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Global seafood trade flows and developing economies: Insights from linking trade and production

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ABSTRACT

Knowing the patterns of marine resource exploitation and seafood trade may help countries to design their future strategic plans and development policies. To fully understand these patterns, it is necessary to identify where the benefits accumulate, how balanced the arrangements are, and how the pattern is evolving over time. Here the flow of global seafood was traced from locations of capture or production to their countries of consumption using novel approaches and databases. Results indicate an increasing dominance of Asian fleets by the volume of catch from the 1950s to the 2010s, including fishing in the high seas. The majority of landings were by high-income countries' fishing fleets in their own waters in the 1950s but this pattern was greatly altered by the 2010s, with more equality in landings volume and value by fleets representing different income levels. Results also show that the higher the income of a country, the more valuable seafood it imports compared to its exports and vice versa. In theory, this implies that the lower income countries are exporting high value seafood in part to achieve the broader goal of ending poverty, while achieving the food security goal by retaining and importing lower value seafood. In the context of access arrangements between developed and developing countries, the results allow insights into the consequences of these shifting sources of income may have for goals such as poverty reduction and food security.

1. Introduction

Globally, trade in food products has been valued at approximately US$ 500 billion annually [1]. Seafood is one of the highest valued food commodities, exceeding the trade value of sugar, maize, coffee, rice and cocoa combined [2,3]. The trade in seafood is characterised by a high proportion of total seafood exports by developing countries to developed ones, i.e., 54% of total export value [3]. The high proportion of seafood exports by developing economies reflects the fact that, for lower income countries, export of primary commodities such as natural resources (including fish) is one of the main sources of income [4,5].

Increasing exports of seafood products benefits developing countries in various ways. The United Nations' sustainable development goals (SDGs) for developing countries [6] aim to eliminate poverty and attain food security by 2030; achieving sustained economic growth via trade can be a powerful way to achieve poverty reduction [7]. However, exposure or reliance on the global economy exposes countries to economic shocks and increased vulnerability [8–10]. There is also concern that, while these exports may enable a country to achieve sustained economic growth at the aggregate level, there is the potential for the loss of food security at a micro level, and increased vulnerability to trade shocks [2,9,11,12].

Another option to support economic growth for developing coastal states rich in natural resources is to enter into access arrangements with developed countries for the right to fish within their waters. The third United Nations' Law of the Sea convention (UNCLOS) established the right of coastal states to a 200-nautical mile (nm) exclusive economic zone (EEZ) extending from the territorial sea baseline, with sovereign rights over the marine resources within. Coastal states are entitled to enter into access agreements and charge access fees to other nations for the right to fish within their EEZs. The circumstances in which foreign fleets seek access arrangements with developing countries and the

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challenges developing coastal nations face in using access arrangements to achieve economic goals have been discussed elsewhere, with most coastal states failing to fully realise the benefits from their fisheries resources [13–17]. These arrangements, however, can yield a significant income for developing countries [18,19].

Recent studies on the global seafood network have developed spatially disaggregated databases on seafood landing and examined the provenance of seafood and its connections with seafood trade [20]. Others have used network theory to analyse the changing structure of the global seafood trade network and the dynamic trade relationships between nations [21], and demonstrated the vulnerability of importing countries to trade shocks [9]. Our research objectives were to develop an improved database of seafood landings, imports and exports and to trace the flow of seafood from its source, whether that is from aquaculture or wild capture, through trading networks to the country where it was imported and consumed. With this database, it is then possible to establish the major flows and trading partners inherent in this global distribution process. This establishes the potential to examine how this distribution process has changed over time, what these changes have meant for other opportunities open to developing countries' such as access payments, and finally what these changes may mean for the achievement of food security and poverty reduction by developing nations in the future.

2. Material and methods

The general approach to tracing seafood from ocean/coastal origin to place of consumption was to first attempt to match reported exports to databases of capture landings and aquaculture production. These matched records were then placed in a virtual marketplace and then used to match reported imports. The focus was on marine production/capture species. The general methodology used was similar to that reported previously [20], however, with several significant advances to improve matching commodities traded and trading partners. The method tried to connect the source location (0.5 degree spatial cell) with the general consumption location (country) so that any associated impacts could be studied, as well as impacts on production resulting from changes to jurisdictions, management and the state of the marine ecosystems involved. Though catch and landings are often used interchangeably, catch properly refers to all animals captured even if discarded and not reported, whereas landings refers to that recorded to authorities as retained. All weights were roughly calculated as real value ($US indexed in 2000) following Sumaila et al. (2007) [22].

2.1. Seafood trade and trading partners

Seafood trade statistics were obtained on-line and covered the period 1976–2009 [23]. Traded seafood could have originated through wild capture or through aquaculture production [24] and these were differentiated in our subsequent attempts to map the source. Freshwater species, plants, shells and corals were not included. To improve the vital step of matching imports to exports a superior approach to previous work was used [20]. Trading partners for seafood were ranked in likelihood based on UN's annual Comtrade data (1988–2015) (http://comtrade.un.org/data/ accessed July 12, 2016) and where no information on trade was available then WTO's primary trading partner data was used (http://www.wto.org accessed July 2016). Imported and exported quantities are expressed, as provided, as the weight of the seafood product after processing.

