



Mapping the unjust global distribution of harmful fisheries subsidies

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ABSTRACT

Harmful fisheries subsidies contribute to overfishing leading to environmental and societal impacts. If only fisheries and ecosystems 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 jurisdictions, so too do the subsidised fishing fleets that target them. As such, the impacts and solutions to subsidies-induced overfishing are often matters of international concern. Mapping the distribution and flows of harmful subsidies is therefore key to understanding these concerns, informing multilateral reform, and empowering impacted nations to strengthen the terms of access to their waters and resources. Here we quantify the amount of harmful fisheries subsidies that supports fishing in the high seas, domestic and foreign waters. We estimate that between 20% and 37% of all harmful fisheries subsidies support fishing in foreign waters or the high seas, that is outside the jurisdictions of the subsidising nations. We show that harmful subsidies primarily originate from nations with high-Human Development Index (HDI), strong fisheries management capacity and relatively sustainable fish stocks, yet disproportionately impact nations with low or very low-HDI, lower management capacity and more vulnerable fish stocks—40% of the harmful subsidies that support fishing in very low-HDI nations waters originate from high-HDI and very-high HDI nations. We show that Asia, Europe, and North America, are net subsidy sources; they provide more harmful subsidies to their fishing fleets than their respective ecosystems are impacted by; while Africa, South, Central America and Caribbean, and Oceania are net subsidy-sinks. This discrepancy between the source of harmful subsidies and the nations that are ultimately impacted is unsustainable and unjust. Prohibiting all harmful subsidies to distant-water fishing and fishing in the high seas—with narrow exceptions for Small Island Developing States—should be prioritised to support the advancement of sustainable and equitable fisheries worldwide.

1. Introduction

Concerns regarding the subsidisation of fisheries are centuries old [1]. Those concerns increased when, in 1992, the Food and Agricultural Organization (FAO) of the United Nations (UN) first estimated that the

annual amount of fisheries subsidies provided by governments globally was likely to be US\$ (USD) 54 billion [2]. 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 [3,4] and, more recently, for

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supporting equitable use of marine resources [5–7]. Consequently, fisheries subsidies reform is widely regarded as a necessary step towards safeguarding our ocean and the people that rely upon it [8–10]. Concerted efforts to achieve such reform continued unsuccessfully for more than twenty years, before the World Trade Organization (WTO) finally reached consensus on a set of rules for the provision of fisheries subsidies, in June of 2022. However, these rules fall short of some of the measures and prohibitions most likely to effectively limit the negative impact of fisheries subsidies [11], and as such negotiations continue. The current rules do, however, prohibit certain subsidies for fishing on unregulated fish stocks in the high seas, but the implementation of this rule (and others) will be impeded by the dearth of data available on the distribution of where subsidies support fishing. Further delay in introducing more comprehensive measures 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 [12,13].(Table. 1).

Although not all fisheries subsidies are harmful [14], the majority of those currently provided are thought to cause harm [3]. Harmful fisheries subsidies can distort markets [15] and contribute to unfair trade practices [16], hinder international fisheries cooperation [7,17], exacerbate inequality by undermining the viability of small-scale producers [18], lead to higher CO₂ emissions [19], act as a driver for illegal fishing [20], and increase the risk of overfishing by increasing fishing fleet capacity [21]. Harmful fisheries subsidies include programs that currently,

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

a. Nation	Total harmful subsidies provided (million US\$)	Total harmful subsidies within their EEZ (million US\$)	Net overall subsidisation (source <100, sink >100) (%)
China	5885.6 (± 1435.6)	3528.3 (± 885.4)	60
Thailand	1068.9 (± 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	1136.2 (± 306.5)	952.1 (± 248.1)	84
Korea Rep	1499.6 (± 356.9)	1320.2 (± 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	2110.6 (± 603.3)	3047.9 (± 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)	1016
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	1162.0 (± 193.7)	1292.2 (± 225.1)	111
Sierra Leone	8.7 (± 2.4)	135.0 (± 24.5)	1547
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)	1058
Namibia	50.4 (± 17.7)	142.5 (± 35.6)	283
India	174.4 (± 58.3)	254.5 (± 89.8)	146

or have the potential to, encourage fishing capacity to develop to a point where the risk of exploitation exceeding the maximum sustainable yield is increased [22]. 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 and fish stocks [14]. This is the basis for the definition of ‘harmful’ fisheries subsidies used herein and in previous fisheries subsidies work (see; [22]).

Importantly, the global distribution of the risks associated with harmful subsidies are largely unknown. This is partly because much of the data on fisheries subsidies are shrouded by a lack of transparency [23] and confined to periodic estimates of the amounts of subsidies provided by each nation [24], rather than focusing on the fisheries and locations that these subsidised fishing fleets are affecting.

