TL}-1)}$$

CC is the carbon content of wet-weight fish biomass, DR is the discard rate for bycatch, TE is the transfer efficiency of biomass between trophic levels, and TL is the trophic level, or hierarchy within the marine foodweb of the species (Borucke et al. 2013). The trophic level consideration allows the footprint indicator to weigh larger, predatory species, whose harvest is generally considered less sustainable, more heavily than an equivalent quantity-weight of species that occupy lower positions in the marine food web. By incorporating these ecological considerations, the fishery footprint of production provides more holistic ecological insight than a mere production volume indicator. Similarly, because the footprint of production focuses strictly on production processes and their ecological implications, but excludes export/import balances, it allows the study to comment directly on the ecological space required to reproduce a country's harvest.

To evaluate the impact of economic growth, this study includes GDP/Capita and its quadratic form (GDP/Capita).[2] Taken from the World Bank development indicators (2020), GDP/Capita is measured in constant dollars to adjust for inflation. Per capita GDP operationalizes economic development and tests for the growth-oriented, environmentally deleterious treadmill dynamic. According to modernization perspectives, as less-affluent nations increase their wealth, there should be a curvilinear or inverted U shape relationship between GDP growth and the environmental impact indicator (Grossman and Krueger 1995). Put differently, at higher levels of economic development, there should be noteworthy declines in the fisheries footprint of production metric, according to this perspective.

To evaluate the potential of export-oriented food system development as a market rationalizing or ecologically deleterious force, this study includes seafood exports and direction of trade data as explanatory variables. Increased seafood exports suggest higher levels of export-oriented, seafood system production. Higher values of the direction of trade statistic, or economic value of trade sent to affluent countries, signify increased economic relations with global North countries. Both these indicators examine incorporation into the world capitalist food system. Again, advocates of blue growth generally argue that such incorporation is an essential component of marine fisheries development that can coexist with long-term improvements in environmental indicators within developing nations. Critical food system scholars generally posit the inverse that increased export-oriented development and economic relations with affluent nations lead to ecologically deleterious outcomes in the material bases of agri-food systems. In focusing on the material bases of aquatic food systems, this study extends upon prior, similar cross-national analyses of terrestrial environmental impact, economic growth, and export-oriented development (Hedlund et al. 2020; Longo and York 2008).

Similarly, models also examine financialization and foreign direct investment, and their potential effects on fishery footprints across less-affluent nations over time. Level of financial development is based on the IMF's financial development index score for nations. Categories of financial development are grouped based on these scores, which the IMF explains as a measure of a nation's depth, access, and efficiency of financial markets and institutions (IMF 2021). More specifically, this indicator includes considerations that rate financial institutions such as banks, investment banks, insurance companies, and venture capital firms. In addition to financial institutions, the indicator evaluates the depth of nation state-level financial markets, mainly stock and bond markets (Sahay et al. 2015). Nations at high levels of financial development are those whose financial development index scores, over time, rate in the top third of possible scores for all countries graded by the IMF. Medium and low financially developed nations follow in similar a suit. This holistic metric allows the study to comment upon the impacts of national financial development according to dominant assumptions about how finance systems should be organized and structured. In other words, it is assumed that nations with higher levels of national financial development would be more amenable to, or vulnerable to, many processes associated neoliberal financial development described in the previous section.

In addition, to assess the long-term impact of increased capital investment in less-affluent nations, models include net foreign direct investment inflows measured as percentage of nations' GDP. According to blue growth and modernization perspectives, such investments, in conjunction with higher levels of financial development, can fund improvements in technological efficiencies, management, and stimulate environmental sustainability over time. Conversely, world food system scholars posit that these indicators constitute social forces that foster exploitative dependency and, ultimately, continued ecological degradation in less-affluent countries. Remaining variables focus on controlling for population dynamics shown to be essential in quantitative, cross-national studies of environmental impact (Dietz, Rosa, and York 2007; York et al. 2003).