2.2. Marine fisheries capture of seafood

Fisheries landings were assembled from a variety of published (and on-line) sources. The Food and Agriculture Organization (FAO) of the United Nations produces global capture fisheries statistics [25]. This data was improved by harmonising with complementary data produced by groups that produce a more detailed spatial breakdowns, including the International Council for the Exploration of the Sea (ICES), the Northwest Atlantic Fisheries Organization (NAFO), the General Fisheries Commission for the Mediterranean (GFCM), the Regional Commission for Fisheries (RECOFI), the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), the South East Atlantic Fisheries Organization (SEAFO) and the Fisheries Committee for the Eastern Central Atlantic (CECAF). Methodology used to map this was generally similar to that used by Watson et al. (2004)[26] and described in Watson (in press) [27]. Estimates of unreported seafood capture were also estimated [28]. Nearly all of the landings were assumed to come from the area reported in the published statistics with the exception of some reporting by China which was adjusted [29]. Highly taxonomically aggregated reporting statistics, which fail to identify the taxon even to the family level, were disaggregated where possible based on candidates from more detailed reporting in nearby locations.

This harmonised dataset representing global reported and unreported landings was mapped to a system of 0.5-degree rectangular spatial cells using a rule-based approach driven by the distributions of reported taxa [30], and what is known and information about the fishing access of national fishing fleets, including quotas, by taxa and by year [27]. Catch data were analysed for three representative time periods, the yearly average of the decades of the 1950s and 1970s, and the 2010s presented as the yearly average of 2010–2011.

2.3. Tracing seafood flows

The description of export and import commodities can be very specific as to the taxon or taxa involved, such as 'Albacore", but unfortunately can often be vague. Overcoming this required a hierarchical approach to matching reported exports to statistics describing landings and aquaculture production. Though some seafood is imported and re-exported, this is still a relatively minor path for most global seafood. This meant that most reported exports described in databases should match with either wild caught landings or aquaculture production by the exporting country on either the same or the previous year. Matched records of exported seafood were recorded in a virtual marketplace, which were then linked to import statistics.

This step, linking import records to those placed in the 'virtual market place' database had to be approached through a series of randomised trials. That is because, as each import record was processed, an attempt was made to match this with the most suitable export record, which created a tendency for some exports to be taken first and denied to later attempts at import matches. That is, once an export record in the virtual market place was matched to an import record it was essentially 'sold'. Given that for each potential importer there was a range of possible and even probable exporters, the order of the importer in our simulation was important to the links made. Therefore because in the real marketplace this process does not happen sequentially and no data was available on the dynamics, the range of possible outcome was approximated through randomization.

Therefore the order of processing was randomised, and 100 trials were completed in order to allow all importers access to this 'marketplace', and the average outcomes were used for our results.

There was a novel and rigorous approach used to match the descriptors of export and import records that allowed for hierarchal matching via the descriptors. The strength of the match of import to market record depended on the match of important primary keywords such as "tuna" or "salmon", as well as minor supportive keywords words (which had less importance) such as 'frozen' or 'mince'. The use of FAO general ISSCAAP codes associated with the export match process assisted the matching process and unlikely commodity matches were not allowed. The known trading partners for seafoods were used to weight the likely matches, as was the year of export. For each trial, each import record used the best matching still available market record.

The seafood tonnages within the virtual market were 'sold' and not available for the remainder of the trial. For country classification into income categories, the World Economic Situation and Prospects (WESP) tables [31] were used.

2.4. Illustrating flow patterns

Two main methods were used to illustrate the flow patterns. The first was the chord or circular plots available as an R routine Migest [32]. The second was Sankey plots or flow diagrams available from an R routine that accesses a googleViz routine. Secondary processing was required to clarify the figures (using vector editing within Draw Freely's InkScape and Microsoft's Powerpoint).

Trade (import and export) was presented mostly by region. Imports to a region that are indicated as originating from the same region were from another country within that region. Seafood imported must originate from another country. For trade, two time periods are presented; the yearly average of the decade of the 1970s and the years 2010–2011 for the 2010s.

3. Results

3.1. Completed database

The database constructed through the methodology described above was novel and superior to previous attempts [20] to link fisheries capture with exports and then to seafood imports. Its superiority stems largely from its greatly enhanced ability to match imports with exports (described in 2.3) and its much superior ability to match probably trading partners (described in 2.1). The database will be made publically and freely available.

3.2. Who caught what and where?

While mapped aquaculture production was not available there was, however, mapped wild capture data, therefore this analysis concentrated primarily on the wild caught or fished supply. Since the sources of seafood products are associated with the fishing locations and their associated fishing gears, the patterns of the fishing regions and their fishing locations can be illustrated. While many fishing fleets operate primarily in their own waters, some fleets catch fish in the waters of distant countries, disputed waters and/or in the high seas (often for tunas). The regional origin of fishing fleets and which regional waters they fished was summarized by the weight of landings for the 1950s, 1970s and 2010s (Fig. 1a-c). Note that the total landings (Mt; million tonnes) increased in each decadal plot.

