

Mapping the unjust global impact of harmful fisheries subsidies

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Abstract

Harmful fisheries subsidies contribute to overfishing leading to environmental and societal impacts¹. If only fisheries within the subsidising nations' jurisdiction were affected, then unilateral actions might be sufficient to help safeguard our ocean and the people reliant upon it. However, just as fish move between jurisdictions², so too do the subsidised fishing fleets targeting them³. As such, the impacts and solutions to subsidies-induced overfishing are matters of international concern. Mapping that impact is therefore key to understanding these concerns and informing multilateral reform. Here we combine existing datasets^{4–6} to quantify the amount of harmful fisheries subsidies impacting the high seas, domestic and foreign waters, respectively. We estimate that between 24% and 43% of all harmful fisheries subsidies impact foreign waters or the high seas. We show that harmful subsidies primarily originate from countries with high-Human Development Index (HDI), strong fisheries management capacity and relatively sustainable fish stocks, yet disproportionately impact countries with low-HDI, lower management capacity and more vulnerable stocks. Indeed, over 40% of the harmful subsidies impacting low-HDI countries originate from high-HDI countries. This discrepancy between the source of harmful subsidies and the nations that are ultimately impacted is unsustainable and unjust. Policy-makers from all nations must push for effective multilateral subsidies reform. Prohibiting subsidies to distant-water fishing should be prioritised to support equitable and sustainable fisheries worldwide.

Introduction

Concerns regarding the subsidisation of the fisheries sector are centuries old⁷. Those concerns increased when, in 1992, the Food and Agricultural Organization of the United Nations (UN) first estimated that the annual amount of fisheries subsidies provided by governments globally was likely to be US\$ 54 billion⁸. Subsequently, more comprehensive estimates of the extent and impact of this practice cemented fisheries subsidies as a key concern for the conservation and management of marine ecosystems^{1,9} and, more recently, for supporting equitable use of marine resources^{5,10}. Consequently, fisheries subsidies reform is widely regarded as a necessary step towards safeguarding our ocean and the people that rely upon it^{11–13}. Concerted efforts to achieve such reform, however, have continued, unsuccessfully, for more than twenty years. During this time there have been numerous international commitments to formally discipline fisheries subsidies, most notably via the Convention on Biological Diversity, the World Trade Organization (WTO) and the UN Sustainable Development Goals. Yet, international agreement on rules for fisheries subsidies remain elusive. Further delay jeopardises the progress needed to achieve sustainable and equitable fisheries, which underpin broader efforts to protect biodiversity, reduce poverty, provide nutritious food and secure livelihoods^{14,15}.

Although not all fisheries subsidies are harmful¹⁶, the majority of those currently provided (e.g., subsidies for fuel, vessel construction or modernisation) are thought to cause harm¹. Fisheries subsidies can distort

markets¹⁷ and contribute to unfair trade practices¹⁸, hinder international fisheries cooperation¹⁹, exacerbate inequity by undermining the viability of small-scale producers²⁰, lead to higher CO₂ emissions²¹, act as a driver for illegal fishing²², and contribute to overfishing by increasing fishing fleet capacity²³. This ‘capacity-enhancing’ nature of fisheries subsidies sets them apart from most other forms of sectoral subsidisation, because increasing fishing capacity by its very nature directly increases the risk of additional pressure on the marine ecosystems from which subsidised fishing fleets are catching fish¹⁶. Importantly, the global distribution of this impact is largely unknown. Furthermore, much of the data that are disclosed are shrouded by a lack of transparency²⁴ and confined to estimates of the amounts of subsidies provided by each country²⁵, rather than focusing on the fisheries and locations (e.g., domestic versus foreign waters) that these subsidies are impacting.

If harmful fisheries subsidies only affected the sustainability and viability of fisheries within the national jurisdictions of the subsidising nation, then unilateral actions might be sufficient to help safeguard our ocean and the people who rely on it. However, the evidence is clear: fish inhabit and move between multiple jurisdictions including the high seas^{2,26}, and fishing fleets –and their impacts on seafood production—are increasingly transnational²⁷ and transboundary too^{28,29}, largely due to the expansion of subsidised ‘distant-water’ fishing fleets³. As such, the environmental and societal impacts of fishing and the heightened risk of overfishing due to the provision of harmful fisheries subsidies are a potential source of fisheries conflict³⁰ and a matter of international concern.