If harmful fisheries subsidies only affected the sustainability and viability of fisheries and ecosystems 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 [25], and fishing fleets—and their impacts on seafood production and consumption—are increasingly transnational [26] and transboundary [27,28]. The expansion of subsidised ‘distant-water’ fishing fleets have played an important role in this expansion [29]. Changes induced by harmful subsidies including the increasing role of distant water fishing fleets, globalisation and associated institutional arrangements and trade, alter the nature of fisheries and wider food systems, and therefore alter social benefits and costs [13]. 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 conflict [30] and a matter of international concern.

However, while fisheries science and management divide the world’s fish and fishing fleets into shared and non-shared, domestic and distant-water, respectively, such that accountability for their management lies predominantly either with nation-states or the international community [31], such distinctions are currently lacking for harmful fisheries subsidies. Estimates now exist of the subsidies provided by almost all the world’s maritime nations [22] and the proportion being directed towards large-scale fishing fleets that are capable of operating outside of domestic waters [5], but we are yet to successfully assign the flows and ultimate distribution of harmful fisheries subsidies in a similar manner. Therefore, building on the most recent global datasets available, we estimate the amount of harmful fisheries subsidies that are supporting fishing within either domestic waters (the Exclusive Economic Zones (EEZs) of the subsidising nation), foreign waters (EEZs of other nations), or the high seas. We also estimate the extent to which different regions and nations are contributing to and being affected by the global subsidisation of marine fishing. In doing so we map, for the first time, the ultimate global distribution of harmful fisheries subsidies, from sources to sinks.

2. Methods

We combine datasets to produce novel estimates of the extent to which domestic and foreign fishing fleets are subsidised in different nations and regions. Based on the distribution of the landed value generated by each fishing nation, we apportion every dollar of harmful fisheries subsidies provided in 2018 as supporting fishing either within a nation’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 nations in 2018 from Sumaila et al. [22]; 2) The division of harmful subsidies provided to small-scale and large-scale fishing sectors by maritime nations 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 nation in 2016 from the Fisheries Economics Research Unit and *Sea Around Us* [32]. 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 port [33]. The latest complete global datasets available for landed value and fisheries subsidies was 2018. All monetary values are presented in 2018 US\$, unless otherwise stated. All three datasets are complete and complementary as they are based on comparable national and fishing fleet definitions.

The approach requires two key assumptions. The first is that the distribution of the relative impact of harmful fisheries subsidies provided to the large-scale fishing sector of any nation is proportional to the distribution of landed value. Given that the impact of an injection of public funds to a fishery is initially an economic one with subsequent enhanced risk of deleterious ecological and social consequences [24], the harm caused by subsidies must, to some extent, be relative to the economic scale of the fishery [34]. We therefore believe that 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 suitable fishing effort data for all fishing fleets at the global scale and the limitations of the data that is available. Harm is caused when artificial reductions to the cost of fishing lead to overcapacity and subsequently to overfishing. While subsidies can cause socially deleterious outcomes by altering the nature of fisheries and the types and distribution of benefits, these can be complex responses and likely to be exacerbated in any case where there are increased risks to the biological sustainability of the fisheries. We therefore argue that it is justifiable, albeit imperfect, to estimate the distribution 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 current status of the specific fish stock being fished, the type of fishing gear used, and the strength of fisheries management and enforcement (e.g., harmful subsidies would have a more detrimental effect on already overfished stocks, to more destructive gear types, and where additional subsidy-induced effort is not curtailed), to allow us to focus on identifying global areas subject to subsidised fishing effort to inform targeted future research on likely and observed impacts. While these assumptions will not stand true across all examples of harmful fisheries subsidies provision, they are deemed necessary for the scale of this analytical study and its central research question. Furthermore, sufficient empirical data on the context-specific impacts of subsidies are currently unavailable to enable us to adjust the relative weight of different subsidy types in different regions or on different fish stocks, in the analyses.

2.1. Defining fisheries subsidies

Various groups have defined and categorised fisheries subsidies differently e.g. [35,36]. We take as the starting point 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 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. However, we subsequently diverge from the WTO's definition, at least what is included in the newly negotiated WTO rules on fisheries subsidies by following Sumaila et al. [37], 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, and includes subsidies to onshore fishing related activities

(currently excluded from WTO negotiations). Harmful subsidies, the focus of this study, are defined as any subsidy that artificially increases revenue or reduces the costs of fishing and include support for vessel construction, tax exemptions, fuel subsidies, and investment in marketing and processing infrastructure [22]. This is different from the general definition of a fisheries subsidy which includes support that confers benefit decoupled from fishing effort.

2.2. Defining fishing fleet sub-sectors and segments

For this study, each nation'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—domestic small-scale fleet, domestic large-scale fleet, foreign large-scale fleet, and high seas fleet. There currently exists no single definition for different fishing fleet segments that is applicable across all nations [38]. We use the *Sea Around Us* definitions as our starting point for fishing fleet definitions [32].