The circular plots reveal which part of the landings each region took from their own or other regions or from the high seas. Our results show that in the 1950s, Asia, Europe and North America (mainly the USA) dominated total fish landings. Mainly Asian and North American fleets fished the high seas, while European and Asian fleets predominantly fished European waters. European fleets also fished within North American waters. The remaining regions' fleets (South America, Oceania and Africa) took the majority of landings from their own regions. In the 1970s, Europe began to increase their fishing activities, landing more from the Asian region and beginning to fish the high seas and the African region (mostly from the northwest). Asia had increased their landings from the Oceania region and North America. The volume of catch taken by North American fleets in European and Asian waters increased, while fishing on the high seas decreased. During this time, Africa, South America and Oceania continued to fish predominantly within their own regions, although there was an increase in the volume of their total catch.

By the 2010s, Asian fleets dominated catch volume and caught the highest amount from the high seas. Asian fleets also began to decrease landings from Oceania. By this time, with the exception of Asia, most regions took the majority of their landings from their own regions; for example, countries in North America confined all of the catch to their own region and took limited catch from the high sea areas. By then European fleets also decreased their catch from the African region. This suggests after the introduction of the EEZ in the early 1980's and further depletion of marine resources in the African EEZs, the number of foreign fleets reduced and countries began to take less catch from other regions. However, the volume of total landings increased in each decade.

3.3. Where does this catch end up?

By tracing the seafood flow it was possible to show where this landed seafood ended up. Figs. 1d and e show the trade flows between regions, for the 1970s and 2010s respectively. Trade in both decades was complex, with all regions engaging in trade. Our results show that in the 1970s, Europe dominated the volume of seafood imports, with most of its imports coming from Africa, South America and North America. Africa also exported to the North American and Asian regions. In the 2010s, Asia became the highest importer of seafood, importing the majority of their seafood from South America, with small volumes from Oceania and North America. Asia also increased its export volume to Africa, North America and Europe. Europe continued to import from Asia and South America, but decreased its imports from Africa.

In addition to examining landings and trade flows, it is instructive to assess the value and flow of global landings. The real value of landings in 2011 is shown in Fig. 2. This figure shows the fishing area, the regional fishing fleets and value to the individual country fleets. The Asian region produced the largest proportion of the real value of landings in that year (US$ 37 billion) with the majority associated with China and Japan in 2011. The European and high seas regions also produced a relatively large proportion of the value. Similar to the flow of landed catch, the real value of catch produced in each region tended to stay within that region. For example, of the value produced in the Asian region, the majority of it flowed to Chinese and Japanese fleets, with the remainder flowing to the fleets of other Asian nations.

In contrast to the flow of landings from fishing grounds to regional fleets, there was a considerable trans-regional exchange when it came to real value of traded seafood (Fig. 3). The Asian region dominated the value flow in 2011 with significant imports to China, Thailand, Japan and other countries in this region. Feeding into these imports from outside the Asian region were those from Europe and to a lesser extent the other regions. The next largest trade flow of seafood by real value was into Europe (with trade being relatively evenly dispersed between countries). Here there was considerable input from other European countries and from Asian fleets. Imports into Europe and North America were quite diverse. For Europe, this meant a considerable import flow from all regions. The USA dominated the value of seafood imports into North America, which included a considerable portion from the Asian region. African imports by value were largely from the Asian region and Nigeria was the biggest importer. Though the fisheries of South America have large tonnages they were not significant in our flow picture either as exporter or as importers in terms of real value of seafood.

3.4. Developed vs. Developing countries – how do trade flows change over time?

As seafood represents considerable sources of protein and national incomes, it is useful to look at the flow of landings and the real value of landings between the claimed EEZ areas of countries and the fleets taking them, based on the country's income level and how this has changed since the 1950s (Fig. 4).

In the 1950s, high income (HI) and upper middle (UMI) countries dominated the landings, with only a small proportion coming from the other categories. Most HI country landings came from the waters of HI