However, while fisheries science and management divides the world’s fish and fishing fleets into shared and non-shared, domestic and distant-water, respectively, such that the onus for their management lies predominantly either with nation-states or the international community³¹, such distinctions are currently lacking for the impact of harmful fisheries subsidies. Estimates now exist of the subsidies provided by almost all of the world’s maritime nations⁴ and the proportion being directed towards large-scale fishing fleets that are capable of operating outside of domestic waters⁵, but we are yet to successfully assign the flows and impacts of harmful fisheries subsidies in a similar manner. Therefore, building on existing global datasets, we estimate the amount of harmful fisheries subsidies that are impacting domestic waters, foreign waters (the Exclusive Economic Zones (EEZs) of other countries), and the high seas. We also estimate the extent to which different regions and countries are contributing to and being impacted by the global subsidisation of marine fishing. In doing so we map, for the first time, the global impact of harmful fisheries subsidies.

Results

We find that of the estimated US\$ 22.2 billion of harmful fisheries subsidies provided to the world's fishing fleets in 2018¹, some US\$ 6.0 (\pm 1.6) billion is likely impacting foreign waters within the EEZs of other countries, and US\$ 1.4 (\pm 0.6) billion is impacting the high seas. The remaining US\$ 14.9 billion (\pm 4.0) supported domestic fishing within the EEZs of the subsidising countries, which consists of both small-scale and large-scale vessels⁵ (Figure 1). Therefore, between 24% and 43% of all harmful subsidies are impacting areas outside of the jurisdiction of the original subsidising country; between 20% and 34% is impacting areas within the jurisdictions of foreign nations, and between 4% and 9% is impacting the high seas.

Such a significant proportion of harmful subsidies impacting foreign waters and the high seas means that the provision and subsequent impact of harmful fisheries subsidies are not equally distributed across geographies. We find that Asia, Europe and North America, provide more harmful subsidies to their fishing fleets than their respective regional ecosystems are impacted by (Figure 2.a). As such, these regions are net subsidy-sources. Conversely, marine ecosystems within Africa and Oceania are net subsidy-sinks—meaning that their waters are impacted by more harmful subsidies than are provided by the countries within those regions (Figure 2.a). Oceania is impacted by more than two times (221%) the amount of harmful subsidies than their constituent countries provide, while Africa is impacted by almost two times (177%) as much. Many of the additional subsidies impacting African waters originate from Asia and Europe; the flows of the impact of subsidies to Africa from these regions are US\$ 654.7 (\pm 188) million and US\$ 541.1 (\pm 119) million, respectively (Figure 2.b).

We also identify individual countries as net subsidy-sources of harmful fisheries subsidies (i.e., countries that provide more subsidies than they are impacted by) from the combination of domestic and foreign subsidies (the reverse are net subsidy-sinks). The majority of the largest net subsidy-sources are Asian and European fishing countries (Table 1.a; see Table S.3 for all countries). For example, China's EEZ is impacted by US\$ 3.5 (\pm 0.9) billion of harmful subsidies from both domestic and foreign sources, yet China provides US\$ 5.9 (\pm 1.4) billion to their fishing fleets, meaning that their EEZ is impacted by 60% of the value of harmful fisheries subsidies they provide. Spain provides US\$ 682.8 (\pm 130.7) million to their fishing fleets, but is only impacted by US\$ 209.6 (\pm 36.1) million, meaning that their EEZ is impacted by 31% of the value of harmful subsidies that they provide. Other key net subsidy-sources include Thailand and Taiwan, whose EEZs are impacted by approximately 36% and 40% of the value of harmful fisheries subsidies that they provide, respectively.

Conversely, other countries are net subsidy-sinks (Table 1.b; see Table S.3 for all countries). Japan's EEZ is impacted by more than US\$ 3.0 (\pm 0.7) billion, or 144% of the value of harmful fisheries subsidies that they provide to their own fishing fleets (US\$ 2.1 \pm 0.6 billion). A handful of other high income nations are net subsidy-sinks, including the United Kingdom and the Russian Federation, which are impacted by 552% and 111% of the value of harmful fisheries subsidies that they provide, respectively. In these cases the, the difference between the amount of subsidies they provide and the amount they are impacted by are likely due to the presence of significant (and often reciprocal) access agreements between neighbouring countries, for example for Japan's EEZ is significantly impacted by harmful subsidies

originating from China, while the United Kingdoms' is significantly impacted by harmful subsidies originating from Norway and the Netherlands. Yet, the majority of the largest net subsidy-sink countries are low-HDI countries with much larger disparity between subsidy provision and subsidy impacts, such as Morocco (305%), Indonesia (158%), Guinea (1,016%), Guinea-Bissau (164,336%) and Somalia (33,533%).