The small-scale fishing sub-sector includes artisanal, subsistence, and small-scale commercial and non-commercial fisheries, but excludes recreational fishing activities. Some maritime nations provide their own definition of small-scale fishing, and these are used where available (see; [5] for detail). We make the reasonable assumption that the small-scale fishing sub-sector only operates within domestic waters (i.e., in their nation's EEZ, <200 NM from shore). There are a few exceptions to this assumption, however, the total value of fish caught by this sub-sector in non-domestic waters is negligible [32].

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 nation's EEZ and includes all activities taking place outside of a nation's own EEZ. All large-scale fishing fleets are assumed to engage in commercial fishing activities. 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 nation 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 nation (overseas territories are considered part of their parent nation and domestic fleets catching in overseas territories are therefore pooled with the domestic fleet) other than the nation 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).

It is also important to note that the practice of re-flagging and the use of 'flags of convenience'—the registering of vessels in a different jurisdiction to avoid transparency or gain access to fishing grounds—is not accounted for here but is known to be a significant challenge in ensuring accountability for both subsidies and the respect for maritime and fishing regulations [39].

2.3. Calculating the distribution of harmful fisheries subsidies

To apportion harmful fisheries subsidies provided by each maritime nation as supporting fishing within either their domestic waters, foreign waters (another nation'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 nation provided by Schuhbauer et al. [5]. All harmful subsidies provided to small-scale fishing sub-sector were categorised as domestic, while all harmful subsidies allocated to large-scale fisheries were 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 supporting fishing within either a) domestic waters; b) foreign waters (another nation’s EEZ); or c) the high seas, for each nation, we used the distribution of the landed value of catch [32] within each individual EEZ and the high seas. To do this, we multiply the total amount of harmful fisheries subsidies provided by a nation to its large-scale fisheries by the proportion of landed value the large-scale sub-sector took from each EEZ, see Eqs. 1 and 2:

$$S_{EEZ} = S_i \times \frac{LV_{EEZ}}{LV_i} \tag{1}$$

$$S_{HS} = S_i \times \frac{LV_{HS}}{LV_i} \tag{2}$$

Where i = nation, LV = landed value (US\$), S – subsidy (US\$), 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 harmful subsidies, with the domestic harmful large-scale fisheries subsidies, with all the foreign harmful subsidies estimated to be supporting fishing within that same EEZ, to complete the analysis.

As these calculations are estimates and not absolute values, the relative quality of the underlying data will affect the robustness of the findings. To reflect this uncertainty, we combine data quality scores for the landed value estimates and 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 data. Harmful subsidies estimates from Sumaila et al. [22], 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 the *Sea Around Us* catch data [32]. The harmful fisheries subsidies data are broken down into seven different subsidy types. For each nation 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. [3]). The quality of the harmful subsidies data for each nation was therefore determined based on the proportion of subsidy types ‘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 nation 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:

Table 2
Data quality scoring for harmful fisheries subsidies estimates, adapted from [40].

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

$$Compoundqs_{EEZ} = \left(\frac{qsS_i + qs_{EEZ}}{2} \right) \tag{3}$$

Where $Compoundqs_{EEZ}$ is the quality score for a specific EEZ, $qsSi$ denotes the subsidy quality score for nation i .

The compound score was then converted into confidence intervals to present our results in ranges rather than absolute values (Table 2). This methodological approach and the confidence intervals presented are the same as in previous publications by *Sea Around Us* (e.g., [32,40]), which we adapt for the subsidies dataset. While there are limitations to this approach, we believe that it is a useful indication of the uncertainty of subsidies data and that presenting a range reflects this more appropriately than a single value.

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 nation and supporting fishing within either the same EEZ or another EEZ (or the high seas). To estimate the total domestic harmful subsidies for each EEZ, we combined the amount provided to a nation’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 amount of harmful subsidies supporting fishing within a single location, such as an individual EEZ, was then calculated by summing the total harmful subsidies supporting fishing in that location from all nations, including all harmful subsidies to foreign large-scale and domestic small- and large-scale fleets.

Following previous global fisheries subsidies studies [3,37], we present an analysis of nations clustered using the 2017 UN Human Development Index (HDI) as an indicator of the development status, not only economic growth, of a nation [41]. Nations were clustered into four groups, very high, high, low and very-low, based on fixed cut-off points, which are derived from the quartiles of distributions of the component indicators.¹ We also used the same categorisation approach for clustering nations based on the relative amount of beneficial fisheries subsidies they provide, taken from Sumaila et al. [22], as an indicator of the fisheries management capacity of a nation. 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 [42], as an indicator of the relative health of the stocks within a nation’s EEZ. This indicator uses data from the *Sea Around Us* [32] to present a percentage of a nation’s total catch that comes from overexploited or collapsed stocks, considering all fish stocks within a nation’s EEZs [42]. A score of 100 indicates that none of a nation’s fish catch come from stocks that are overexploited or collapsed, and a score of 0 indicates worst performance. As the categorisation is based on the quartiles of distribution this metric is relative to the nations in the list and do not present an objective measure of stock status. We clustered all nations into the four 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.