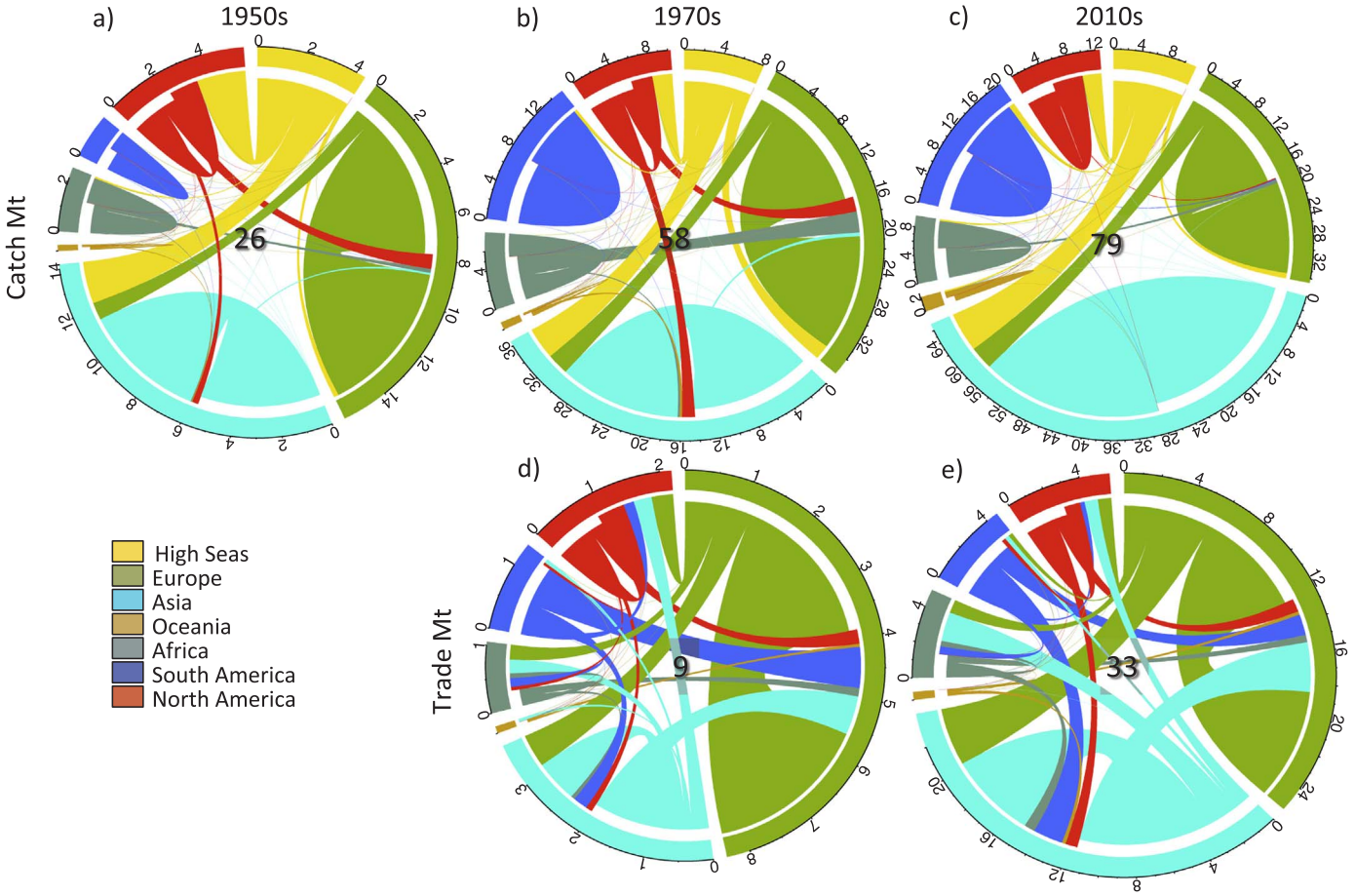

Fig. 1. Average annual flow between regions (M t) of global catch between fishing regions and regional fishing fleets in a) 1950s, b) 1970s and c) 2010s, and global trade in d) 1970s and e) 2010s. Totals shown at centres. Destination or importing region is represented in the outer ring of circle while the source (fishing) or exporting region is represented in the inner circle.

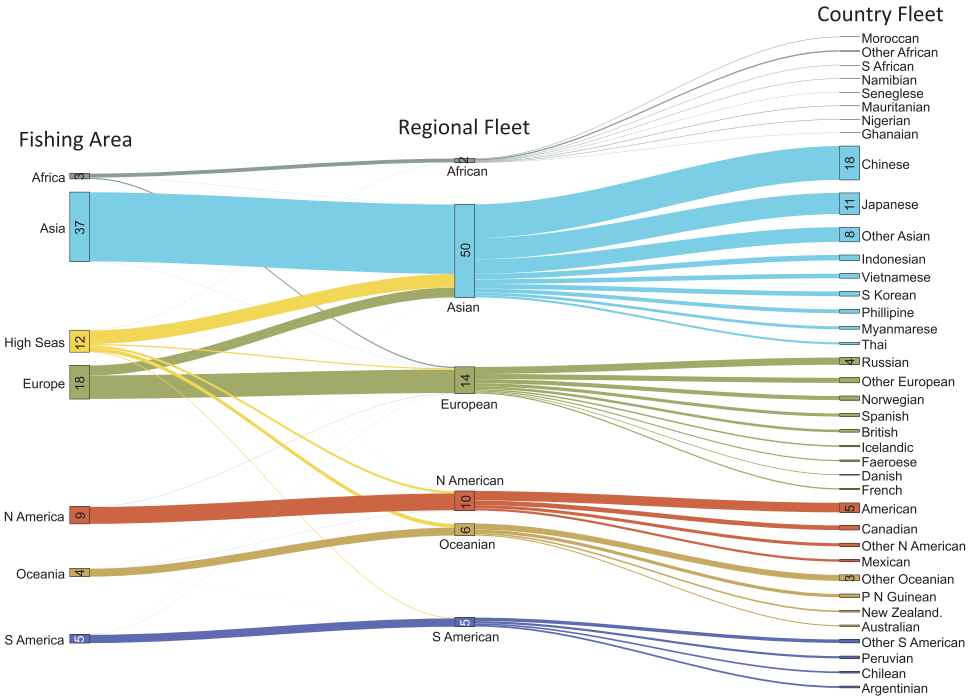

Fig. 2. Flow of annual real value of landings in 2011 ($USD billions indexed 2000) from fishing areas to regional fishing fleets broken down to major countries.