Following previous global fisheries subsidies studies^{1,32}, we present the overall provision and impact of harmful fisheries subsidies by clustering countries using various metrics of human developmental status³³, fisheries management capacity⁴, and relative stock status³⁴ (Figure 3). These metrics act as *de facto* indicators of a country's potential resilience against the impacts of harmful subsidies. We find that while countries with high Human Development Index (HDI) scores provide 83% of the world's harmful subsidies (US\$ 17.7 billion), they are impacted by 74% (US\$ 15.4 billion) of the global total. Conversely, countries with low HDI scores that provide approximately 17% of the world's harmful subsidies (US\$ 3.4 billion), are impacted by more than 26% (US\$ 5.7 billion) of the global total (Figure 3.a). Indeed, over 40% of the harmful subsidies impacting low-HDI countries originate from high-HDI countries. We see a similar flow of the impact of harmful subsidies when considering countries clustered by the amount of beneficial subsidies that they provide (Figure 3.b) and the overall status of the fish stocks within their EEZs (Figure 3.c). Beneficial subsidies refer to government support towards fisheries management, enforcement and research, as well as the implementation and maintenance of marine protected area⁴. Countries that provide high levels of beneficial subsidies provide more harmful subsidies than their EEZs are ultimately impacted by. Similarly, countries with relative high stock status also provide more harmful subsidies than their EEZs are ultimately impacted by. Whereas those countries that provide low levels of beneficial subsidies and have relative low stock status are impacted by more harmful subsidies than they provide.

Discussion

Largely due to the global extent of subsidised distant-water fishing, the impact of harmful fisheries subsidies is being felt by all the world's coastal nations, regardless of the amount of subsidies they provide to their own fishing fleets. We estimate that between 24% and 43% of all harmful fisheries subsidies are impacting either foreign waters (20–34%) or the high seas (4–9%). The damage that harmful subsidies provided to distant-water fishing fleets cause, by increasing the risk of overfishing, is therefore impacting the ecosystems, economies and societies outside of the original subsidising country's national jurisdiction. This demonstrates that harmful fisheries subsidies are a matter of international concern and not an issue that can be resolved by unilateral action alone³⁵.

Previous studies show that distant-water fishing, including that within the high seas, is almost exclusively conducted by a handful of rich nations^{3,36} and that the majority of their activity occurs within the EEZs of low-HDI nations^{19,37}. However, few, if any, studies have quantified the subsidies being channelled towards this activity. We show that there is a disproportionate flow of harmful subsidies from high-HDI countries but impacting low-HDI countries—more than 40% of the harmful subsidies impacting low-HDI countries

originate from high-HDI countries. The risk of overfishing, therefore, is being disproportionately exported to low-HDI nations which further entrenches global inequities, poverty and malnourishment, and makes the achievement of interconnected UN Sustainable Development Goals less likely¹⁴. This study corroborates previous findings³⁸ that demonstrate that high seas fishing, a sub-component of distant-water fishing, is heavily subsidised and therefore raises questions regarding the economic viability of high seas fishing³⁹, and whether this activity would be profitable at all without subsidies^{40,41}.

While these disproportionately impacted nations may benefit from fees and clauses included within access agreements, such as clauses that ensure the distant-water fishing nation processes a certain amount of catch in the host nation or employs a certain number of local people on board their fishing vessels⁴², evidence suggests that only minimal compensation is received and that the terms of these access agreements are often unfavourable for hosts⁴³. Therefore, while the host nations contend with the negative ecological, economic and social consequences that harmful fisheries subsidies impose, most of the benefit derived from the subsidised foreign fishing fleets is likely captured by the distant-water fishing nation⁴⁴. High-HDI countries use their capital to gain access to resources and subsequent revenues from catches taken from low-HDI countries, and may be less incentivised to fish sustainably because they do not feel the direct impacts of overfishing³⁸. Another reason to address the increased risk of overfishing by subsidized distant-water fishing nations is that many developing nations also have aspirations to develop their own sustainable and equitable blue economies that provide livelihoods and economic benefits, which require fish stocks to be rebuilt and maintained at a sustainable level, and for the benefits from those fisheries to be retained locally⁴⁵. Removing foreign harmful subsidies from their waters would represent a key step towards achieving this goal in the long-term⁴⁶.

In addition, there is a net flow of harmful subsidies originating from countries with stronger fisheries management capacity and relatively sustainable fish stocks, towards countries with lower fisheries management capacity and relatively poor status fish stocks (Figure 3). This phenomenon is critical because having limited fisheries management and enforcement capabilities results in a lack of regulation and control that might otherwise mitigate the impact of harmful subsidies¹². Similarly, as the greatest threat from harmful subsidies is the heightened risk of overfishing, fish stocks with relatively poor stock status are at the greatest risk. Conversely, vast sums of public money that are spent by many high-HDI countries on beneficial subsidies invariably go towards protecting and rebuilding the fish stocks within their own domestic waters, while the same countries simultaneously use public money to erode the fish stocks, livelihoods, and food security of low-HDI countries⁴⁷. As such, the impacts of and rewards from subsidising fishing are not equally shared. This imbalance highlights the structural inequities that are baked into the global practice of providing harmful fisheries subsidies, and further exacerbates the risk

that harmful fisheries subsidies pose towards collective attempts to rebuild and sustain marine biodiversity across our ocean.

