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Global fisheries losses at the exclusive economic zone level, 1950 to present

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ABSTRACT

Up to one-third of commercial fishery stocks may be overfished at present. By analyzing catch trends and applying an empirical relationship derived from stock assessments, this article tracks the geographic spread of overfishing at the country level in terms of lost catch and lost revenue, from the start of industrialized fishing in 1950–2004. The results tell a cautionary tale of serial depletion to meet the ever-rising demand for fish. Examining country losses with respect to fishery management reveals that overcapacity and excess fishing effort are widespread, but also that recent trends towards sustainability can stabilize or reverse losses (e.g. for Norway, Iceland, the US, Canada, Australia, and New Zealand). Global trade effectively masks the successive depletion of stocks, so that without decisive action to reduce fishing effort, many more stocks will suffer and undernourishment impacts for the major exporting, food-deficit nations will only magnify.

1. Introduction

Overfishing and overcapacity are costing the world's fishery sector dearly, reducing resource rent—the surplus after fishing costs have been subtracted from revenue—by an estimated US$50 billion a year according to two recent studies based on different methodologies [1,2]. Meanwhile, the gap between global revenue and costs narrows [1], with global revenue from marine fisheries at approximately US$95 billion [3–6] and the total variable cost of fishing estimated at US$92 billion (both in real 2005 dollars) [7]. Excess subsidies, by one estimate topping US$27 billion per year currently [8], largely fuel this cycle of dysfunction.

Against this backdrop, the human consumption of fish has been rising, up 9% from 2002 to 2006 alone [9]. To support this, overall fish production from both capture fisheries and aquaculture continues to climb, reaching a level in 2006 more than seven times that recorded for 1950 [9]. The phenomenal growth of aquaculture is responsible for the recent growth, and nearly half of the world's food fish supply is farmed at present [9]. But just as the overall rise in fish production hides the stagnation in catches from the world's capture fisheries over the past two decades [6,9], global catch trends mask successive declines in regional stocks [10] and the geographic spread of overfishing in time [11,12]. Indeed, the roughly fivefold increase in marine fishery catches from 1950 to the late 1980s when catches peaked was facilitated by the expansion into and exploitation of new fishing areas, from the North Atlantic and Western Pacific coastlines southward and into the high seas [12].

Defining thresholds of unsustainable fishing across the diverse marine ecosystems and fisheries of the world is an uncertain task and a matter of lively debate (e.g., [13,14]). In the absence of scientific stock assessments for all commercial species, studies have evaluated overfishing at a global scale by extrapolating from available stock assessments and research surveys [9,15,16]; using catch trends as an indicator of stock biomass levels [17]; combining catch data with primary productivity levels [12,18] or empirical stock-assessment based relationships [19]; or some combination of these methods [20]. Despite ongoing controversy regarding the interpretation of data sources, consensus is emerging; according to several recent assessments, up to one-third of global fishery stocks are now overexploited or collapsed [9,11,15,16,19,21]. These assessments document the geographic spread and intensification of overfishing from the 1950s to the 1990s, with the proportion of depleted stocks stable since the 1990s in some analyses [9,21] and increasing at different rates in others [17,19,20].

While there have been many efforts to quantify when and to what extent fishing of a commercial stock may have crossed into unsustainability [16,17,20,22,23,25], few studies have estimated how much catch and revenue may have been lost [1,19,23]. Recently, Srinivasan et al. [19] estimated trends in potential catch

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losses in terms of tonnage and landed value for six continental regions and the high seas from 1950 to 2004. Using the same methodology, these trends are examined here at the next higher level of detail: that of countries' exclusive economic zones (EEZs).

2. Methods

To estimate trends in overfishing at the EEZ level, methodology described in previous work [19] was applied. According to the empirical approach from that analysis, 16–31% (central estimate 24%) of species-based stocks in countries' EEZs were deemed overfished between 1950 and 2004. This wide range encompasses the Food and Agriculture Organization's (FAO) estimate that 28% of stock groups were overexploited, depleted or recovering from depletion by 2007 [9], and is more conservative than a recent assessment by Branch et al. [16] that 28–33% of all stocks are now overexploited. Compared to the other catch data-based (and sometimes criticized [24]) method of Worm et al. [17], the approach by Srinivasan et al. [19] is far less likely to overestimate losses by conflating natural fluctuations and variable fishing effort with overfishing. Instead of the yearly collapse criterion used by Worm et al. [17], Srinivasan et al. [19] deemed a stock overfished if its time-smoothed landings remained depressed for 10 years continuously or 15 years in total following the year of maximum recorded catch (also averaged over time).