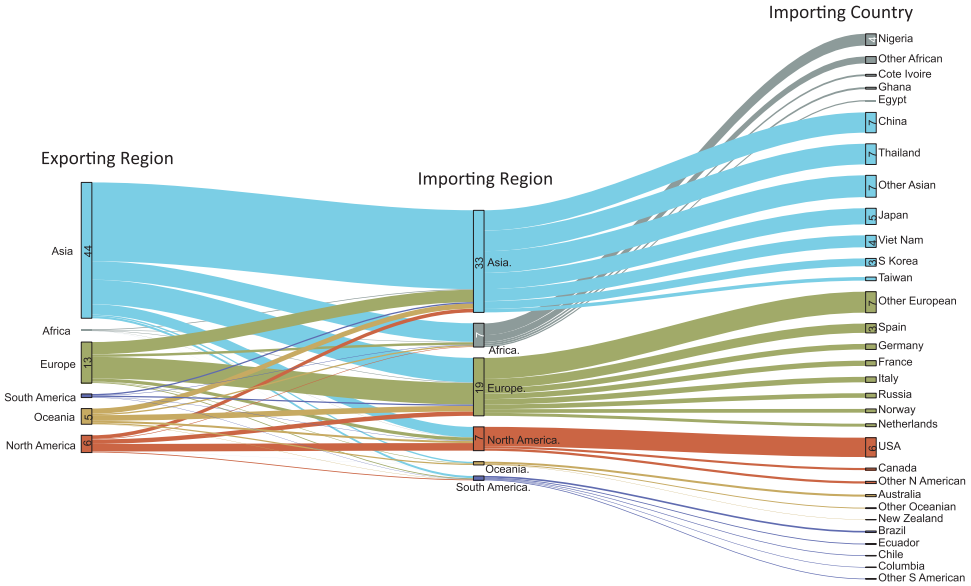

Fig. 3. Flow of annual real value of seafood trade in 2011 ($USD billions indexed 2000) from exporting regions to importing regions broken down to major countries.