Concluding Remarks

This research provides, for the first time, a snap-shot of the current global flows and impacts of harmful fisheries subsidies, taking into consideration the fact that subsidised fishing fleets operate across multiple national jurisdictions and regions, including the high seas. It highlights the complexity and interconnected nature of distant-water fishing and of the provision of harmful fisheries subsidies. Understanding the sources and ultimate destinations of the impact of harmful fisheries subsidies through this dataset provides evidence to support multilateral fisheries subsidies reform and for measuring the impact of such reform.

Our conclusion is that subsidies provided to fishing fleets operating outside of the source-countries' EEZs should be prioritised for removal, particularly when they operate in the high seas or the EEZs of low-HDI countries or countries with limited fisheries management capacity and/or poor stock status. Such removal would ensure that the onus for managing the impact of any remaining harmful fisheries subsidies lies predominantly with the subsidising country themselves. This would begin to redress the unjust global impact of harmful subsidies on the fisheries that provide essential food and livelihoods to millions of people, particularly in low-HDI countries⁴⁸. Instead, we have seen some key subsidising regions propose the reintroduction of harmful fisheries subsidies that have already been removed^{49,50}, in direct contradiction of fisheries science, economic theory and insights.

While ongoing negotiations of fisheries subsidies rules are necessary and any consensual agreement would represent a significant step in the right direction, it is unlikely to address the ongoing and historic inequity and unfairness of the demonstrable transfer of the burden of harmful subsidies to the waters of low-HDI nations. The most impacted regions require significant funding to help manage and rebuild their fish stocks in order to effectively undo the damage caused by the continued provision of harmful fisheries subsidies to fishing fleets that operate outside their own waters. However, recent studies show that there is a significant gap in current ocean financing⁵¹. Moreover, net subsidy-sink countries will need to find ways of generating alternative funds if they lose the revenues from foreign fishing access agreements, which for some countries, are a major contributor to national Gross Domestic Product. Redirecting the vast sums of public money currently being used to potentially support overfishing or to reduce the costs of fuel consumption, for example, towards more equitable coastal development and better fisheries management and enforcement⁵² would be a step in the right direction.

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Tables

Table 1: Top fifteen countries that are net subsidy-sources (a) and net subsidy-sinks (b) of harmful fisheries subsidies. Each country is ranked in terms of their US\$ net overall impact, that is the difference between the amount of harmful subsidies that in total (domestic and foreign) impacts their EEZ against the total amount of harmful subsidies that they provide. See Table S.3 for all countries.

a. Country	Total harmful subsidies provided (million US\$)	Total harmful subsidies impacting their EEZ (million US\$)	Net overall impact (source <100, sink >100) (%)
China	5,885.6 (± 1,435.6)	3,528.3 (± 885.4)	60
Thailand	1,068.9 (± 366.3)	389.2 (± 116.8)	36
Spain	682.8 (± 130.7)	209.6 (± 36.1)	31
Taiwan	708.4 (± 309.1)	279.9 (± 116.6)	40
USA	1,136.2 (± 306.5)	952.1 (± 248.1)	84
Korea Rep	1,499.6 (± 356.9)	1,320.2 (± 342.0)	88
Hong Kong	112.9 (± 45.2)	0.7 (± 0.4)	1
Senegal	250.3 (± 48.3)	147.1 (± 29.0)	59
Netherlands	141.5 (± 46.2)	42.1 (± 9.9)	30
Yemen	142.4 (± 67.5)	61.4 (± 28.3)	43
France	163.5 (± 45.2)	113.3 (± 26.6)	69
Belize	47.1 (± 17.5)	0.6 (± 0.3)	1
Germany	70.7 (± 21.2)	24.5 (± 6.0)	35
Portugal	95.9 (± 24.3)	59.6 (± 12.3)	62
Kenya	47.3 (± 14.7)	13.1 (± 2.7)	28
b.			
Japan	2,110.6 (± 603.3)	3,047.9 (± 739.1)	144
Morocco	208.4 (± 51.9)	635.6 (± 160.7)	305
United Kingdom	85.0 (± 17.2)	468.9 (± 133.6)	552
Indonesia	566.0 (± 167.6)	895.5 (± 302.8)	158
Guinea	16.5 (± 3.5)	167.8 (± 58.0)	1,016
Guinea-Bissau	0.1 (± 0.0)	149.6 (± 14.4)	164,336
Somalia	0.4 (± 0.1)	142.2 (± 63.5)	33,533
Malaysia	472.0 (± 142.5)	607.5 (± 182.3)	129
Russian Federation	1,162.0 (± 193.7)	1,292.2 (± 225.1)	111
Sierra Leone	8.7 (± 2.4)	135.0 (± 24.5)	1,547
Kiribati	17.4 (± 6.7)	140.1 (± 30.3)	804
Mauritania	28.9 (± 8.0)	145.5 (± 35.8)	504
Cambodia	11.5 (± 5.7)	121.4 (± 49.6)	1,058
Namibia	50.4 (± 17.7)	142.5 (± 35.6)	283
India	174.4 (± 58.3)	254.5 (± 89.8)	146