3. Results

We find that of the estimated US\$ 22.2 billion of harmful fisheries subsidies provided to the world’s fishing fleets in 2018, some US\$ 5.3 (± 1.4) billion is likely supporting fishing within foreign waters, within the EEZs of other nations, and US\$ 1.0 (± 0.4) billion is supporting

¹ UNDP, Data and statistics readers guide (Accessed: 27/02/2023):<https://hdr.undp.org/reports-and-publications/2020-human-development-report/data-readers-guide#:~:text=Human%20development%20classification&text=The%20cutoff%2Dpoints%20are%20HDI,for%20very%20high%20human%20development>.

fishing within the high seas. The remaining US\$ 15.9 billion (± 4.3) supported domestic fishing within the EEZs of the subsidising nations, which consists of both small-scale and large-scale vessels (Fig. 1). Therefore, between 20% and 37% of all harmful subsidies are supporting fishing in areas outside of the jurisdiction of the original subsidising nation; between 17% and 30% in areas within the jurisdictions of foreign nations, and between 3% and 7% in the high seas.

Such a significant proportion of harmful subsidies supporting fishing in foreign waters and the high seas means that the provision (benefits) and subsequent environmental and social costs 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 affected by (Fig. 2.a). As such, these regions are net subsidy-sources. Conversely, marine ecosystems within Africa and Oceania are significant net subsidy-sinks—meaning that fishing in their waters is supported by more harmful subsidies than are provided by the nations within those regions (Fig. 2.a). In this respect, fishing in Oceania is supported by more than three times (339%) the amount of harmful subsidies than their constituent nations provide, the vast majority of which originates from Asia, some US\$ 404.6 (± 112) million, while fishing in African marine waters is supported by more than 1.5 times (161%) as much. Many of the additional harmful subsidies supporting fishing in African waters originate from Europe and Asia; the flows of harmful subsidies to Africa from these regions are US\$ 561.5 (± 116) million and US\$ 408.6 (± 136) million, respectively (Fig. 2.b).

We also identify individual nations as net subsidy-sources of harmful fisheries subsidies (i.e., nations that provide more harmful subsidies than they are affected by) from the combination of domestic and foreign harmful subsidies (the reverse are net subsidy-sinks). The majority of the largest net subsidy-sources are Asian and European fishing nations (Table 1.a; see Table S.3 for all nations). For example, China's EEZ is affected by US\$ 4.0 (± 1.0) billion of harmful subsidies from both domestic and foreign sources, yet China provides US\$ 5.9 (± 1.4) billion to their fishing fleets, meaning that their EEZ is affected by 69% of the value of harmful fisheries subsidies they provide. Spain provides US\$ 682.8 (± 130.7) million to their fishing fleets but is only affected by US\$ 175.2 (± 40.4) million, meaning that their EEZ is affected by 26% of the value of harmful subsidies that they provide. Other key net subsidy-sources include Panama and Taiwan, whose EEZs are affected by approximately 28% and 71% of the value of harmful fisheries subsidies that they provide, respectively.

Conversely, other nations are net subsidy-sinks (Table 1.b; see Table S.3 for all nations). Japan's EEZ is impacted by more than US\$ 2.6 (± 0.7) billion, or 123% of the value of harmful fisheries subsidies that they provide to their own fishing fleets (US\$ 2.1 ± 0.6 billion). A handful of other high-income nations are net subsidy-sinks, including the United Kingdom and New Zealand, which are impacted by 607% and 147% of the value of harmful fisheries subsidies that they provide, respectively. In these cases, the difference between the amount of

harmful subsidies they provide and the amount of harmful subsidies spent on supporting fishing in their EEZ is likely due to the presence of significant (and often reciprocal) access agreements between neighbouring nations, for example Japan's EEZ is significantly impacted by subsidised fishing originating from China, while the United Kingdom's is significantly affected by subsidised fishing originating from Norway and the Netherlands. Yet, most of the largest net subsidy-sink nations are very-low and low-HDI nations with much larger disparity between the subsidies they provide and the subsidies that support fishing within their EEZs, with relatively undeveloped fleets of their own but with high value fisheries present in their EEZs, such as Morocco (240%), Papua New Guinea (451%), Mauritania (774%), Kiribati (814%), Guinea (845%), Somalia (36,775%), and Guinea-Bissau (124,970%).