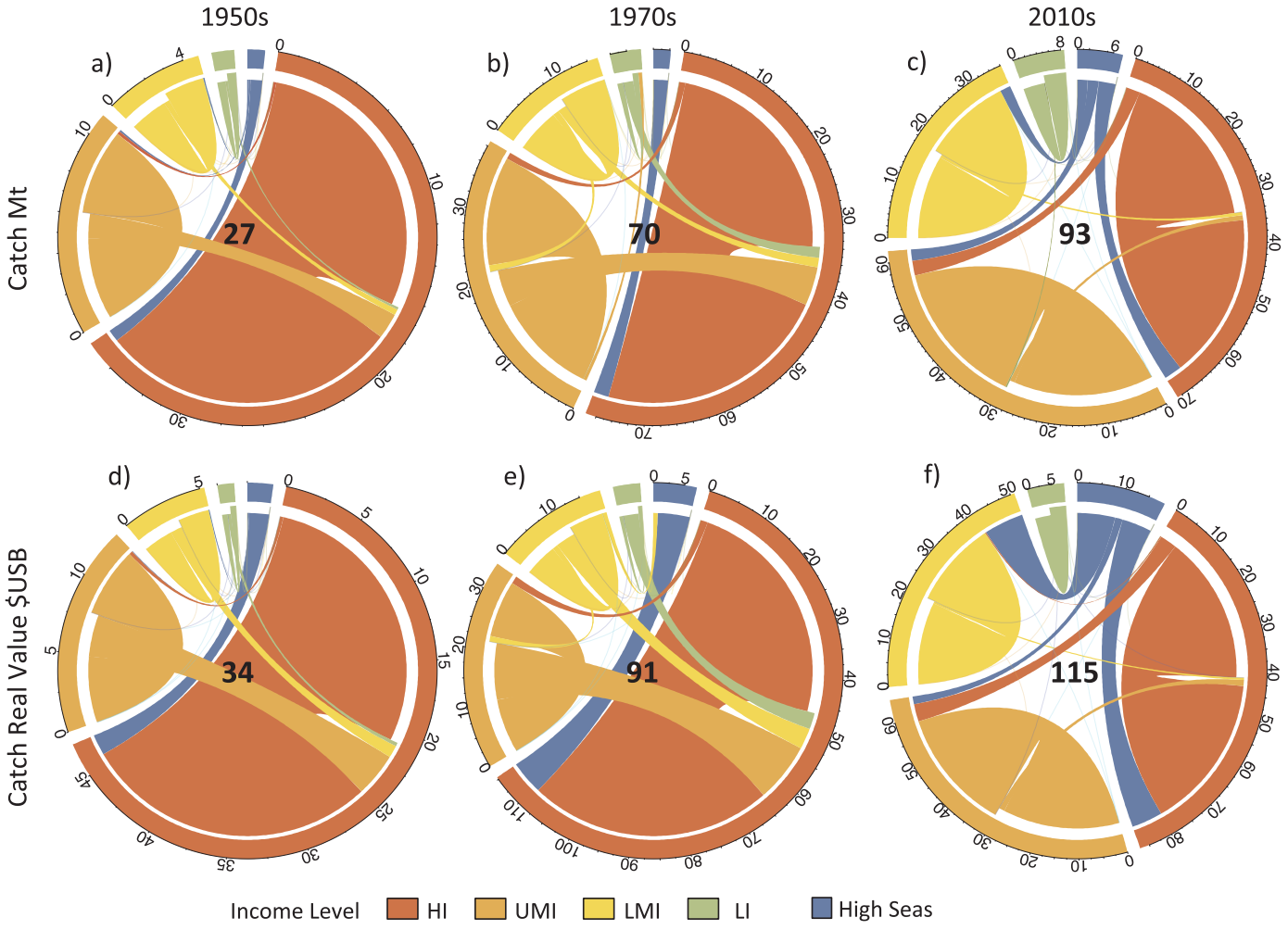

Fig. 4. Average annual flow (M t) of global catch between country income level groups (HI = High, UMI = Upper Middle, LMI = Lower Middle and LI = Low) between country exclusive economic zone (EEZ) claim and fishing fleets in a) 1950s, b) 1970s and c) 2010s, and for catch real value ($USD billions indexed 2000) in d) 1950s, e) 1970s and f) 2010s. Totals shown at centres. Fishing country income group is outer ring of circle while the country (EEZ) income level is shown in the inner circle.