To assess the potential catch losses due to overfishing in both lost tonnage and lost revenue, Srinivasan et al. [19] relied upon catch statistics from the *Sea Around Us* Project (SAUP) covering 1066 species of fish and invertebrates in 301 EEZs, as well as an empirical relationship they derived from catch statistics and species stock assessments from the U.S. National Oceanic and Atmospheric Administration (NOAA). This enabled the estimation of maximum sustainable yield (MSY) levels for all species-based stocks in EEZs already identified as overfished. Comparison with actual catch levels then produced estimates of lost catch by mass. To estimate the foregone revenue of these potential landings, a database of ex-vessel fish prices compiled by Sumaila et al. [5] was applied. This paper maps country-level results not analyzed previously [19]. In addition, estimates of the relative revenue losses for all countries with overfished stocks are presented for the year 2000. All results are based on EEZ statistics at the SAUP database (http://www.seaaroundus.org/eez/). In addition, throughout the article, statistics on landings and revenues as well as information on fishing by country have been drawn from this database as well [6].

3. Results and discussion

3.1. Geographic expansion of overfishing

The world map in Fig. 1 illustrates the progression of estimated overfishing losses by mass over the 1970s, the 1980s, and the 1990s. Results for all of a country's waters are summed to calculate the overall loss for the EEZ. That is, losses for the Russian Federation include those from its waters in the Baltic and Barents Seas, as well as its Asian waters (and are estimated from the former Soviet Union records in earlier years).

The geographic pattern of losses accumulated by the 1970s (Fig. 1a) reflects the distribution of fishing effort in previous decades. By 1945, fisheries in the North Atlantic and North Pacific were already well-developed and contributed nearly equally to global catch, while those in the southern areas of these oceans and the Indian Ocean contributed just 7% [22]. During the 1950s, most of the Northern oceans came under exploitation [12], and accordingly, 14 of the 15 EEZs registering top losses in the 1970s were Northern hemisphere countries. The only southern country on the list, Peru, whose losses were second only to Norway's in the 1970s, ranked highest in the 1980s (Fig. 1b), due to the severity of the early 1970s collapse of the world's largest single-stock fishery, Peruvian anchoveta.

As fishing effort intensified and spread southward, catches peaked in the Atlantic by the early 1970s [22], deepening losses for European countries and the US in the 1980s (Fig. 1b). Peru's losses from the continued depression of anchoveta mounted as well in this decade. In the 1980s, Namibia and South Africa also ranked in the top 15 country losses (7th and 12th, respectively) due to the depletion of the cod-like hake and the small pelagic sardine in their EEZs.

The greatest global scale expansion of fisheries took place in the 1980s to the mid-1990s [12]. In European waters, losses appear to have leveled off from the 1980s to the 1990s (Fig. 1c), likely due to previous depletion and the shift of fishing in and imports from Southern waters. Although dissolution of the USSR in 1991 led to reduced fishing in the waters of its member countries (notably in the Pacific waters off Russia), catches in the EEZ of the present-day Russian Federation peaked in the early 1980s [6]. Thus, the catch losses for Russia and other Black Sea countries in Fig. 1c may be overestimated, but not greatly. In the Pacific, landings reached their highest level by the late 1980s [22], and Japan and China, 8th and 17th in losses in the 1970s, jumped to 5th and 8th place in the 1990s—significant movement given the head start in stock depletion in European and American waters. Although Peru's anchoveta landings recovered in the 1990s, overfishing of sardine in the waters off Ecuador and Chile caused these countries' losses to rise to 11th and 18th place, respectively.

Meanwhile, landings in the Indian Ocean, where many stocks are presently under terrific stress, continue to increase [9] so that large losses to overfishing have not yet been tallied (Fig. 1c). However, high levels of underreporting for East African EEZs [25] may contribute to the low losses estimated for these waters. In addition, tuna losses for Pacific island countries, although severe, are not mapped here because of the size of the countries but also the recent nature of their losses.

3.2. Overfishing losses and fishery management

Table 1 lists the 25 countries with the highest estimated losses to overfishing by mass over the study period, 1950–2004. As a measure of relative cost, Fig. 2 maps the potential revenue lost in the year 2000 as a percentage of the actual revenue from landings in that year in each country's waters.

