Global fishing and seafood trade burdens places with ineffective fisheries management

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Article

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Abstract

Seafood is the most traded food commodity globally, but is underpinned by unsustainable fishing practices. When a country obtains seafood from outside its jurisdiction, any negative social and environmental impacts associated with fishing are displaced to the fished location. 'Unequal displacement' occurs when seafood is obtained from a place with poorer, less-effective, fisheries management than the country that catches or imports the seafood. We found that up to 22% (19.9 MT) of wild-capture seafood was unequally displaced, much of which is caught in the high seas, Russia, Malaysia, and Angola. Unequal displacement occurs for up to 50% (10.0 MT) of traded seafood. Almost all 172 countires that we assessed unequally displace seafood, but few are responsible for the majority (China, India, Thailand, Russia, South Korea, Spain, Netherlands, UK, USA). Achieving both sustainable food provision and ocean health requires new policies that encourage the reduction of unequal seafood displacement.

Main Text

Introduction

Global per capita seafood consumption has more than doubled since the 1960s, providing billions of people around the world with a nutritious source of protein [1,2]. In addition to its health benefits, seafood supports the livelihoods of 100s of millions of people involved in capture fisheries [3] and aquaculture [4]. Although aquaculture is a rapidly increasing seafood source [2], fisheries remain important not only as a direct source of seafood, but indirectly, providing fishmeal required for many types of aquaculture and agriculture [5,6]. This reliance on fishing has had severe ecological [7–9] and socioeconomic [10–12] consequences, including widespread declines in fish populations, habitat destruction, and slavery [13–15].

Individual countries are primarily responsible for managing fisheries within their own exclusive economic zone (EEZ: 200 nautical miles from the coast), and are supported by numerous national and international mandates for sustainable, or effective, management (e.g., 2030 Agenda for Sustainable Development, USA Magnuson-Stevens Fishery Conservation and Management Act). However, a country can obtain fisheries products used for human consumption or animal feed (henceforth referred to as 'seafood') from waters outside their own jurisdiction through trade and international fishing (Figure 1) [16–18]. Thus, the seafood demand in one country impacts the oceans and fishing economies that extend beyond its boundaries, outside of its management jurisdiction.

We define a country's 'seafood footprint' as the total amount of fisheries products used by a country. The amount obtained from outside of a country's own jurisdiction is referred to here as 'seafood footprint displacement'. Displacing a country's seafood footprint is unsustainable when it introduces negative social and environmental problems elsewhere [19,20], including those associated with destructive, illegal, and overfishing [13,21]. Numerous terms and concepts from multiple disciplines have been used to describe such displacement, including 'externality', 'leakage', 'spillover effect', and 'unequal ecological exchange' [20]. We characterize seafood footprint displacement as 'unequal' when seafood is obtained from a place with poorer, or less-effective, fisheries management than the foreign country that catches (or imports) the seafood. This definition draws upon the ecological economic theory of 'unequal ecological exchange' pioneered by Bunker (1984), which is the unequal material exchange structured by trade and the corresponding movement of ecological footprints of economically strong regions to weaker ones [22,23]. For example, at the expense of the country where seafood is caught, the foreign fishing (or importing) country reaps the economic and/or nutritional benefits of consuming and trading the seafood [24]. Unequal displacement is particularly problematic when the seafood is obtained from a country that is heavily reliant upon coastal resources for subsistence [25] and/or is caught or consumed by a country that manages its own fisheries well.

One of the most significant challenges in assessing displacement is that the traceability of seafood supply chains is poor [26]. However, substantial effort has been made to track global fishing and document seafood trade [27–31]. Resulting international fishing data is important for identifying which, and how much, countries are fishing outside of their own jurisdiction and where displaced fishing is occurring (Figure 1). Since the fishing country does not necessarily consume the seafood they catch, trade data from wild-capture fisheries can be used to estimate which countries consume displaced seafood – these places play an important role in driving seafood displacement. Coupled with information on fisheries management effectiveness [32,33], the magnitude and spatial extent of unequal seafood displacement can be estimated, and the countries whom are the biggest culprits can be identified. Such information is critically needed to improve the social and environmental sustainability of global seafood.