Models

I present findings from five multi-variate regression models, all of which are organized in a log–log form, consistent with approaches in cross-national time series regression analysis in environmental sociology (Jorgenson and Clark 2012; York et al. 2003). This allows for a relatively straightforward interpretation of coefficients; for example, a coefficient of 1 would indicate a 1 percent increase in the dependent variable for every 1 percent change in the explanatory variable.

Model 1 serves a base model that includes population controls along with per capita GDP and the GDP quadratic. Models 2 and 3 include additional variables that assess export, trade, financial development, and foreign investment to assess potential effects on the dependent variable, footprint of fisheries production. Models 4 and 5 utilize interaction effects to further examine the extent to which export and investment indicators vary according to a nation's level of financial development. These interaction models enable the study to comment on how these key indicators vary across different levels of less affluent nations, which (as the financial development index implies) differ in terms of the modernization of their financial institutions and markets. Prior, similar studies have applied interactive effects across continuous variables and categorical variables that delineate both region and time period (Clark and Longo 2019; Jorgenson and Clark 2010; Jorgenson and Givens 2015; York and Gossard 2004). Constructing interaction terms enables the models to assess the extent to which the effects of the continuous variables of interest vary at different levels of national financial development. All models also include country-specific intercepts, or a country-based categorical variable, which enable the models to adjust for unobserved country-specific differences time invariant differences, like available coastline or latitude.

Diagnostic tests of the base model, model 1, indicated that heteroscedasticity and serial correlation were present in the panel data. To adjust for these common issues, models utilized panel corrected standard errors (xtpcse, under STATA's xt suite of commands) and an autoregressive option (ar1), both of which help account for these common issues in large-scale panel data (Beck and Katz 1995; Rabe-Hesketh and Skrondal 2012). Models are unbalanced and incorporate pairwise deletion to avoid losing relevant observations. Multi-collinearity between explanatory variables occurs among population controls, particularly urban and working age population. I therefore removed the urban population control from more specified models. Table 2 describes the models utilized in this study.

Results

Table 3 presents the coefficients and coefficient standard errors for models 1, 2, and 3. Interpretations of coefficients report magnitude net of all other effects within the respective model.

The population controls presented in model 1, 2, and 3, all reach statistical significance. Total population and non-dependent age population (i.e., percent working age) suggest that more people, and specifically more people of working age, correspond with increases in the fishery footprint of production within less-affluent nations. After running post model estimation commands to check for collinearity, urban population rate illustrated high collinearity with per capita GDP and non-dependent age structure, so subsequent models remove it for the sake of clarity and parsimony.

A noteworthy finding from model 1 is the statistically significant and negative GDP quadratic. This negative coefficient suggests that, at

Table 2. Models Presented in Study

Models	Description	Time Frame	Observations	Nations	Average Observations Per Nation	R^2
Model 1	Base Model	1975–2016	3,387	114	29.7	.926
Model 2	Seafood Trade, Trade Direction	1975–2016	2,470	105	23.5	.957
Model 3	Financial Investment, Integration	1975–2016	2,218	102	21.75	.970
Model 4	FDI*Financial Development Level	1975–2016	2,231	102	21.87	.970
Model 5	Seafood Exports*Financial Development Level	1975–2016	2,231	102	21.87	.970

Table 3. Results from Models 1, 2, and 3

Variables	Model 1, Base	Model 2, Trade	Model 3, Trade + Investment & Finance
Per Capita GDP, Constant USD	.249***	.154**	.070
	SE .07	*SE .073*	*SE .082*
GDP Quadratic	–.1.04e–9***	–9.79e–10	–9.51e–10***
	SE. 2.01e–10	*SE. 1.89e–10*	*SE 2.12e–10*
Total Population	1.53***	1.27***	1.18***
	SE .145	*SE .100*	*SE .085*
Non-Dependent Population, % Total	1.09**	.1.36**	2.27***
	SE .540	*SE .570*	*SE .621*
Urban Population, % Total	–.316*	–	–
	SE .145		
Seafood Exports, MT	–	.090***	.085***
		SE .016	*SE .020*
Trade Toward Affluent Nations, Constant USD	–	–.008	–.014
		.018	*SE .019*
FDI Inflow, % GDP	–	–	.020**
			SE .007
Moderate Financial Development	–	–	5.93***
			SE .310
High Financial Development	–	–	3.1***
			SE.370