Methods

We combine existing datasets in order to estimate the global impact of harmful fisheries subsidies and the extent to which different countries and regions are impacted. Based on the distribution of the landed value generated by each fishing country, we are able to apportion every dollar of harmful fisheries subsidies provided in 2018 as impacting either a country's own domestic waters, foreign waters or the high seas. Given the paucity and lack of transparency in global fisheries subsidy information, we place particular emphasis on incorporating uncertainty in all results (see below).

The analysis draws on three existing global datasets: 1. Harmful fisheries subsidies provided by maritime countries in 2018 from Sumaila *et al.*⁴; 2. The division of harmful subsidies provided to small-scale and large-scale fishing sectors by maritime countries in 2018 from Schuhbauer *et al.*⁵; and 3. The distribution of the landed value of catch produced by the large-scale fishing sectors of each maritime country in 2016 from the Fisheries Economics Research Unit and *Sea Around Us*⁶. The landed value is defined as all landed catch (including reported and unreported, but excluding discards) multiplied by ex-vessel prices, which is the price the vessel receives when catch is landed at the port⁵³. The latest data available for landed value was 2016, and for fisheries subsidies was 2018. All monetary values are presented in 2018 USD (US\$), unless otherwise stated. All three datasets are complementary as they are based on comparable country and fishing fleet definitions.

The approach requires two key overarching assumptions. The first is that the distribution of the relative impact of harmful fisheries subsidies provided to the large-scale fishing sector of any country is proportional to the distribution of landed value from that country's large-scale fishing sector. This is a reasonable assumption given available information regarding the costs and benefits of fisheries in local versus distant waters and targeting lower-value versus higher-value species, and necessary given the dearth of data at the global scale and the limitations of the data that is available. Our definition of the harm caused by subsidies is underpinned by the biological sustainability of the fisheries. Harm is caused when artificial reductions to the cost of fishing or increases to the revenues from fishing lead to overcapacity and subsequently to overfishing, reducing opportunities to profit from sustainably-managed stocks. We therefore argue that it is justifiable to estimate the distribution of impact of harmful subsidies based on the value derived from the fish being extracted.

The second assumption is that the negative impact of harmful fisheries subsidies is uniform and linearly related to the amount of subsidy being provided. That is, any fisheries subsidy that is deemed to be harmful in its nature will have the same degree of impact. Here, we temporarily set aside the status of the fish stocks being fished (e.g., certain harmful subsidies would have a more detrimental effect on fish stocks that are already overfished) in order to allow us to consolidate all harmful subsidies and simplify the calculations at the global scale. While these assumptions will not stand true across all examples of fisheries subsidies provision, they are deemed appropriate and necessary for the scale of this analytical study and its central research question. These assumptions do however require clear definitions of what is considered to be a harmful fisheries subsidy and the specific fleet segments (or regions of the ocean) to which subsidies are provided (or impacting).

Defining fisheries subsidies

Various research groups and organisations have defined and categorised fisheries subsidies differently e.g.^{54,55}. We take as the basis for our definition the WTO's Agreement on Subsidies and Countervailing Measures, which defines a subsidy as any direct or indirect financial contribution by a government or any public body that confers some kind of benefit to the private sector. This includes grants, loans, equity infusions, loan guarantees, fiscal incentives, the provision of goods or services and the purchase of goods. In addition, we follow Sumaila *et al.*³², who categorises fisheries subsidies as either 'harmful', 'beneficial' or 'ambiguous' in their nature, based on the subsidy's likely impact on fish stock sustainability over time. Harmful subsidies, the focus of this study, are broadly defined as any subsidy that artificially increases revenue or reduces the costs of fishing and include support for vessel construction, renovation and modernisation, tax exemptions, fuel subsidies, port construction and investment in marketing and processing infrastructure⁴.