We develop an index - Seafood Footprint Displacement Index – and apply it to fisheries and seafood trade datasets independently from 1976-2015 to determine: (1) total Seafood Footprint Displacement (for fishing and trade separately) - the amount of seafood each country obtains from outside its own jurisdiction, whether the high seas or another country's EEZ and; (2) unequal Seafood Footprint Displacement - the amount of seafood each country obtains from jurisdictions with less effective fisheries management [32,33] (we refer to this as 'unequal fishing displacement' when applied to the fisheries dataset and 'unequal import displacement' when applied to trade; Figure 1); and (3) where unequally displaced seafood was caught, revealing the spatial distribution of the burden of unequal displacement.

Materials and Methods

Seafood Footprint Displacement Index

The Seafood Footprint Displacement Index (S_i) is the total amount of seafood country i (i=1,…,172) sources from outside its own EEZ. We calculate the index for two different datasets (described below) that represent the amount of seafood exchanged between countries through: (1) international fishing and (2) international trade of wild capture fisheries (Figure 1). We assess displacement for each dataset separately for fishing and trade, as each reveals different elements of displacement, and we exclude illegal, unreported and unregulated estimates of fishing. The fishing data are the basis for estimating how much country i caught in the EEZ of country j and the high seas. However, fishing country i does not necessarily consume the seafood they caught as it can be exported (Figure 1). The consuming (i.e., importing) country also plays a role in driving displacement, and can be determined using data on international trade.

When using the wild-caught global fishing data, $S(fishing)_{i,} = \sum_{j \neq i}^{N} R_j + H_k$, where R_j is the amount of seafood (tonnes) obtained in the EEZ of country j and H_k is the amount obtained from the high seas, by country i. When using global trade data, $S(trade)_{i,} = \sum_{j \neq i}^{N} Q_j$, where Q_j is the amount of seafood (tonnes) imported from country j by country i. To determine the unequal Seafood Footprint Displacement, we calculate the amount (in tonnes) of seafood footprint displaced to places with less-effective fisheries management (defined below) than the importing or fishing country, a subset of S_i, annually between 1976-2015 – referred to as 'unequal import displacement' and 'unequal fishing displacement', respectively. Finally, we use the fishing data to determine where such fishing occurs globally.

Data

International fishing

We used a global catch database to estimate the annual volume of fish caught by each fishing country in industrial and non-industrial fisheries [28,31]. The database is spatially explicit, allowing estimation of the location and quantity of seafood caught, whether in a specific EEZ or the high seas. For the high seas, the data do not indicate catch per region; thus, we treat the high seas as one region. The data combines publicly available data from the Food and Agriculture Organisation of the United Nations (FAO) with a range of other input sources for reported fisheries landings, including the Regional Fisheries Management Organisation, the Sea Around Us Project, Global Fishing Watch, and satellite positional data. Previous comparisons have confirmed that the catch database we used has the same general patterns as that made available by the Sea Around Us[28,31,34].

Seafood trade

We used a global seafood trade database that estimates the annual volume of seafood imported by each country (i.e., our best estimate of where the species is consumed) and its origin (i.e., exporting country) [27]. The data identifies if the export is aquaculture or wild-capture, and categorizes if each record was a re-export (i.e., exported more than once). We excluded re-exported trade and aquaculture records when assessing the Seafood Footprint Displacement Index for each country. The trade data that we used only indicates the exporting/importing countries, and does not indicate where the seafood was initially fished (Figure 1), thus we evaluate fishing and trade individually.

Fisheries management effectiveness

We used historical fisheries management effectiveness determined by Mora et al. (2009) for individual countries ($0>m_j>1$, where higher scores represent more effective fisheries management) and Cullis-Suzuki et al. (2010) for the high seas (m_k). Mora et al. (2009) determined management effectiveness scores based on 1,188 responses to a survey that measured the degree to which six key fisheries sustainability objectives were achieved within a country. Cullis-Suzuke et al. (2010) assessed the effectiveness of the world's regional fisheries management organizations (RMFO) at managing 48 fish stocks. We used the average management effectiveness value across RMFO (m_k=0.49) for the high seas because the fishing data that we used considers the high seas as one unit. This value is consistent with the values that we used for individual countries (m_j, range 0.41-0.77; average 0.61), supporting the consensus that high seas fisheries are poorly managed [35] relative to most countries.