Note: Model 3 Constant, Low Financial Development, Value of –18.2.
$^{***}p < .01$; $^{**}p < .05$; $^{*}p < .1$.

higher levels of per capita GDP, increases in this measure of affluence correspond with decreases in less-affluent nations' fishery production footprints. This quadratic effect remains statistically significant and negative in more specified models as well, although the magnitude of the coefficient decreases across models 2 and 3. I comment more on the nature of this effect in the discussion section.

Model 2 includes coefficients for seafood exports and direction of trade statistics. The statistically significant and positive coefficient for seafood exports suggests that, for every 1 percent increase in a less-affluent nations' seafood export quantity, there is a corresponding increase of these nations' fishery production footprints by about .1 percent. The coefficient for direction of trade, or constant dollar amount of exports sent to affluent nations, did not reach statistical significance. I provide more substantive interpretation of these and all remaining findings in the discussion section.

Model 3, the last model with no interaction terms, includes measures of financial development and foreign direct investment dependence. The coefficient for foreign direct investment dependence, measured

Table 4. Interaction Models

Variables	Model 4, FDI*Financial Development	Model 5, Seafood Exports*Financial Development
Per Capita GDP, Constant USD	.061 *SE .082*	.055 *SE .081*
GDP Quadratic	−9.73e−10*** *SE. 2.06e–10*	−9.64e−10 *SE. 2.02e–10*
Total Population	1.17*** *SE .089*	1.17*** *SE .083*
Non-Dependent Population, % Total	1.98** *SE .655*	1.96** *SE .635*
Urban Population, % Total	–	–
Seafood Exports, MT	.084*** *SE .019*	.064** *SE .016*
Trade Toward Affluent Nations, Constant USD	–	–
FDI Inflow, % GDP	.020* *SE .010*	.017** *SE .010*
Moderate Financial Development	1.90*** *SE .322*	5.05*** *SE .435*
High Financial Development	1.32*** *SE .321*	2.53*** *SE .481*
Moderate Financial Development*FDI Inflow	.007 *SE .017*	–
High Financial Development*FDI Inflow	−.016 *SE .012*	–
Moderate Financial Development*Seafood Exports	–	.102** *SE .040*
High Financial Development*Seafood Exports	–	−.038 *SE .032*

***$p < .01$; **$p < .05$; *$p < .1$.

as percent of GDP, is statistically significant and positive, and suggests that a 1 percent increase in this measure corresponds with a predicted increase of about .02 percent in less-affluent nations' fishery production footprints. The statistically significant categorical terms for financial development suggest that the least financially developed nations typically have a lower floor for fisheries production impact than nations with more higher metrics of financial development.

Models 4 and 5 include interaction terms. These models sought to explore if statistically significant indicators of world food system incorporation varied across levels of financial development. Table 4 presents findings from these models.

Results from model 4 indicate that the impact of foreign direct investment dependence does not substantively vary at different levels of