Defining fishing fleet sub-sectors and segments

For the purpose of this study, each country's fishing fleet is divided into two broad sub-sectors—the small-scale fishing sub-sector and the large-scale fishing sub-sector—and further divided into four fleet segments—the domestic small-scale fleet, domestic large-scale fleet, foreign large-scale fleet and high seas fishing fleet. We use the *Sea Around Us* definitions as our starting point for fishing fleet definitions⁶.

The small-scale fishing sub-sector includes artisanal, subsistence, and small-scale commercial and non-commercial fisheries, but excludes recreational fishing activities. Some maritime countries provide their own definition of small-scale fishing and these are used where available (see⁵ for detail). We make the reasonable assumption that the small-scale fishing sub-sector only operates within domestic waters (i.e., in their country's EEZ, <200 NM from shore). There are a few exceptions to this assumption, however, the total amount of fish caught by this sub-sector in non-domestic waters is negligible⁶.

The large-scale fishing sub-sector, including industrial and semi-industrial fisheries, includes all other fishing activities that are not included within the small-scale fishing sub-sector definition. This usually consists of large vessels with fixed and/or mobile fishing gears operating within a country's EEZ, and also includes all activities taking place outside of a country's own EEZ. All large-scale fishing fleets are assumed to engage in commercial fishing activities. There currently exists no single definition for different fishing fleet segments that is applicable across all countries⁵⁶. Our definition of the large-scale fishing fleets is divided into three fleet segments—although in practice, individual vessels may operate across multiple fleet segments and may be flagged to a different nation than they originate from:

- Domestic large-scale fleet. This segment includes the catch of any vessel that is not considered to be small-scale made from within the EEZ of the maritime country under which the vessel is flagged;
- Foreign large-scale fleet. This segment includes the catch of any vessel that is made from the EEZ of another maritime country (excluding overseas territories) other than the country under which the vessel is flagged; and
- High seas fleet. This segment includes the catch of any vessel that is taken from either the high seas or any area beyond national jurisdiction (>200 NM from shore).

Calculating the distribution of the impact of fisheries subsidies

In order to apportion every dollar of harmful fisheries subsidies provided by each maritime country as impacting either their domestic waters, foreign waters (another country's EEZ) or the high seas, we followed the steps outlined here:

First, under the assumption that small-scale fisheries only operate within their own domestic EEZ, we used estimates for the proportion of harmful fisheries subsidies provided to the small-scale and large-scale fishing sub-sectors for each maritime country provided by Schuhbauer *et al.*⁵. All harmful subsidies provided to small-scale fishing sub-sector were therefore categorized as domestic, while all harmful subsidies allocated to large-scale fisheries were further divided into the three spatially discrete fleet segments (domestic, foreign and high-seas).

Second, to apportion the percentage of harmful fisheries subsidies for the large-scale fisheries as impacting either a) domestic waters; b) foreign waters (another country's EEZ); or c) the high seas, for each country, we used the distribution of the landed value of catch⁶ broken down by each individual EEZ and the high seas. To do this, we multiply the total amount of harmful fisheries subsidies provided by a country to its large-scale fisheries by the proportion of landed value that the large-scale fishing sub-sector took from a particular region or EEZ, see equations 1 and 2:

$$\text{Equation 1)} \quad S_{\text{EEZ}} = S_{(i)} \times \frac{[\text{LV}]_{\text{EEZ}}}{[\text{LV}]_i}$$

$$\text{Equation 2)} \quad S_{\text{HS}} = S_{(i)} \times \frac{[\text{LV}]_{\text{HS}}}{[\text{LV}]_i}$$

Where i = country, LV = landed value (US\$), S – subsidy (USD), EEZ - Exclusive Economic Zone, and HS – high seas.

For each individual EEZ (and the high seas), we then added the harmful small-scale fisheries subsidies from Schuhbauer *et al.*⁵ as domestic subsidies, with the domestic harmful large-scale fisheries subsidies, with all the foreign harmful subsidies estimated to be impacting that same EEZ, to complete the analysis.