Following previous global fisheries subsidies studies [3,37], we present the overall provision and distribution of harmful fisheries subsidies by clustering nations using various metrics of human developmental status, fisheries management capacity [22], and relative stock status [42] (Fig. 3). These metrics act as *de facto* indicators of a nation's potential resilience to the impacts of harmful subsidies. We find that while nations with high Human Development Index (HDI) scores provide 83% of the world's harmful subsidies (US\$ 17.4 billion), they are affected by 75% (US\$ 15.9 billion) of the global total. Conversely, nations with low and very-low HDI scores that provide approximately 10% (US\$ 2.2 billion) and 6% (US\$ 1.4 billion) of the world's harmful subsidies, respectively, are affected by 14% (US\$ 3.0 billion) and 10% (US\$ 2.1 billion) of the global total, respectively (Fig. 3.a). Indeed, 40% of the harmful subsidies supporting fishing within very low-HDI nations originate from very-high and high-HDI nations collectively. When clustered by the amount of beneficial subsidies that nations provide, we see a net flow of harmful subsidies from those that provide a large amount of beneficial support to those that provide low amounts (Fig. 3.b), and similar net flow is observed from those nations with good relative status of the fish stocks within their EEZs to those with lower overall relative stock status (Fig. 3.c). Beneficial subsidies refer to government support towards fisheries management, enforcement, and research, as well as the implementation and maintenance of marine protected areas [22]. Nations that provide high levels of beneficial subsidies provide more harmful subsidies than their EEZs are ultimately impacted by. Similarly, nations with relative high stock status also provide more harmful subsidies than their EEZs are ultimately impacted by. Whereas those nations that provide low levels of beneficial subsidies and have relative low stock status are impacted by more harmful subsidies than they provide.

4. Discussion

Largely due to the global extent of subsidised distant-water fishing, the impact of harmful fisheries subsidies is being felt across the entire ocean and by all the world's coastal nations, regardless of the amount of harmful subsidies they provide to their own domestic fishing fleets. We estimate that between 20% and 37% of all harmful fisheries subsidies

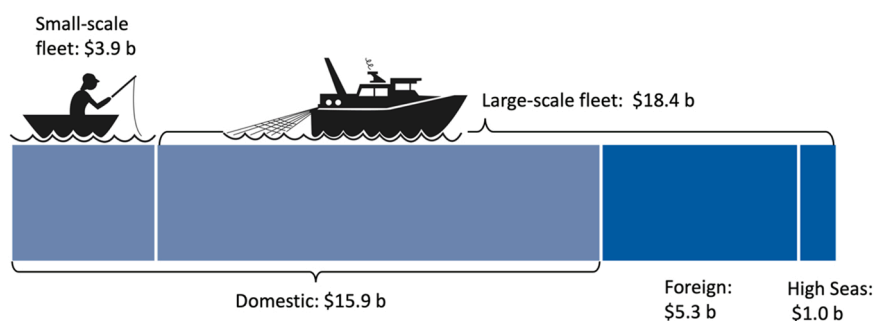


Fig. 1. : The global distribution of harmful fisheries subsidies in 2018. Harmful fisheries subsidies provided to the small-scale and large-scale fleet in 2018 are estimated at US\$ 3.9 and 18.4 billion, respectively⁵. Harmful fisheries subsidies supporting fishing within domestic waters, foreign waters, and the high seas, estimated herein to be approximately US\$ 15.9, 5.3 and 1.0 billion, respectively.