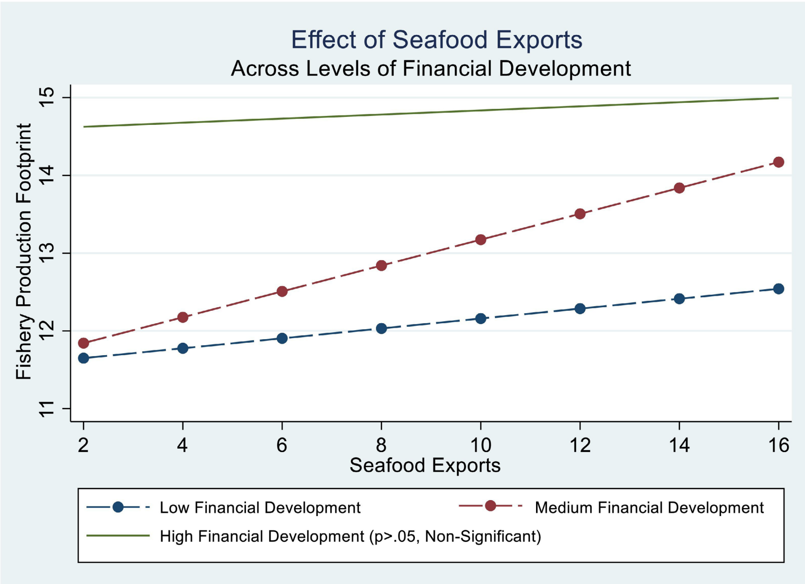

Figure 2. Predicted Effects of Seafood Exports At Different Levels of Financial Development. [Colour figure can be viewed at wileyonlinelibrary.com]

financial development. Conversely, model 5 indicates that the impact of seafood exports on fishing production footprints of less affluent nations does vary according to the level of financial development. Post estimation commands (margins, in STATA) were utilized to learn more about the nature (significance and magnitude) of the interaction terms' slope coefficients. Figure 2 presents these slope coefficients, and their differences, more clearly.

Figure 2 indicates that, while the most financially developed nations in the sample generally have higher levels of fishery production footprints, seafood exports tend to have more substantive impacts in nations with low-to-moderate levels of financial development. The effect, or slope coefficient, is most substantial, and thus statistically significant, in nations with a medium or moderate degree of financial development. The discussion section unpacks the nature and meanings of these findings in further detail.

Discussion

Blue Growth versus the Treadmill of Production

This study did not find substantial support for the theses advanced by blue growth frameworks. The study did reveal a statistically significant

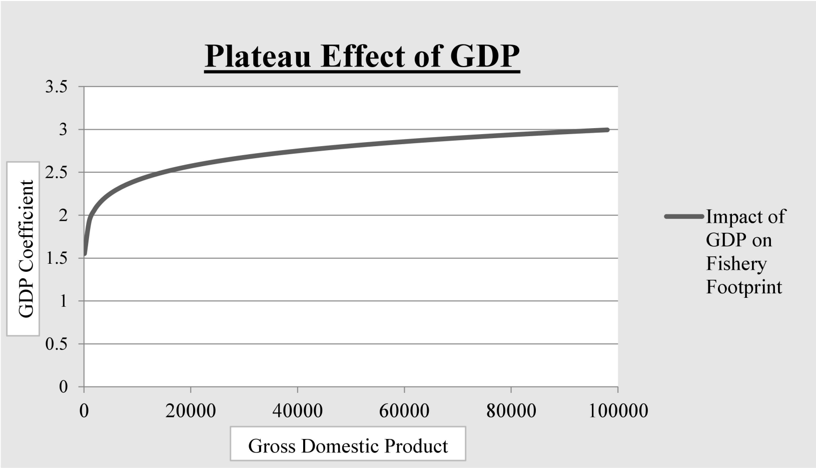

Figure 3. Quadratic Fit of Per Capita GDP (Constant USD).

quadratic effect, which echoes ecological modernization's arguments over the potential of market-oriented growth to positively shape environmental impact over time. However, the coefficient for the quadratic term was rather small and, furthermore, the turn occurs at a very high level of affluence—especially when controlling for other relevant developmental factors. Figure 3 visualizes the effect of the GDP quadratic on fisheries production, controlling for trade, financialization, and foreign investment dependence.

The statistically significant GDP quadratic thus suggests that a quadratic fit is more appropriate to chart this non-linear relationship. However, the nature of this coefficient does not indicate an inverted U-type relationship or qualify as strong evidence of sustainable modernization necessary for blue growth.

Rather, as the chart title suggests, the effect of GDP plateaus, or reaches a ceiling, at higher levels. In addition to the lack of declining impact, one must also consider the limited capacity for marine ecosystems to generate economic wealth. While commodity exchange value is theoretically limitless, ecological systems are governed by certain universal requirements. Fish and marine life, for example, exist within a greater marine food web where nutrients, matter, and energy must be (re)cycled through to reproduce life (Pauly et al. 1998. Because such processes can be disrupted significantly if certain species are extracted, they cannot always abide by the economistic, limitless demands of generalized commodity production (Longo et al. 2015; Saito 2017). Marine science on global fisheries strongly emphasizes that, in recent years, the productive capacity of marine systems to procure seafood is stressed with little room for expansion (Victorero et al. 2018). Substantive declines in the reliability of wild marine systems to produce fish for harvest have led to increased reliance on aquaculture production; however, this industry is still somewhat nascent and scholars debate its impacts (Longo et al. 2019).