For countries that had more than one management score for different areas (e.g., Hawai'i and Alaska within the United States), we used the average of all scores for each surveyed area to obtain one overall management effectiveness score for each country as other data used in our analysis were only available by country, not individual regions within a country. We assumed management effectiveness for a given country was constant from 1976-2015 but acknowledge that it can be highly variable through time [36]. Given the management effectiveness data is likely to be more relevant in more recent years, we report most of the results as an average of the most recent five-year period (2011-2015). We calculated the Seafood Footprint Displacement Index for countries containing data for management effectiveness, trade, and international fishing (n = 172).

Results

Seafood Footprint Displacement (using fishing data)

Depending on the year, we found that 24-48% (27.8-40.0 million tonnes) of all fisheries production is caught outside of the fishing countries' jurisdiction (i.e., displaced) and 17-22% (16.1-19.9 million tonnes) is displaced from less-effectively managed places annually (i.e., unequal fishing displacement; Figure 2). Over time, the proportion of displaced seafood that is unequally displaced by fishing has steadily increased from 40 to 73% between 1976-2015 (Figure 2c). Since 2013, the majority of unequally displaced seafood was caught in the high seas (up to 52%), but historically the majority (up to 79%) was caught in EEZs (Figure 2a; Supplementary Table 1).

We assess average annual fishing displacement and unequal fishing displacement by each country during the most recent period (2011-2015) (Supplementary Table 1). Nearly 76% of countries fish outside of their own EEZ (n=130) and most of these counties (n=113) fish in less-effectively managed areas (i.e., unequal fishing displacement; Figures 3 and 4). Of the countries that partake in unequal fishing displacement, 107 (95%) do so in the high seas and 51 (45%) do so in other EEZs. Sixty-two countries that unequally fish, only do so in the high seas; similarly, six countries only unequally fish in other EEZs (Supplementary Table 1). China, India, Thailand, Russia, South Korea, and Spain account for the majority (52%) of unequal fishing displacement, conducted in both the high seas and in other country's EEZs. These same countries account for 34% of the unequal fishing displacement occurring in the high seas.

We found that 17 of the countries that fish outside of their own EEZ, did not unequally fish. These countries either have very low fisheries management scores (bottom quartile) or displace negligible amounts of seafood by fishing (<0.1% of displaced seafood by fishing collectively), and most are remote island nations (i.e., America Samoa, Northern Mariana, Guam, US Virgin Islands, Belgium, and Niue). On the other end of the spectrum, there are 60 countries where 100% of their displaced fishing is done unequally (i.e., in places with less effective fisheries management) – these countries have a wide range of management effectiveness scores. Although a country with a high management effectiveness score may be expected to catch more in places with poorer management effectiveness, these two factors were not correlated (R^2=0.030, when considering total tonnes of unequal fishing displacement; R^2=0.059 when considering the proportion of unequal fishing displacement (Figure 4a)).

We assessed which areas bear the burden of unequal fishing displacement, i.e., which areas have the largest amount of fish extracted by a country with more effective management (Figure 3). Unsurprisingly, the high seas had the most fish caught by countries with better management (8.7 million tonnes) from 2011-2015. The countries with the greatest amount of unequal fishing displacement occurring in their waters were (thousand tonnes): Russia (2700), Malaysia (755), Angola (752), Saudi Arabia (661), Norway (388), Ireland (364), Japan (352), Mauritania (250), Iceland (242), and Spain (216). The countries that are the sources of the greatest amount of unequal fishing displacement vary in size of EEZ, spatial location and governance and fisheries management effectiveness.

Seafood Footprint Displacement (using trade data)

We found that, depending on the year, 1.97-23.5 million tonnes of fish are imported and 36-50% (0.98-10.0 million tonnes) of a country's imports originate from less-effectively managed countries annually (referred to as unequal import displacement; Figure 2b; Supplementary Table 1). The proportion of imports classified as unequal has remained relatively stable (below 44%) since 1982 (Figure 2c).