As these calculations are estimates and not absolute values, the relative quality of the underlying data may affect the robustness of the findings. In order to reflect this uncertainty in our calculations, we combine data quality scores for the landed value estimates and the harmful fisheries subsidies estimates to produce a compound data quality score for each subsidy-EEZ calculation in the dataset. For landed value, we use the weighted average reliability scores taken directly from the *Sea Around Us* catch data⁶. Harmful subsidies estimates from Sumaila *et al.*⁴, however, do not include data quality scores. We therefore revisited the original data for all harmful fisheries subsidies and estimated data quality scores by adapting the method used for from the *Sea Around Us* catch data⁶. The harmful fisheries subsidies data are broken down into seven different subsidy types. For each country and each subsidy type there is a record describing whether the estimate was ‘reported’ (i.e. taken directly from a cited source) or ‘modelled’ (i.e. calculated using the value transfer model applied in Sumaila *et al.*¹). The quality of the harmful subsidies data for each country was therefore determined based on how many subsidy types had been ‘reported’ versus ‘modelled’. For example, if all data points were ‘reported’, the quality score applied was 4 (very high data quality), if ‘reported’ data points were less than 25% of overall data points the quality score was 1 (very low) (Table 2). We averaged the subsidies data quality scores by fishing country with the weighted catch quality scores for each EEZ (and the high seas) to produce a compound score between 1 and 4 for each subsidy-EEZ calculation. The compound quality score for each EEZ was calculated as follows:

$$\text{Equation 3) } \text{Compound qs}_{EEZ} = ((\text{qs}_S)_i + \text{qs}_{EEZ}) / 2$$

Where Compound qs EEZ is the quality score for a specific EEZ, qs_S denotes the subsidy quality score for country i .

The compound score was then converted into confidence intervals to present our final results in ranges rather than absolute values (Table 2).

Table 2: Data quality scoring for harmful fisheries subsidies estimates.

Data quality score	Reported data points / Total data points	Confidence intervals +/- (%)	Corresponding criteria
4 - Very high	0.76 - 1.0	10	Robust evidence
3 - High	0.51 - 0.75	20	Medium evidence
2 - Low	0.26 - 0.50	30	Limited evidence
1 - Very low	0 - 0.25	50	Low evidence

This resulted in a new dataset where every dollar of harmful fisheries subsidies provided in 2018 for all subsidizing fishing nations was apportioned to a single region (EEZ or high seas) of the ocean. This new dataset consisted of 852 individual subsidy-EEZ entries, i.e. flows of harmful fisheries subsidies being provided from one country and impacting either the same country or another country (or the high seas). In order to estimate the total domestic impact for each EEZ, we combined the amount provided to a country's small-scale fleet with the total estimated to have been provided to the large-scale fishing fleet fishing within its own EEZ. The cumulative impact of harmful subsidies on a single location, such as an individual EEZ, was then calculated by summing the total harmful subsidies impacting that location from all countries, including all subsidies to foreign large-scale and domestic small- and large-scale fleets.

Following previous global fisheries subsidies studies^{1,32}, we present an analysis of countries clustered using the 2017 UN Human Development Index (HDI) as an indicator of the development status, not only economic growth, of a country³³. Countries were clustered into two groups, high and low, based on the second quartile. We also used the same categorisation approach for clustering countries based on the relative amount of beneficial fisheries subsidies they provide, taken from Sumaila *et al.*⁴, as an indicator of the fisheries management capacity of a country. Beneficial subsidies include funding for fisheries management programs and services, fisheries research and development, and marine protected areas. Finally, we used the Environmental Performance Index for fish stock status, as an indicator of the relative health of the stocks within a country's EEZ. This indicator uses data from the *Sea Around Us*⁶ to present a percentage of a country's total catch that comes from overexploited or collapsed stocks, considering all fish stocks within a country's EEZs. A score of 100 indicates that none of a country's fish catch come from stocks that are overexploited or collapsed, and a score of 0 indicates worst performance. We clustered all countries into the two groups for each of the three indicators, and presented them using Sankey plots, to understand the flow of harmful subsidies from one group to another.

Data availability

All data used in this study are either publicly available from the sources provided or made available with publication of this study. The model code is publicly available with publication of this study along with all necessary data files (https://github.com/annaschu/mapping_fisheries_subsidies).

Method References

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Figures

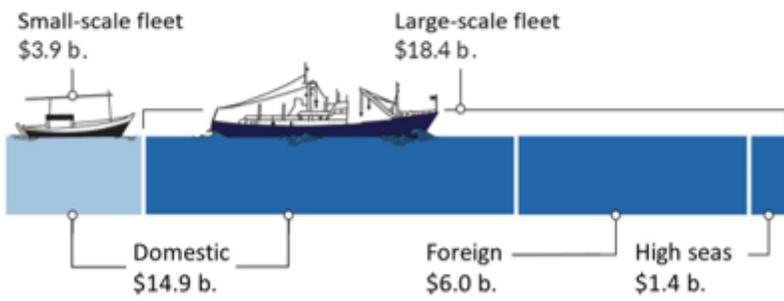


Figure 1

The global distribution of the impact of harmful fisheries subsidies in 2018. Harmful fisheries subsidies provided to the small-scale and large-scale fleet in 2018 are estimated at US\$ 3.9 and 18.4 billion, respectively⁵. Harmful fisheries subsidies impacting domestic waters, foreign waters and the high seas, estimated herein to be approximately US\$ 14.9, 6.0 and 1.4 billion, respectively.