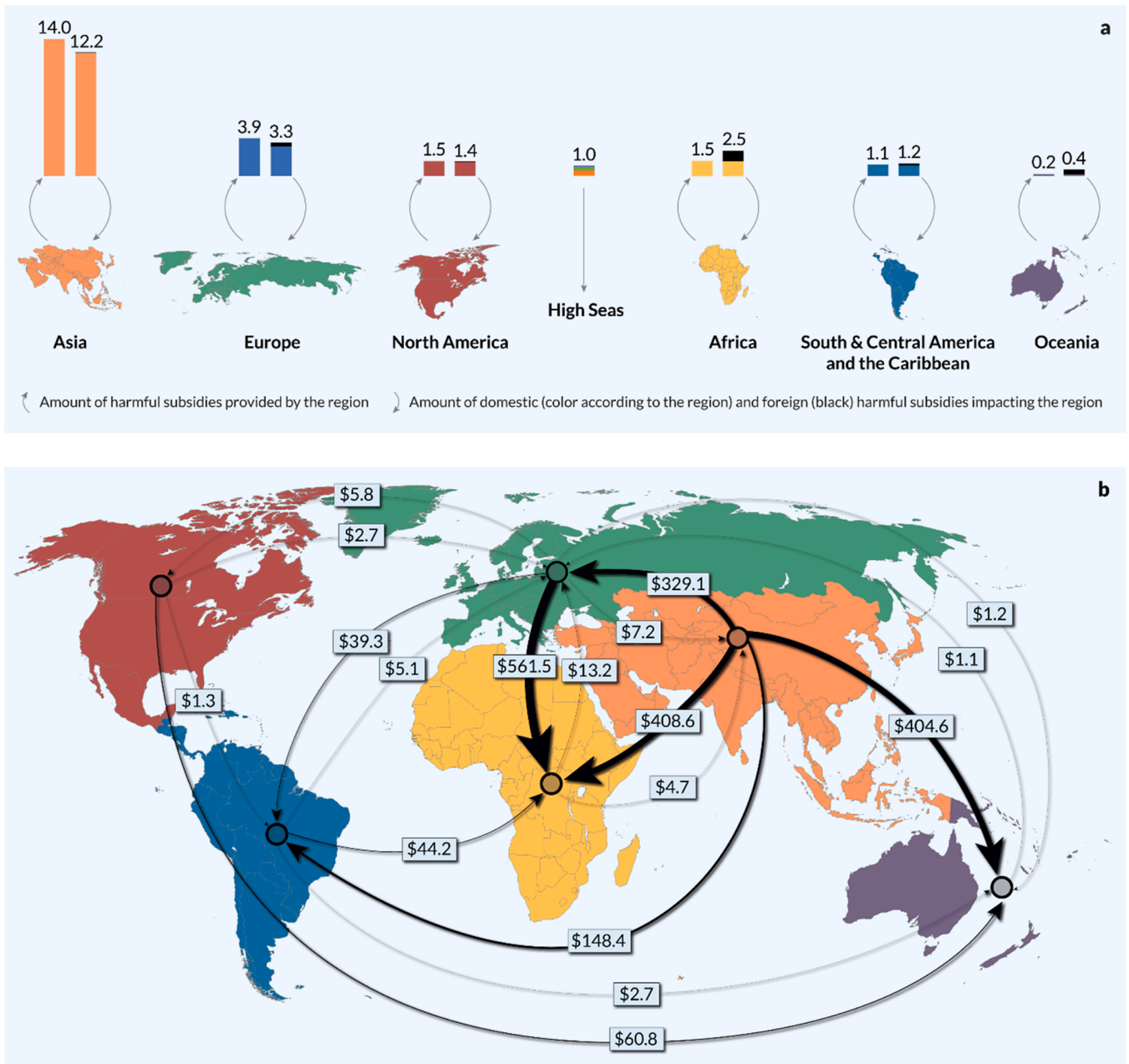


Fig. 2. : The regional distribution of the provision and flows of harmful fisheries subsidies. (a) Total amount of harmful fisheries subsidies being provided by each region and the total amount of domestic and foreign harmful fisheries subsidies estimated to be cumulatively supporting fishing within each region, in US\$ billions (See Table S.1 for corresponding data); **(b)** Inter-regional flows of harmful fisheries subsidies, due to their provision to regional distant-water fishing fleets, in US\$ millions (See Table S.2 for corresponding data).

are supporting fishing within either foreign waters (17–30%) or the high seas (3–7%). Harmful subsidies provided to distant-water fishing fleets can therefore increase the risk of overfishing outside of the original subsidising nation’s jurisdiction. While the study focused on risk and harm in relation to fish stocks and marine ecosystems, the impacts are also relevant to economies, and societies, and can be significant even where the biological risk is not realised [13]. This demonstrates that harmful fisheries subsidies are a matter of international concern and not an issue that can be easily resolved by unilateral action alone, not at least at the global scale [43]. This study also corroborates previous findings 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 fishing [44,45], and whether this activity (and distant-water fishing more generally) would

be profitable at all without government subsidies [46,47].

Previous studies show that distant-water fishing, including that within the high seas, is almost exclusively conducted by a handful of rich nations [29,48] and that the majority of their activity occurs within the EEZs of poorer nations [17,49]. However, few, if any, studies have quantified the flow of harmful subsidies being channelled towards this activity at the global scale. We show that there is a disproportionate flow of harmful subsidies from very-high and high-HDI nations supporting fishing within very-low and low-HDI nations waters’—more than 40% of the harmful subsidies supporting fishing in low-HDI nations originate from very-high and high-HDI nations. While we recognize that reductive nation classification systems, such as HDI, oversimplify and decontextualize the socio-economic reality of the world and potentially obscure important relationships that may explain some of these subsidy flows