We assessed average Seafood Footprint Displacement by each country during the most recent period (2011-2015) in terms of amount imported and amount unequally imported. We found that 91% of countries (n=157) imported (i.e., displaced) seafood, and that a majority (51%) of imports can be explained by 11 countries (China, Japan, USA, Spain, Thailand, Netherlands, France, Sweden, Germany, Nigeria, and South Korea). Most of these countries (n=145) partake in unequal import displacement (Figure 3b and 4b), but the magnitude of this varies enormously between countries (Figure 3b and 4b). China, USA, Spain, Thailand, Netherlands, South Korea, and the UK account for the majority (55%) of unequal import displacement. We analyse this relative to the fishing countries management effectiveness score and found that the amount (in tonnes) of imported seafood is not well correlated with management effectiveness (R^2=0.080); however, the proportion of unequally imported seafood correlates with management effectiveness (R^2=0.62) (Figure 4b). For example, the twelve countries that imported seafood, but not unequally, have very low (<0.55) management effectiveness scores. Additionally, the countries whose imports were nearly all classified as unequal have very high (>0.70) management effectiveness scores (Supplementary Table 1).

Discussion

We found that unequal seafood displacement is a widespread problem that has increased over time. Almost every country, despite the rigor of their fisheries management policies, obtains seafood from places with poorly managed fisheries through international fishing and/or trade. A majority of unequal seafood displacement is done by a small number of countries, some of which engage in unequal fishing and import displacement (e.g., China, Thailand, South Korea, Russia and Spain). The result that China is one of the biggest drivers of unequal seafood displacement is unsurprising given that it is the biggest seafood consumer, producer, and exporter in the world [4,37]. We discuss how our results reveal important insights into improving the social and environmental sustainability of seafood globally, a goal that is ubiquitous in national and global resource management policies (e.g., United Nations 2030 Sustainable Development Goals) as it is essential for a better future [21]. We make policy recommendations that would minimise unequal seafood displacement, but acknowledge that any policy change would require a more comprehensive assessment of social and economic implications.

Unequal seafood displacement is a form of "ocean grabbing", when inadequate governance results in the grabbing of resources (e.g., fish) that cause negative social and ecological consequences [38,39]. For example, Africa has witnessed declines in ecosystems and fisheries due to foreign fishing in their waters, usually by European and Asian nations, leading to the erosion of food self-sufficiency, food security, and disappearance of livelihoods for many coastal communities in these regions [40,41]. The displacement of environmental and social impacts from one jurisdiction to another is recognised as a fundamental challenge to environmental and conservation policies [20,24], but requires more attention in global fishing and seafood trade given the important role that seafood has in sustainably feeding our growing population.

Our results support a commonly suggested improvement to fisheries management: the reduction of fisheries subsidies. Fishery subsidies are estimated to range from US$14-54 billion per year, occur in 91% of the EEZs [4,32] and are associated with other unsustainable fishing activities (e.g., overfishing and IUU) (UNEP 2005). Interestingly, some of the biggest subsidizers of fisheries capacity were also highlighted as drivers of unequal seafood displacement (e.g., China, Japan, U.S., the European Union), investing billions of dollars towards fishing, often in distant waters, in other nations' EEZs [42]. Thus, a reduction in fishing subsidies globally would help reduce unequal seafood displacement, which is in line with current World Trade Organization negotiations aimed to "prohibit subsidies that threaten the sustainability of fishing to help ensure the sustainable use and conservation of marine resources" [43].

We found that the source of unequal fishing displacement has changed over time, with more seafood obtained from the high seas in recent years than in another country's jurisdiction. This is consistent with the well-known trend that the high seas is increasingly being fished and has been explained by several factors, including: technological innovations, fishery subsidies, too many ships chasing too few fish, establishment of EEZs as a result of United Nations Law of the Sea in 1982, and a growing demand for seafood [30,44]. Existing fisheries management in the high seas has been woefully ineffective, with >60% of fish stocks on the high seas designated as 'depleted or overexploited' [35]. Our results emphasise that fisheries management in the high seas is urgently required, including the elimination of transhipments that can mask the provenance of seafood and promote illegal fishing activity associated with perverse outcomes for both people and ecosystems [13,45–47].

Most countries practice unequal fishing displacement. Thus, improving country level policies that limit fishing in less-effectively managed places (i.e., high seas or other EEZs) is critical to mitigating unequal seafood displacement. Coordinated fisheries management relevant to the high seas and EEZs is important given the highly migratory nature of many commercially harvested species. For example, overfishing in one jurisdiction can lead to depleted stocks of that same species, in another jurisdiction [13,42,48]. Also, coordination is important as improving fisheries management in one jurisdiction, such as closing the high seas to fishing, could negatively impact low-income countries that are reliant upon marine resources [49].