The capacity of ecological impact to continuously expand alongside GDP is therefore doubtful, especially in wild marine ecologies where capital cannot easily "improve" upon metabolic rates as it can in terrestrial-based agri-food systems with inputs like soil fertilizer (Campling and Colas 2021). This dynamic results in the continuous pushing of metabolic boundaries in wild capture fishery systems, specifically with more efficient productive technologies that can withdraw fish at rates necessary to sustain treadmill demands. Thus, as Bunker and Ciccantell (2005) reason, long-term declines in ecosystem fecundity can stimulate treadmill developmental dynamics in market economies over time. This general tendency is especially apparent in treadmill-based fisheries, where growth and material expansion constitute the overarching logic. There exists, in modern fisheries, a kind of paradox where extractive capacity of modern fishing fleets is vastly greater than in prior periods; yet, fishing is a far less efficient activity in terms of time, costs, and total impact. To save labor costs and maintain profits, commodity fishing has expanded its spatial terrain and its investments in fixed capital, realized in larger vessels, more intensive technologies, and pressures to reduce worker pay (EJF 2019; Howard 2017; Parker and Tyedmers 2015).

These tactics "work" to increase fishing productivity and extraction to an extent, but eventually run out of new terrain, species, and waters to appropriate (Campling and Colas 2021; Longo et al. 2015). Thus, from a treadmill perspective, the long-term ecological harm caused by growth-oriented dynamics has come home to roost in global fisheries. There are, simply, not enough fish in the sea to support endless treadmill-oriented production. Thus, more direct, non-market approaches that transcend modernist blue growth logics are necessary to mitigate fishery impact. In other words, there is insufficient evidence to support the notions that economic growth can self-regulate via continued development of efficient technologies and more effective, industrial methods.

World Food System Dynamics

Model 3 revealed that foreign direct investment dependence corresponded with increasing fishery production footprints over time for the sample of less-affluent nations. This finding follows other quantitative, environmental political economic work on the world system, which illustrates that foreign direct investment dependence, measured as percent of national GDP comprised by FDI, corresponds with increasing environmental impacts of various productive sectors in less-affluent nations over time (Doytch 2019; Jorgenson 2010; Kentor and Grimes 2006). Importantly, such scholarship emphasizes that the world political economic order is structurally unequal, and that incorporation into this system allows for affluent nations to continuously outsource ecological intensive production (Jorgenson 2012, 2016). In food systems, this larger globalization project is stimulated via export-oriented development, FDI dependence, and the growing importance of finance capital (Clapp 2014; McMichael 2005).

This study largely confirms that these trends, which sociologists have generally explicated more in terrestrial based production, occur in fisheries and marine environments. For example, seafood exports proved to be a consistent, positive driver of less-affluent nations' fishery production footprints. This suggests that export-oriented seafood production has had unsustainable consequences over time in the waters of less affluent nations. This pattern also points to a dynamic of inequitable environmental load displacement and global environmental injustice. Indeed, nations in the EU, Japan, and the United States consume roughly one-third of the world's seafood despite comprising only about 10 percent of the global population (Swartz et al. 2010). In the United States, specifically, around 80 percent of total volume seafood consumed is not produced domestically (NOAA 2017).

These dynamics become clearer in models that include level of financial development's main and interactive effects. Nations with higher levels of financial development generally have larger fishery production footprints to a statistically significant extent. These differences are described further in Table 5.