Europe's high representation in Table 1 and the high revenue losses of several of its countries in Fig. 2 (ten with lost revenue potentially greater than actual revenue in 2000, and another seven with losses 50–99% of actual revenue) are not surprising. Given its history of early overexploitation, Europe was likely the first continent to accrue significant debts to overfishing [19,22]. In the Northeast Atlantic, nearly half of the stocks were overfished within a decade of exploitation, with the march to collapse faster than for global stocks [26]. Government subsidies, especially in the 1980s–1990s, fattened large fleets [11,27], and in spite of the capacity-reduction goal of the EU's Common Fisheries Policy, excess capacity is still widespread and monitoring under-developed [11,28]. By reducing fleets 50–79% and fishing stocks at higher biomass levels, a study commissioned by the World Bank and the FAO [1] estimated that Norway, Iceland, Denmark and the UK—four countries in Table 1—could achieve additional net economic benefits 22–61% of current landed values.

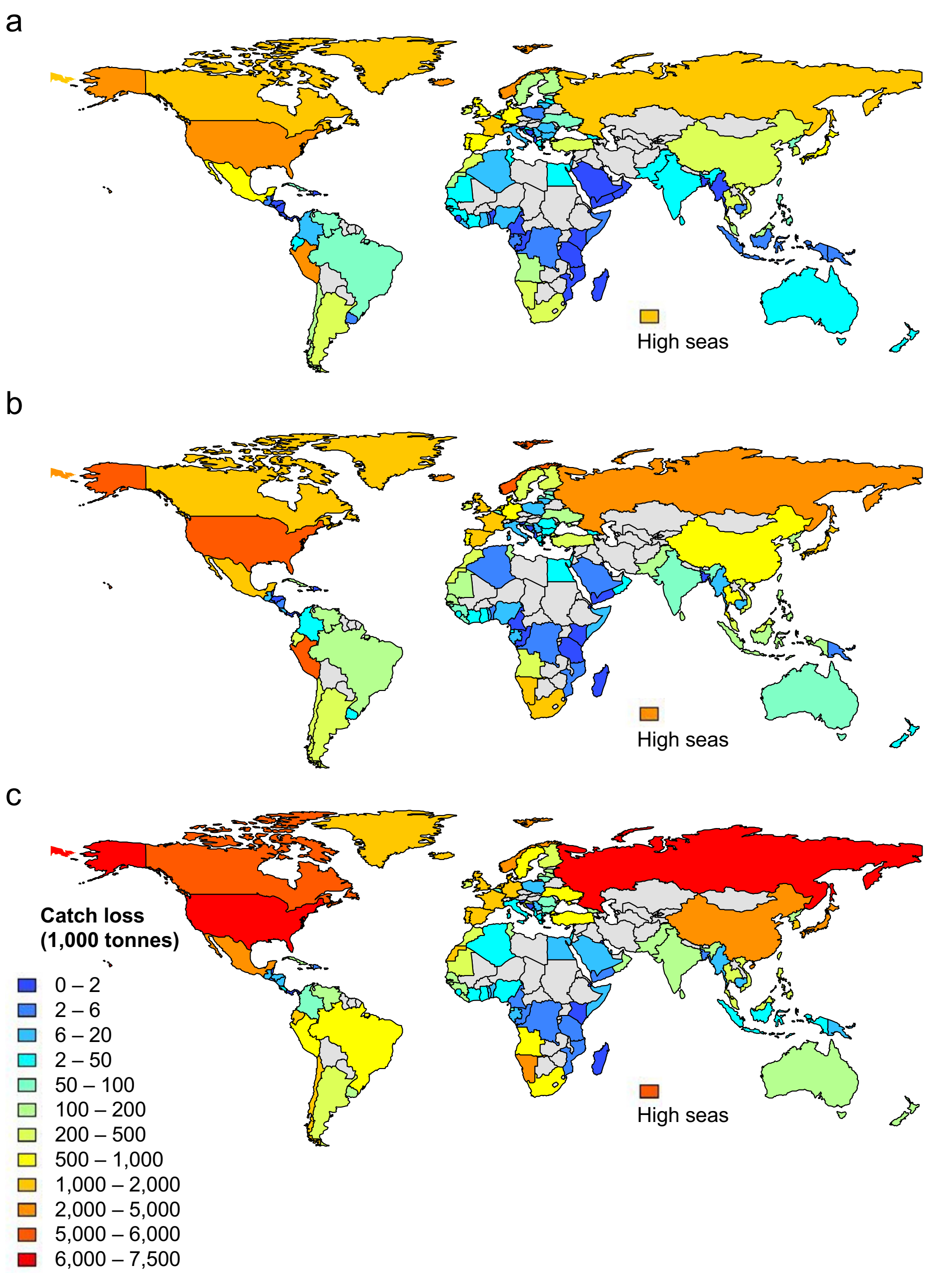

Fig. 1. Potential catch lost in 1000 tonnes over (a) 1971–1980, (b) 1981–1990, and (c) 1991–2000.