The responsibility for the lion's share of unequal fishing displacement lies with few countries, namely China, India, Thailand, Russia, South Korea, Spain. Policy changes in these countries that focus on limiting fishing in places with ineffective fisheries management would most effectively mitigate unethical seafood displacement globally. Countries that allow a large amount of unequal fishing displacement to occur in their own EEZ, like Russia and Spain, could make an even bigger contribution towards minimising unequal seafood displacement by imposing stricter fishing regulations in their EEZ. Reducing fishing in these places would also help mitigate any perverse social and environmental impacts of fishing that they are experiencing [50]. On the other hand, countries with effectively managed fisheries (e.g., Iceland) that also allow countries with even better management to fish in their EEZ, are less likely to experience perverse impacts due to their rigorous management policies.

Countries with relatively good management effectiveness scores are assumed to effectively manage fisheries in their own jurisdiction. However, some of these countries engage in unequal seafood displacement, and thus may not be 'practicing what they preach' in regards to fisheries management. These countries (Figure 4) are proving the idiom 'you can't have your cake and eat it too' to be false, as they are benefiting from well managed fisheries in their own country (e.g., healthy ecosystems) and obtaining seafood from places with poorer fisheries management for their benefit (e.g., nutrition, economic). For countries with the highest management effectiveness scores (e.g., Namibia, UK), it is difficult to source seafood from countries with equal or better fisheries management, but they could catch more within their own, well-managed waters, or seek alternative sources of protein (e.g., seafood from sustainable aquaculture). In contrast, there are countries with relatively good management that source most of their seafood from counties with equal or better fisheries management (Denmark, France, Iceland); the policies of these countries should be investigated to help other countries improve.

Countries that import seafood from less-effectively managed places can improve trade policies to help mitigate unequal displacement. Similar to unequal fishing displacement, large gains could be made if leadership were to be demonstrated by the few countries that are responsible for a majority of unequal import displacement. Imposing trade restrictions (or modifying trade rules) on countries with poorly managed fisheries could incentivise those countries to improve local domestic fisheries management. Such changes to trade, however, should consider the socioeconomic implications on developing nations, similar to Fishery Improvement Projects, which engage ecological and social aspects of the fishery through supply chain incentives [51]. Similar trade restrictions have been imposed to improve the sustainability of other nation's domestic fisheries management, including the "shrimp-turtle" case and the "tuna-dolphin" case. For example, the US banned shrimp imports from nation's which did not utilize turtle exclusion devices in nets used to capture shrimp. Such trade restrictions are controversial as they could discriminate against developing nations, such as India and Malaysia in the case of the shrimp-turtle case [52]. However, in this case, the World

Trade Organisation did not consider it an infringement of free trade [53]. Further, minimising the reliance on trade could be an important strategy given the impact COVID-19 has had on seafood trade [54].

We identified key countries involved in unequal seafood displacement from international fishing and from trade. Ideally, however, we would apply our Seafood Footprint Displacement Index to data that indicates where the seafood imported by a given country was caught (Figure 1); data that is not yet available. Improving the traceability of seafood is a significant research priority that would allow for substantial improvements in fisheries policies globally [26]. Although we acknowledge that our results are heavily dictated by historical static estimates of fisheries management effectiveness, they are likely to be conservative estimates of unequal displacement as they do not include the substantial amount of seafood caught in illegal, unreported, and unregulated fisheries [55,56]. Further, the social, ecological, political and economic complexities of why a country may fish in another country's waters should be explored in more detail when developing new policies for reducing negative impacts of unequal fishing and trade displacement.

Improving seafood policies is complicated as seafood production and trade is associated with a complicated mix of social (e.g., seafood preferences in different countries), political (e.g., alliances), economic (e.g., subsidies), and environmental factors (e.g., health of the ocean) [26,57]. Considering these factors, we acknowledge that some of our recommendations for reducing unequal seafood displacement may be parsimonious and not pragmatic enough. Nevertheless, exploring governance and market options that reduce unequal seafood displacement has merit. Improving the sustainability of seafood, including reducing unequal seafood displacement, is an innovative solution that individual countries can adopt to help protect the ocean outside of its own EEZ. This is unique as individual countries have limited opportunities to protect the marine environment beyond their own EEZ, but critical given the highly connected nature of the ocean. Leadership by the few countries responsible for a majority of unequal seafood displacement could substantially improve health of the ocean and the people that it supports.