This pattern makes sense, given that higher levels of financial development correspond with more advanced commodity markets that international private firms can access with ease. Financial development includes

Table 5. Historical Mean Fishery Production Footprint According to Financial Development Level

Financial Development Level	Observations	Mean Fisheries Production Footprint (Log)
Low	1,607	11.6
Moderate	1,022	12.0
High	1,717	13.9

the deepening of both financial institutions, like private banks, but also financial stock and bond markets (Sahay et al. 2015). In a trade and investment dependent industry, like global seafood, it makes sense that more highly financially developed nations would accumulate larger fishing production footprints.

These findings pose two key challenges to modernization perspectives. First, these perspectives typically argue for financial deepening to spur investment in efficient technologies and environmental management programs. Moreover, advancing financial development may imply a less production-intensive method of accumulating capital within nations (Roberts 2018). However, models presented here suggest that financial development has, so far, not led to more sustainable outcomes in the waters of less-affluent nations. Second, when one considers the predicted effects of seafood exports by level of financial development, presented in Figure 2, this developmental pattern largely conforms to what unequal ecological exchange theorists have posited for years: more firmly peripheral states, with lower levels of economic development and formal marketization, serve as export-oriented supply depots and commodity frontiers (Bunker 1984; Frey, Gellert, and Dahms 2018; Jorgenson 2016; Moore 2000). Thus, this finding suggests that higher levels of financial development, while not necessarily producing more sustainable outcomes, procure nations economic power within the global seafood supply chain.

Indeed, nations with historically moderate and low financial development index scores have, over time, engaged in more ecologically intensive export-oriented seafood production. These nations consume substantially less seafood per capita than nations within the highest level of financial development in the sample. Specifically, the per capita seafood consumption of nations at the highest level of financial development was roughly 43 percent greater than nations at the lowest level of development, and about 27 percent higher than moderate nations. These low to moderate nations, which comprise the majority of the sample, are at risk of sacrificing their own marine environments to meet the demands of global commodity production and external seafood consumption, both of which are disproportionately enjoyed by global North firms and consumers.

These findings also point to tensions regarding financial development, sustainability, and blue growth. As a proxy of the nebulous concept of financialization, financial development can be understood as developing means through which the accumulation capital can continue to occur in the context of a less profitable productive sphere (Roberts 2018). Interestingly, this critical conception of financialization sounds quite similar to arguments advanced by the most ardent critics of blue growth and the broader blue economy project. Brent et al. (2020) reason that blue growth approaches constitute a geographic fix to the problem of declining profitability and circulation of fixed capital. Thus, as briefly described in the theoretical review section, new initiatives to finance marine conservation efforts (i.e., the marine protected area or MPA) also constitute efforts to generate profits in stressed ecosystems, where new productive and profitable fishing potential may be limited.

However, in addition to problems associated with neocolonialism and ocean grabbing (Bennet et al. 2015; Barbesgaard 2018), the creation of MPA's or similar blue financing initiatives does not negate the growth imperative, or the treadmill dynamic, of capitalist fisheries. This persistent trouble is evident in studies that highlight how fishing intensity often increases outside or just beyond the borders of the MPA (Agardy, Di Sciara, and Christie 2011; Kleiven et al. 2019). Thus, despite new finance mechanisms, the need to expand the productive base of the capitalistic ocean economy will remain (Mallin and Barbesgaard 2020). As such, the findings and implications presented here suggest that the "plateau effect" of GDP, as described in this study, will likely continue without radical change in the productive imperatives of global fisheries.

Limitations and Non-Findings

Future scholarship should work to clarify if world polity dynamics, such as membership in international organizations, treaties, agreements, or conservation efforts moderate the effects of the deleterious impacts of growth, trade, financial development, and foreign investment in marine systems. This approach would echo calls for strong ecological modernization, guided by a democratic environmental state and international civil society (Jänicke, 2008, 2009; Mol 2002). This would be an interesting avenue of research in marine sociology and policy, especially given the somewhat nebulous governance of marine environments and the high seas. However, such currents of thought have received important theoretical challenges from some scholars, who reason that large-scale marine conservation or protectionary policy and rhetoric can conceal exploitative and unjust ocean-grabbing processes (Barbesgaard, 2018; Bennett et al. 2019; Mallin and Barbesgaard 2020).