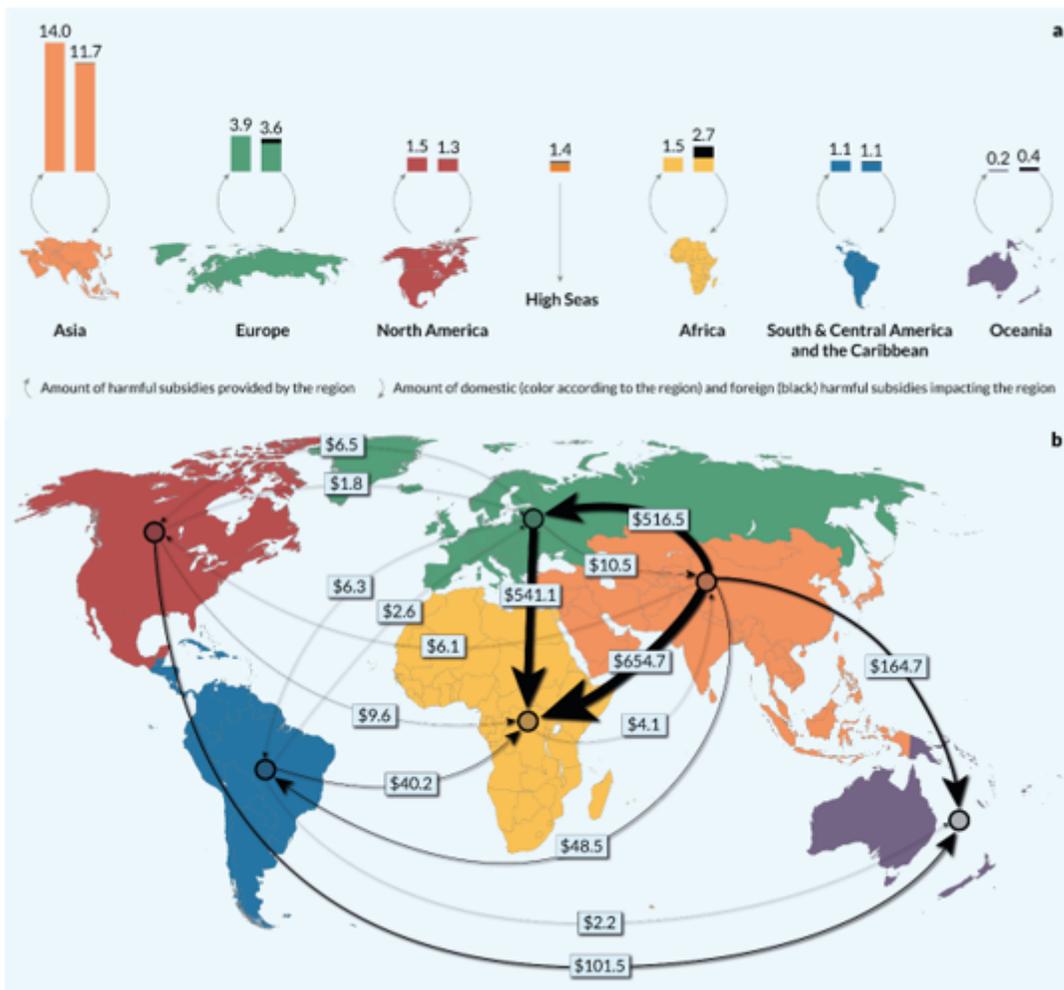


Figure 2

The regional distribution of the provision and impact of harmful fisheries subsidies. (a) Total amount of harmful fisheries subsidies being provided by each region and the total amount of domestic and foreign

harmful fisheries subsidies estimated to be cumulatively impacting each region, in US\$ billions (See Table S.1 for corresponding data); (b) Inter-regional exchanges of the impact of harmful fisheries subsidies, due to their provision to regional distant-water fishing fleets, in US\$ millions (See Table S.2 for corresponding data).

a. Human Development Index



b. Beneficial subsidies



c. Stock status



Figure 3

The distribution of the provision (left axis) and net impact (right axis) of harmful fisheries subsidies in billion US\$. The total amount of harmful fisheries subsidies being provided by each country and the total amount of domestic and foreign harmful fisheries subsidies estimated to be impacting each country clustered as either high or low for; (a) the UN Human Development Index, (b) the amount of beneficial fisheries subsidies provided, and (c) the 2020 Environmental Performance Indexes for fish stock status.

Supplementary Files

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