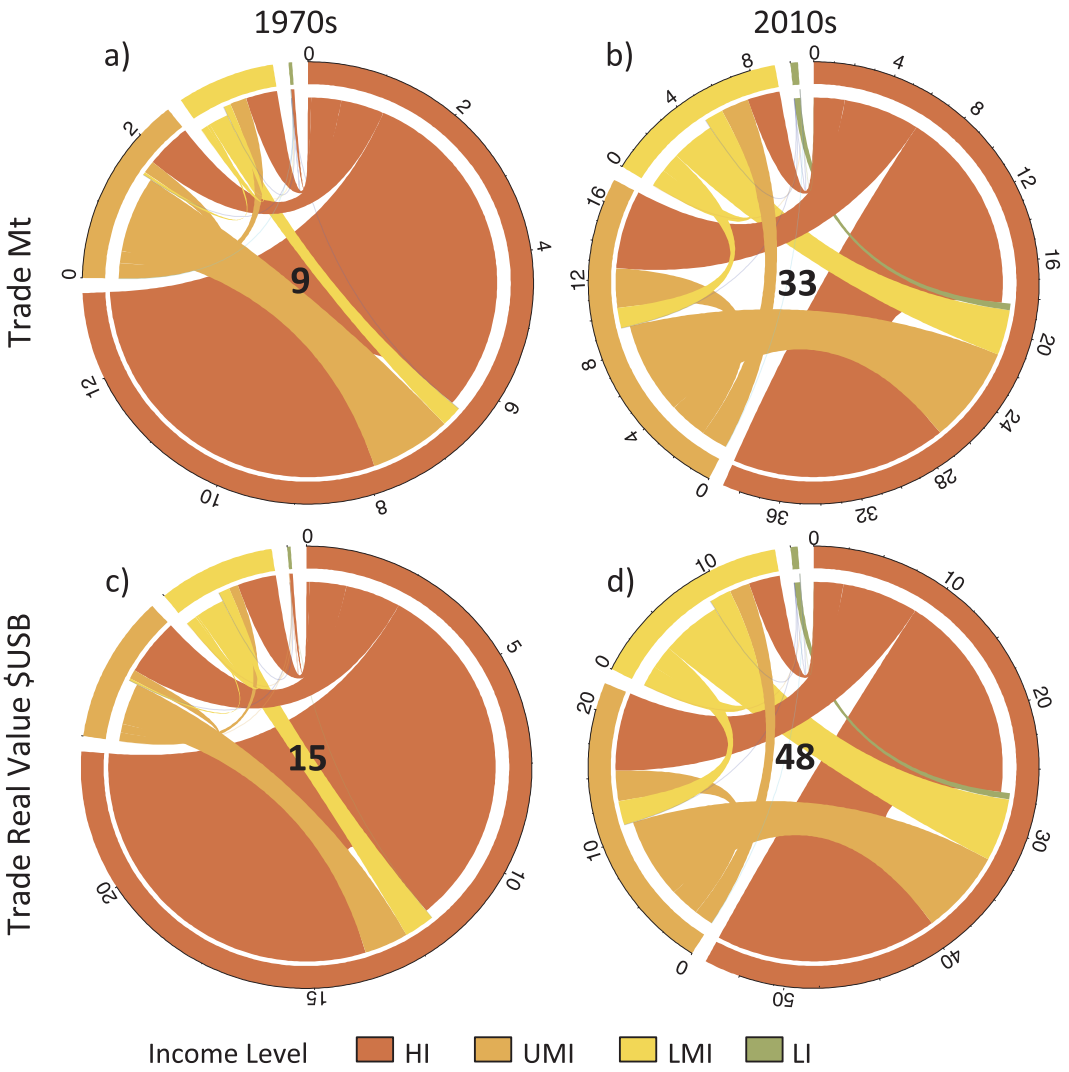

Fig. 5. Average annual seafood trade between countries ranked by income (HI = High, UMI = Upper Middle, LMI = Lower Middle and LI = Low) in (M t) in a) 1970s, b) 2010s, and in real value ($USD billions in 2000) for c) 1970s and d) 2010s. Totals shown at centres. Importing income group is outer ring of circle while exporting income group is the inner circle.

countries (mainly their own EEZs), and a smaller amount originated from the high seas and the waters of upper middle (UMI) countries (Fig. 4a). This remained the case in the 1970s (Fig. 4b), where a slightly higher proportion of the HI catch came from the UMI countries, and landings by UMI countries increased; landings by UMI countries came from the waters of UMI countries, and also the waters of HI countries. In the 2010s the HI countries share of total landings declined (Fig. 4c); the HI and UMI regions had a relatively even share of the total catch. Lower middle (LMI) countries increased their landings, once again mainly from the waters of LMI countries. LMI countries also increased landings from the high seas. An important point here is that the flow of catch is unidirectional – the landings flowed from the lower income countries to the higher income countries. For example, in the 1950s HI countries caught fish from the UMI, LMI and low-income (LI) regions, but none of those regions fished in HI waters. The same pattern held in the 1970s and 2010s.

In the 1950s, the flow of real value of landings closely reflected that based on tonnage alone (Fig. 4d). In the 1970s (Fig. 4e) the value of fishing by HI fleets in the waters of lower income groups and in the high seas was proportionally higher than that based on landings alone (Fig. 4b), reflecting the higher value products that HI fleets pursued outside their own countries' waters. By the 2010s (Fig. 4f), the value of high seas catch had increased to all except the LI group. As with the tonnages, the real value was now more distributed across income levels through an expansion to the LMI. There was not much increase to the LI value.

The diagram with the flow of seafood trade for the 1970s between income groups (Fig. 5) shows the dominance of HI countries, with LI countries not accounting for much of the import or export flow. HI countries imported from all other income groups, especially those from UMI. HI countries did have exports to UMI countries (Fig. 5a). By the 2010s, the flow of traded seafood was slightly more equitable with the expansion of exports and imports by LMI (Fig. 5b). The UMI were exporting more seafood to lower income countries. Again, when the real value of the seafood trade was examined, the patterns seen with landings tonnage were enhanced, with most seafood value in the 1970s traveling within the HI countries (Fig. 5c). By the 2010s (Fig. 5d) this had changed, with other income groups now exporting and importing a larger proportion of the global flow. Flow was more omnidirectional. Typically, however, the flow of traded seafood value did go to higher income groups. All of the seafood from the LI group was imported by the HI group. Most of the seafood value in the UMI group was exported to the HI group, which was replaced with some reverse flow and by imports from the LMI.

Though not specifically addressed here, there are many sustainability issues connected to seafood capture. Besides those in productive inshore areas managed by national agencies there are those which limit production from current high seas areas, specifically from tuna stocks

[33] and from those waters associated with seamounts [34]. Here again there are problems but progress is happening [35]. Patterns of seafood production in the future will not only be driven by access and sustainability, but also by the modifications of climate change [36], the incentives of subsides [37] and the various forms of trade tariffs. Access to markets, though outside the scope of this paper will determine where these widely traded exports end up, and whether repacking or reprocessing by intermediaries further complicates linking capture to eventual consumption.

4. Discussion and conclusions

Many factors are involved in the supply pattern of global seafood. Seafood production is, of course, ultimately finite and based on the ocean's primary productivity and the ecosystem pathways that support the harvested stocks [38,39]. This limitation drives many development and supply patterns in fisheries, and undoubtedly motivated the distant-water fleets to fish in foreign waters as our analysis highlights. Fishing patterns drive patterns of seafood supply. There have been significant shifts in the pattern of global fishing since the 1950s [40,41]. Since that time fleets from Europe have intensified their fishing in NW Africa [42] and beyond [43], while more recently China has increased its fishing outside of Asia, in Africa and elsewhere [29]. This use of foreign waters by European and Asian fleets is also illustrated clearly in our results. Documented overcapacity in fishing effort, especially in the Asian regions, suggests that some fleets have struggled to meet their targets [44,45], and while many improvements in fisheries management have occurred globally [46], it is still widely accepted that there are many over-exploited stocks [35] which motivated the patterns of fishing in distant waters which our results illustrate.