Within this study, the lack of statistical significance for the direction of trade statistic and the FDI*Financial Development interaction was somewhat surprising. The direction of trade metric quantifies the amount exports sent to affluent nations, in terms of market value. This lack of significance may stem from larger patterns in the global seafood trade that have intensified in recent years. Specifically, global seafood value chains are increasingly buyer-driven, with global North grocery and food distribution firms pushing competition upstream to producers who must lower their prices to remain competitive (Clark et al. 2021). Thus, while seafood is generally considered higher value than other food commodities, this distinction may be blurring as upstream competition intensifies. The lack of statistically significant FDI variation at different levels of financial development signifies that foreign investment dependency's impact is somewhat typical across these levels. While this did not conform to initial expectations, this non-finding suggests that FDI dependency results in similarly unsustainable outcomes regardless of nations' financia development.

Conclusion

This study makes several important contributions to the fields at the intersection of environment, food systems, and community development. First, it answers the calls made by scholars to advance sociological and critical political economic knowledge of marine socioecological dynamics (Hannigan 2017; Longo and Clark 2016). More particularly, while sociological scholars have conducted similar studies of terrestrial and atmospheric ecological impacts (e.g., deforestation or carbon emissions), far less sociological attention has been paid to the social drivers of marine sector degradation. This study thus answers Longo and Clark's (2016) call to further sociohistorically informed, marine sociological scholarship.

In that vein, marine sociological scholarship has utilized fishery footprint indicators in prior analyses (Clark et al. 2018; Clark and Longo 2019; Jorgenson et al. 2005). Those studies, however, examined the fishery footprint of consumption and, thus, could not comment authoritatively on how export dynamics and ecological exchange considerations mattered within their models. This study is (to author knowledge) the first of its kind, then, to apply sociological theory and methods to examine the ecological impact of nation's fishery production systems at this scale.

Accordingly, the findings point to the need to drastically rethink developmental assumptions of the blue economy—particularly those that promote a modernist, blue growth frame. Calls for blue degrowth are therefore increasingly relevant. Blue degrowth advocates for relocalization of production, collective ownership and stewardship, just distribution of resources, as well as cultural and regional specificity that resists the homogenizing tendency to imagine the ocean as strictly a means to economic growth and capital accumulation (Childs and Hicks 2019; Ertör and Hadjimichael 2020; Hadjimichael 2018). In these discussions, it is vital to center the concerns and demands made by fishing peoples, especially from historically marginalized, dispossessed, and threatened communities. Critically, in advancing food sovereignty and justice in coastal and marine systems, the World Forum of Fisher Peoples (2017) already is advocating for programs that articulate fundamental challenges to the blue growth paradigm:

> The industrial model of food production, its so-called Green and Blue Growth/Economy and various forms of Ocean, Land and Water grabbing all contribute to dispossessing fishing communities and destroying our natural habitats. The industrial food system is a key driver of the multiple crises of climate, food, environment, public health, and others. Free trade and corporate investment agreements, investor-state dispute settlement agreements, and false climate solutions such as the Blue Carbon scheme of the United National Framework Convention on Climate Change, and the growing financialization of nature and food, all further aggravate these crises.

In short, the blue growth paradigm cannot solve problems of displacement, hunger, and ecological injustice because these issues are fundamentally driven by the very same mechanisms that have long contributed to these overlapping crises.

The analysis presented here finds evidence to support these critiques, especially pertaining to environmental impact and inequity. This study's overarching contribution indicates that the political economy of global fisheries and the world seafood system result in uneven and inequitable marine ecological impacts at a cross national scale. To help resolve this on-going problem, scholars should critically examine blue growth discourses that advance mechanisms of expansion, trade, capital investment, and finance capital. According to this study, there is little reason to believe that these market forces, especially without intentional regulation, can advance sustainable development goals in global fisheries. In addition to exploring more direct, policy-oriented routes to just and sustainable development, this study reasons that it will be important to re-imagine developmental goals, especially as they pertain to profit and economic development that, all too often, come at the expense of marine systems and coastal communities across the global South.

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