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TBA

Data Availability

We used four databases that have been published previously. The full databases (n=2) for the fishing and trade data are available upon request from the original authors. The full databases for the management effectiveness can be found in the original publications and/or Supplementary Table 1. We provide the subsets of the private fisheries catch and trade data that are needed to reproduce the results and figures as in Supplementary Table 1.

Code Availability

Analyses were conducted in R and the code used to produce the figures and tables will be provided in R Markdown files in a public GitHub repository.

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Figures

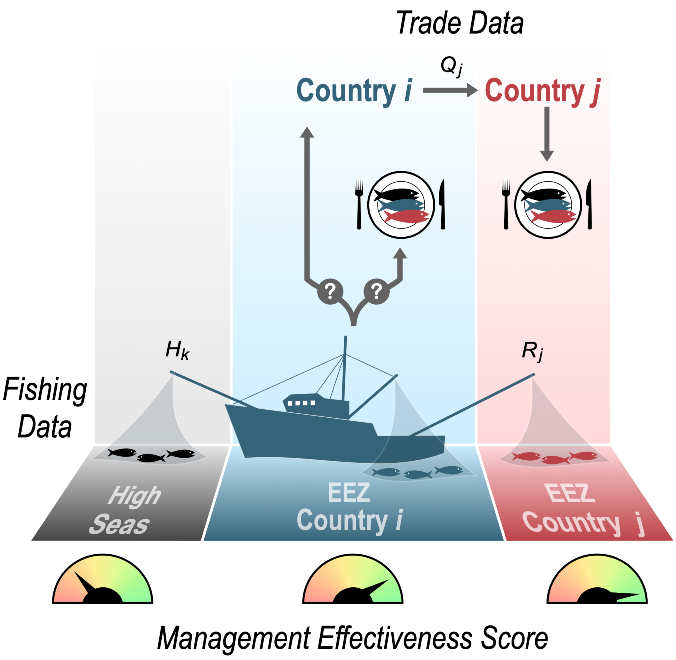

Figure 1. Wild caught seafood can be obtained by a country through fishing in its own Exclusive Economic Zone (EEZ), in another country's EEZ *(R_j)*, fishing in the high seas *(H_k)* and through trade *(Q_j)*. The amount of wild-capture seafood obtained from outside of a country's own jurisdiction is summed to determine their 'seafood footprint displacement' (in the example, for country i, it is $H_k + R_j$). We characterize seafood footprint displacement as 'unequal' when seafood is obtained from a place with poorer, or less-effective fisheries management than the foreign country that catches (or imports) the seafood (in the example, H_k). We used fishing data to understand where seafood is caught, and by whom, and we used trade data to understand who is ultimately consuming wild caught seafood.