Many countries have distant water fleets (DWF), which have traditionally fished great distances from their home waters. Considering the movements of DWF, seafood, including that produced by aquaculture, is sourced increasing distant from consumers [40]. While some DWF fish the offshore high seas for tuna, others fish in the richer inshore areas, those same areas that were once open but now are claimed as exclusive economic zones (EEZ) by coastal states. Our results also clearly show the pattern of DWF fleets fishing both the high seas and the EEZ waters of other countries. One usual historical exemplar is the fishery for Atlantic cod in North America, which, developing over a century, motivated colonization and which eventually supported a complex trade network which included the movement of slave labour. Cod fisheries even played a large role in the development of the declaration of EEZ surrounding coastal states and were central to jurisdictional claims in fisheries that dominate many of today's patterns of seafood sourcing [47]. So while initially these DWF might have fished waters of many countries, which may not themselves have had commercial fishing fleets, eventually they required negotiated arrangements with coastal nations for access. This need to now negotiate fishing access is the most likely reason for the reduction of fishing in foreign EEZ areas that our results illustrate.

Local depletions of domestic stocks [48] can intensify national reliance on imports and access via DWF fishing [49], also explaining the recent reductions our results illustrate. By linking wild seafood capture with exports and eventual imports, our analysis found that fishing by DWF of foreign EEZ areas decreased after global EEZ declarations. No information was available to test if access costs increased, affecting profitability, or whether national fleets began to take most of the harvest. This can be challenging to examine as arrangements can see foreign vessels reflagged, changing their identity by arrangement from that of a DWF to a locally flagged vessel. Importantly for development goals, it has been shown that the ability of coastal states to benefit from allowing access to DWF in their declared EEZ waters varies considerably depending on the trade-offs between receiving a fair return for their fishery resources through access fees and the benefits of retaining resources to maintain their own active fleet capacity [50]. There are, however, arguments that, overall, closure of the high seas would benefit island nations by improving inequities [51]. Resources would not be taken just outside EEZ waters but rather inside, requiring access fees to be paid. What was observed in the linked seafood trade resulted from these various trade-offs and the overall reduction in access of foreign EEZ waters observed.

This paper presents findings from a new database of fishing activity and trade, which illustrate the fishing and trade behaviours of countries on a global scale. This has necessarily meant the aggregation of data at a country level, and further aggregation at the developed vs. developing country divide. The conclusions drawn from the results above are therefore general in nature. Our results suggest that, with the exception of Asian countries, most countries have shifted from fishing in international waters, to fishing in domestic waters. This change in fishing activity has coincided with an increase in seafood trade between countries, both in landed weight and value. Our work supports the work by Gephart and Pace [21] but our new methodology provides a means of drilling into the details for wider study. Additionally, it is evident that the highly valued seafood has tended to flow to high-income countries, with the lower valued seafood flowing to low-income countries. This suggests that developing coastal states tend to export high value seafood to earn income and import low value seafood for consumption, and again accords with conclusions drawn elsewhere [2,52].

These results suggest that although access payments may have yielded a significant income for some developing coastal nations in the past, if the trend shown in our results continues into the future, engaging in seafood trade may be their only significant means to achieve and support sustained economic growth. There are consequences to generating income through seafood trade rather than through access payments. One consequence is that access agreements are not only a source of income for developing coastal states, but also financial, capital and technological support of fishing industry.[1] Another consequence is that foreign aid payments from developed countries to developing countries in some cases formed part of the access arrangements, and in other cases aid payments are made in exchange for cheaper access fees [53]. A shift from access payments to seafood exports may therefore lead to less aid and fishing industry development. Seafood trade may, however, generate higher incomes for countries which are able to negotiate trade deals as a bloc, although the ability for developing coastal states to do this may be limited [54]. Therefore, economic growth driven by seafood exports rather than alternatives such as access payments may result in higher economic growth and therefore fuller achievement of poverty reduction outcomes, but this is not a certainty, and will be highly region specific. This suggests that developing countries that have high natural resource endowments fuelling their economic growth (for example, the African, Caribbean and Pacific island nations) might do better to enter into collective bargaining arrangements with developed countries to ensure the seafood trade generates high enough benefits to increase economic growth and compensate for the reduction in access payments. The shift in fishing behaviour coupled with the high-value exports/low-value imports of low-income countries suggests that, if developing countries are striving to achieve goals such as food security, they are achieving these goals via trade liberalisation rather than consumption of their own resources. The ability of seafood trade to achieve goals such as food security is extremely unclear [11,55]. The potential increase in economic growth that comes from engaging in seafood trade may improve food security [56], although it is unlikely without appropriate redistribution of incomes within the developing economy [57].

Overall, it can be demonstrated that changes in fishing behaviour and increases in the volume and value of seafood trade have meant that

[1] UNCLOS Article 62(4)(a)

developing coastal states with high economic dependence on their natural resources have turned to exporting their high value seafood to developed nations and importing low value seafood for local consumption. This increase in trade has occurred at a time when access payments from developed nations are a less certain source of income and investment due to a tendency for countries to fish proportionately more in their own waters. These results are important because they suggest that careful attention to trade policy at a country level may be required to get the maximum benefit from their fishery resources, particularly developing countries who engage in trade to support economic growth, poverty reduction and food security.

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