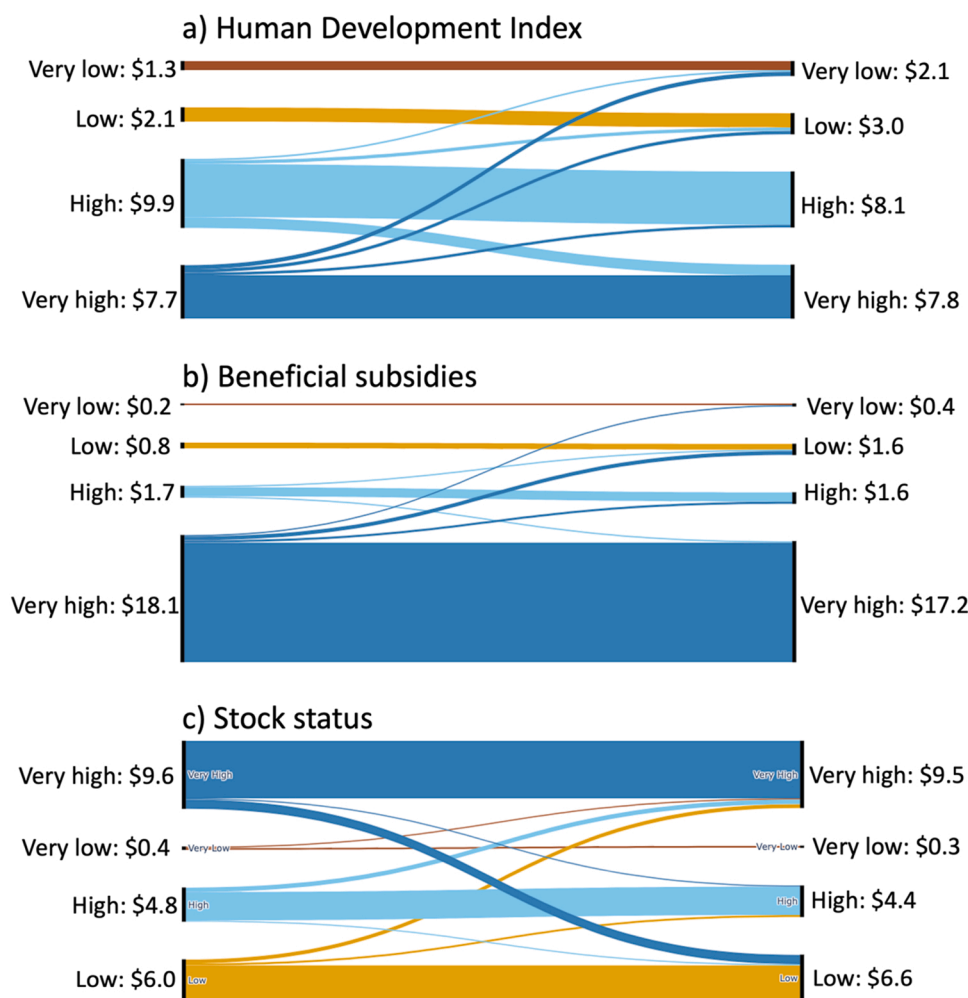


Fig. 3. : The distribution of the provision (left axis) and net flow (right axis) of harmful fisheries subsidies in billion US\$. The total amount of harmful fisheries subsidies being provided by each nation and the total amount of domestic and foreign harmful fisheries subsidies estimated to be supporting fishing within each nation clustered as either very-high, high low, or very-low for; (a) the UN Human Development Index, (b) the amount of beneficial fisheries subsidies provided, and (c) the 2020 Environmental Performance Indexes for relative fish stock status.

[50]. Clearly, our findings show that the risks and costs associated with overfishing, are being disproportionately exported to low-HDI nations which can further entrench global inequities, poverty, and malnourishment, and makes the achievement of interconnected UN Sustainable Development Goals less likely [12]. Simultaneously, the ‘benefits’ from subsidising these fishing fleets, i.e. reduction in the costs of fishing and the ability to maintain or even increase fishing effort, are largely accrued and maintained by the wealthiest nations [7].

We demonstrate that 65 of the world’s coastal nations are ‘net-subsidy sinks’; 17 (26%) of which are low-HDI nations and 26 (40%) are very-low HDI (see Table S.3). While these disproportionately affected nations may benefit from fees and conditions included within agreements that grant distant-water fishing fleets access to their waters, such as clauses that ensure distant-water fishing nations processes a certain amount of catch in the host nation or employs a certain number of local people on board their fishing vessels [51], evidence suggests that only minimal compensation is received and that the terms of these access agreements are often unfavourable for hosts [52]. 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 nation [53]. High-HDI nations use their capital to gain access to resources and subsequent revenues from catches taken from low-HDI nations and may be less incentivised to fish sustainably because they do not consider the direct effects of overfishing [44]. Another reason to address the increased risk of overfishing by subsidized distant-water fishing nations is that they may also prevent developing nations from developing their own sustainable and equitable

blue economies as these require fish stocks to be rebuilt and maintained at a sustainable level, and for the benefits from those fisheries to be retained locally [54]. Removing foreign harmful subsidies from their waters would represent a key step towards achieving such goals in the long-term [11]. However, it is not straight forward, as subsidies, including the fees and conditions for access, are part of broader drivers of change associated with ideologies, legal frameworks and markets and technologies that play critical roles in the shaping of fisheries and the wider food systems that they are associated with [17]. While continued efforts to strengthen and enforce global rules on the subsidisation of fishing via international organisation such as the WTO should help to achieve this aim, it is also important that these efforts are in combination with focused bilateral and plurilateral action to mitigate the impact of fisheries subsidies on specific nations and regions. Very-low and low-HDI nations that are the destination of much of the world’s subsidised fishing must be empowered to reshape the nature of access arrangements, data collection, and benefit mechanisms that have historically served (neo)colonial powers and fishing conglomerates [7, 55].