In a report card on fisheries management [28], most EU countries hovered around the 40% failing threshold. Norway and Iceland were notable exceptions, scoring a ~60% rating, corresponding perhaps to their reduction in estimated losses from the 1980s to the 1990s (Fig. 1b and c). Russia and Ukraine squarely received failing grades [28], coinciding with Russia's unsustainable rating in another recent assessment of the management effectiveness of the world's fisheries [29]. Although the revenue losses for former Soviet Union and Balkan countries may be overestimated in Fig. 2 due to the scale-back of fishing effort post-1991, the Russian Federation fleet is currently the largest in terms of tonnage landed [9].

For South America, the force of the anchoveta crash placed Peru 5th in overall catch losses (Table 1), although the country may have ranked higher given that peak landings were underreported by perhaps 33% [10,11]. Although Peru's recent losses have been mitigated by the recovery of anchoveta stocks, it has been estimated that a 60–80% reduction in excess fleet and processing capacity could allow fish stocks to rebuild meaningfully, adding potentially $400 million per year in economic benefits [1]. For a country rated tenth in its economic dependence on its fisheries sector [30], establishing sustainable fisheries management is critical. For Peru and Ecuador in particular, high historical losses (Table 1) have food security implications as both countries have a 15% prevalence of undernourishment yet are among the top 30 exporters of marine products [31]. As in Europe, South American countries largely fished their own or their neighbor's EEZs over the study period [6], but unlike Europe, South America was a net exporter and presently dominates the fishmeal trade [9].

According to the management report card by Pitcher et al. [28], Peru just failed; Brazil, Argentina, and Ecuador, whose estimated losses mounted in the 1990s (Fig. 1c), failed; and Chile, also listed in Table 1, barely passed. The assessment by Mora et al. [29] gave South American countries a mid-level rating for their policy-making transparency, found to be a key attribute of fisheries sustainability, but deemed Peru's and Chile's fisheries very likely unsustainable at present.

Fishing in the continental shelves off North America has been intensive for centuries [32], and by 2005, the Northwest Atlantic had one of the highest percentages of depleted marine species [15]. Not unexpectedly, the US and Canada rank 1st and 4th in Table 1. Recently, however, the US and Canada's management schemes have been rated well [28] with a good level of policy-making transparency [29]—reasons, perhaps, why their estimated catch losses fell or stabilized, respectively, since the late 1990s. This is consistent with a study by Beddington et al. [33], who reported a recent decline in the number of US stocks classified as overfished. At the same time, however, high US demand has been served by rising imports, increasingly from Asia [9]. Looking to Central America in Fig. 2, Guatemala's high relative losses were likely driven by a spike in foreign fishing in the early 1970s (including fleets from Mexico, Panama and the US, but also Japan and the Soviet Union), while Cuba largely depleted its own waters [6].

Overfishing in the waters of Asia has been proceeding on different timelines. Overall landings in Japan's and South Korea's EEZs clearly peaked in the mid to late 1980s and have been declining ever since [6]. Meanwhile, catches in China's waters rose by an order of magnitude from 1950 to 2000 [6] (even after having been corrected for the substantial overreporting by the Chinese government [34]), and this has obscured the species-level depletions that occurred along the way. Overall landings in many Asian EEZs continue to climb. Thailand and Viet Nam may have lost more than a million tonnes each to overfishing from 1950 to 2004, placing them 26th and 29th in the world in losses, but this is not at all apparent in the increasing overall catch trends from their waters [6].

Table 1
Twenty-five countries with highest overall potential losses in tonnes, 1950–2004.

Country	Potential loss 1950–2004 (million tonnes)
United States	19
Norway	17
Russia	15
High Seas	14
Canada	11
Peru	11
Japan	10
Iceland	6.5
France	5.8
Namibia	5.4
China	5.0
United Kingdom	5.0
Greenland	4.9
Mexico	4.9
Spain	4.7
Denmark	3.6
Portugal	3.6
Germany	3.2
Netherlands	3.0
Chile	3.0
South Korea	2.9
South Africa	2.7
West Sahara[a]	2.6
Ecuador	2.5
Angola	1.8

[a] Contested territory administered by Morocco.