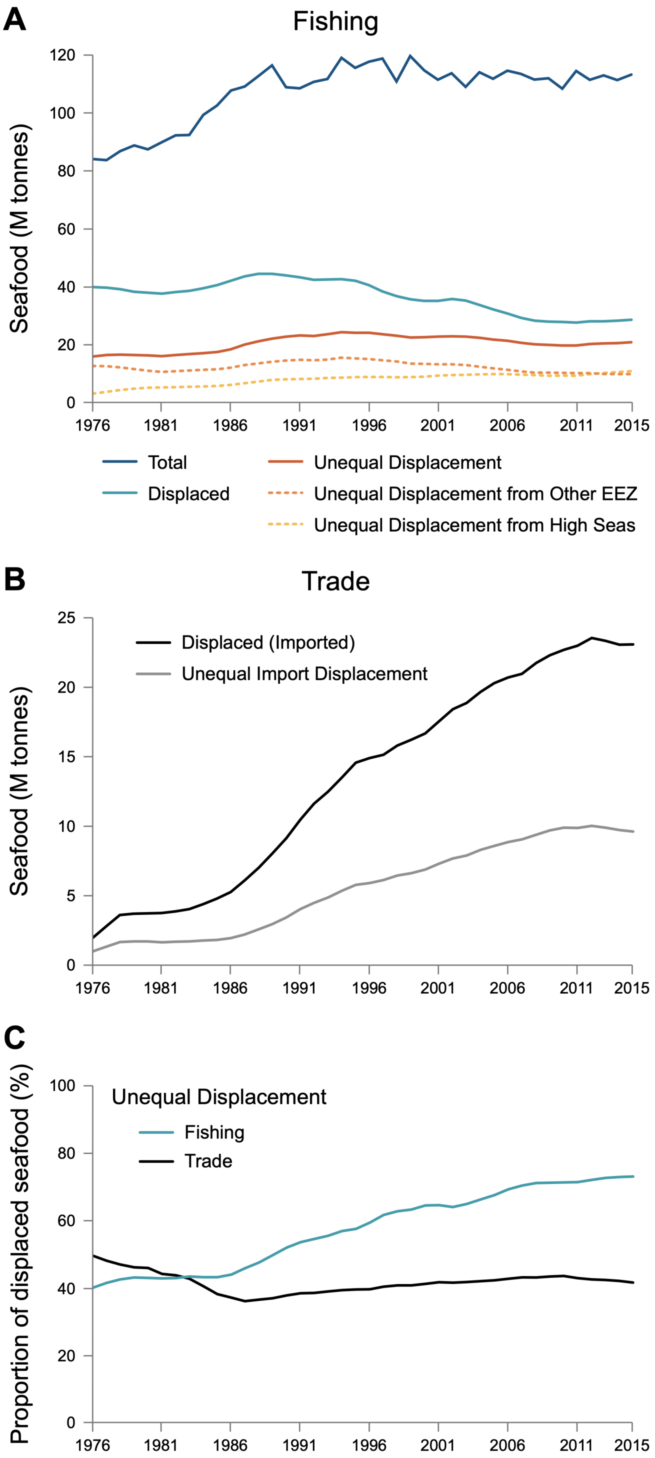

Figure 2. Annual amount of seafood caught (in other EEZs or high seas) (a) and imported (b) in total and unequally (from places with less effective fisheries management) by 172 countries between 1976-2015. The proportion of unequally displaced seafood obtained is shown in (c) for both fishing and trade (imports).

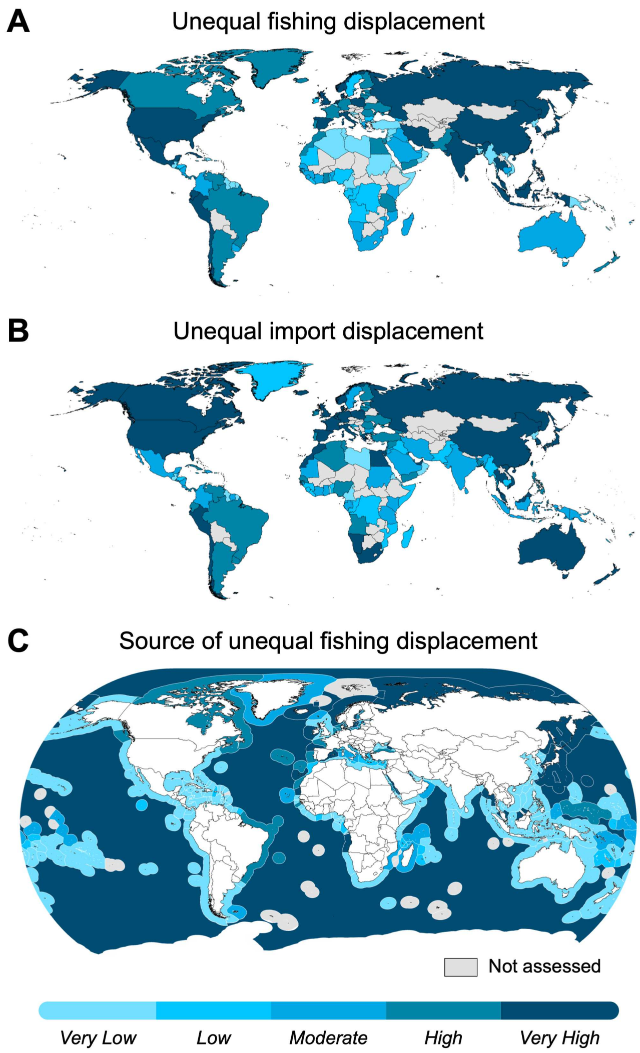

Figure 3. Unequal Seafood footprint Displacement Index, showing the relative amount of seafood displaced from less-effectively managed places through international fishing (a) and trade (imports) (b) on average between 2011-2015. The jurisdictions where seafood was caught by countries with more effective fisheries management are shown in (c).