Analyses showing a net flow of harmful subsidies originating from nations with stronger fisheries management capacity and relatively sustainable fish stocks, towards nations with lower fisheries management capacity and relatively poor status fish stocks (Fig. 3), emphasises the need for bilateral and regional actions in addition to global action via the WTO. This is particularly vital for Africa and Oceania. These continents and regions also include some of the nations that are most dependent on access to marine fish for nutritional and food security and whose food systems are most threatened [56,57].

This analysis matters because having limited fisheries management and enforcement capabilities results in a lack of regulation and control that might otherwise help mitigate the negative effects of harmful subsidies [9]. The threat of heightened risk of overfishing that harmful subsidies can create are greatest for those fish stocks with relatively poor stock status, and the flows of harmful subsidies is undermining the efforts by developing nations to rebuild their resources. Conversely, vast sums of public money that are spent by many high-HDI nations on beneficial subsidies invariably go towards protecting and rebuilding the fish stocks within their own domestic waters, while the same nations simultaneously use public money to increase the risks to fish stocks, livelihoods, and food security of very-low and low-HDI nations [58]. As such, the risks 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. Redressing this unjust imbalance requires a shift in power. This shift may be supported within the rules currently being negotiated within the WTO, an organisation whose core activity is to resolve trade disputes and facilitate trade to raise living standards, rather than to intervene in the governance and management of international fisheries. Ultimately, it is essential that the so-called subsidy-sink regions can individually and collectively determine and enforce the rules of access to their waters and resources.

4.1. Concluding remarks

This research provides, for the first time, a snapshot of recent global flows and distributions 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 harmful fisheries subsidies through our new complete dataset provides evidence to support further bilateral and multilateral fisheries subsidies reform and for measuring the effectiveness of the new WTO measures. Addressing these issues is not straightforward but information about subsidies and the risks and rewards associated with them can potentially enable and empower nations to make informed choices about their fisheries and increase accountability and pressure on all actors to support least developed nations in dictating and strengthening the terms of use and access to their waters. This requires an understanding of the scope and impacts of subsidies, as well as comparative analysis of the impacts and benefits of reducing subsidised foreign fishing for local fisheries and economies.

Our conclusion is that harmful subsidies provided to fishing fleets operating outside of the source-nations' EEZs should be prioritised for removal, particularly when they operate in the high seas or the EEZs of low-HDI nations or nations with limited fisheries management capacity and/or poorer stock status. Currently, the new WTO measures do prohibit subsidies acting on overfished stocks, with some caveats, but only limit subsidies for fishing on unregulated stocks in the high seas, excluding all fisheries managed within Regional Fisheries Management Organisations (RFMO) or indeed EEZs, for example. Along with necessary reforms to RFMO governance and access allocation [7,55]—and following a thoughtful approach regarding the rights and aspirations of least-developed nations—removal of all harmful subsidies to distant-water fishing would ensure that the onus for managing the impact of any remaining harmful fisheries subsidies lies predominantly with the subsidising nation themselves. This would begin to redress the unjust global distribution of harmful subsidies on the fisheries that provide essential food and livelihoods to millions of people, particularly in low-HDI nations in Africa and Oceania [59]. Instead, we have seen some key subsidising regions propose the reintroduction of harmful fisheries subsidies that have already been removed [60], in direct

contradiction of the evidence and discussion that led to a need for a subsidy agreement in the first place.

While the recent consensual WTO agreement represents a significant step in the right direction, further negotiations on fisheries subsidies rules are necessary 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. However, if international organizations are unable to step in to solve this problem, then low-HDI nations are not necessarily divorced of power or agency in dictating the terms of their access agreements. Furthermore, the most affected regions may require significant funding to help manage and rebuild their fish stocks to effectively undo the damage caused by the continued provision of harmful fisheries subsidies to foreign fishing fleets that operate within their waters. However, recent studies show that there is a significant gap in current ocean financing [61]. Moreover, net subsidy-sink nations will need to find ways of generating alternative funds if they lose the revenues from foreign fishing access agreements, which for some nations, are a major contributor to national Gross Domestic Product. Indeed, a 'loss and damages' fund, like that established at 27th Conference of the Parties of the UN Framework Convention on Climate Change, could provide a model for support to historically impacted nations that bear the burden of harmful fisheries subsidisation. 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 enforcement in heavily affected regions [62] would be a step in the right direction.

CRediT authorship contribution statement

Individual contributions to this paper were as follows: conceptualisation, D.J.S., U.R.S.; methodology, D.J.S., A.S., S.V., A.M.C.-M., V.W.L.L., W.W.L.C., M.L.D.P., U.R.S.; data analysis, D.J.S., A.S.; data visualisation, A.S., S.V., K.R.; writing—original draft, D.J.S.; writing—review and editing, All authors; funding acquisition, U.R.S.

Competing interest statement

The authors declare no competing interests.

Data Availability

Data will be made available on request.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.marpol.2023.105611](https://doi.org/10.1016/j.marpol.2023.105611).

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