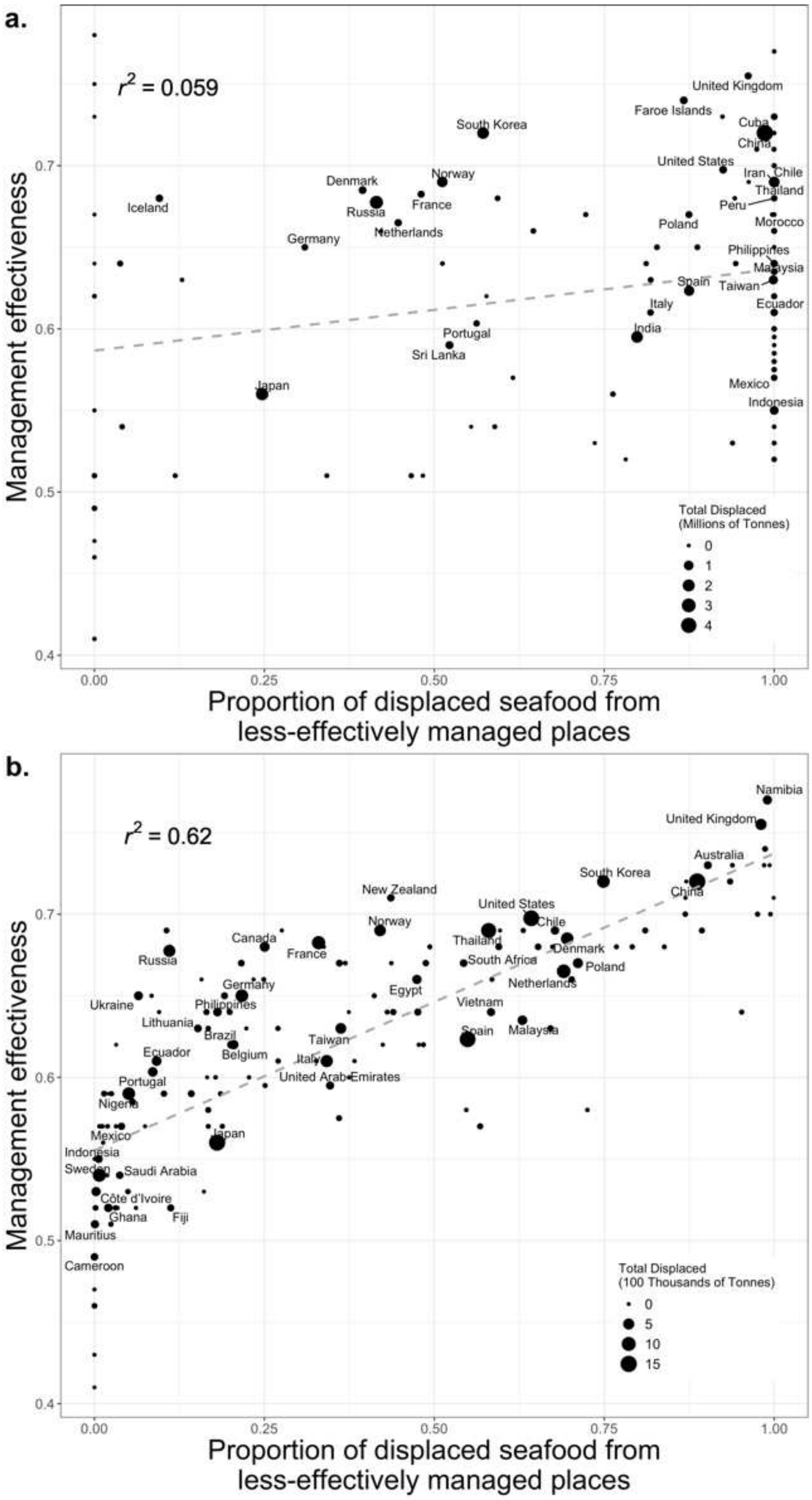

Figure 4. Proportion of displaced seafood that is unequally displaced for each country from fishing (a) and trade (imports) (b) versus its management effectiveness score. Countries collectively responsible for 90% of the total unequal seafood footprint displacement between 2011-2015 are labelled.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- KleinSeafoodFootprintDisplacement4June2021Supplementary.docx