Whereas Japan passed according to Pitcher et al.'s assessment of fisheries management, China received a failing score (~40%), and Thailand and Viet Nam fared much worse (~20%) [28]. Mora et al. however, gave Japan and China low likelihood of fisheries sustainability, highlighting Japan's heavy reliance on subsidies [29]. Overcapacity afflicts the region, the number of Asian fishing vessels having doubled over 1976–2000 [11,31]. Despite China's capacity-reduction plans, its fleet continues to build [9]. In Viet Nam's Gulf of Tonkin, where engine power rose by a factor of 11 over just 20 years, fisheries quickly moved from initial development to overexploitation [1]—especially ominous for a country rated most economically dependent on its fishery sector in the world [30]. For Asia, export income and access to global markets has spurred the spread of overfishing, and in 2000, Thailand and China were the top two exporters of marine products [31]. As a net exporter, China is a significant importer too, recently consuming 26.1 kg/yr per capita, nearly double the average world per capita consumption excluding China [9].

In the waters off Africa, both South Africa and Namibia, present in Table 1, are beneficiaries of the rich Benguela upwelling system. Before independence in 1990, Namibia's waters were fished mainly by South African vessels [6], leading to the depletion of hake in the 1970s [35,36] and the legacy of losses in Figs. 1 and 2. The country has since Namibianized its fisheries, providing incentives for greater Namibian involvement and employing better enforcement methods [28,36], contributing to high effectiveness ratings for its management [28,29]. Indeed, Namibia is now regarded as a model among developing countries for its sustainable fisheries management [1].

In Fig. 2, estimated revenue losses were deep for many of Africa's Atlantic coast countries. Among these, the high prevalence of undernourishment in the population (%) is a serious concern for the Democratic Republic of Congo (76%), Angola (43%), Liberia (40%), Guinea Bissau (32%), Namibia (19%), and Guinea (17%) [31]. Pitcher et al. scored Angola as failing badly in its fishery management, as FAO code compliance was strongly correlated to both corruption and poor governance [28], and fishing by foreign fleets is extensive [6,29]. A net exporter in the 1960s, the Cameroon-to-Angola region is now a net importer, partly due to the civil war and other turmoil endemic to African

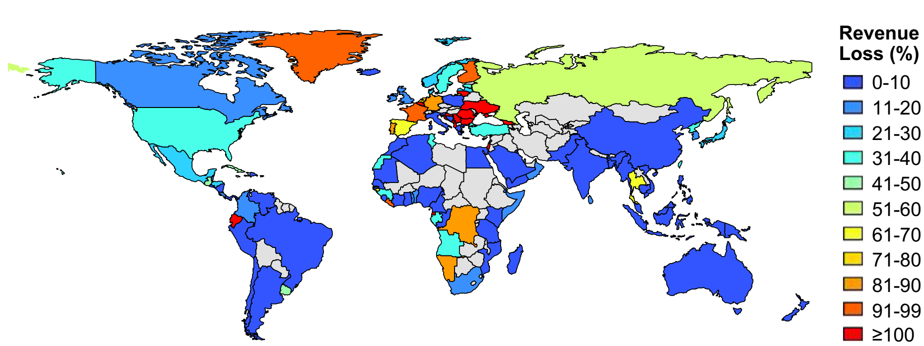

Fig. 2. Potential revenue lost as a percentage of actual revenue in the year 2000.

nations following independence from colonialization [36,37]. Regardless of conflict, foreign fleets have depleted African fish stocks for decades and sizable fleets still operate with or without permits off the coast of West Africa, mostly to serve EU demand but without much benefit to the local populaces [11,29,38]. In fact, the lack of Somali fishery protection from foreign commercial vessels targeting tuna and possibly dumping waste has been suggested as a potential cause of the piracy problem in the country's waters [39,40].

Although no countries from Oceania appear in Table 1 or Figs. 1 and 2, serious losses to island states related to heavy foreign fishing [29] merit discussion. The island groups of Palau and Tuvalu lead the world in relative losses of revenue from landings in their waters in the year 2000, although neither nation collected more than 6% of the landed value caught in their waters 1994–2004 [6]. In 2000, landings from Tuvalu's EEZ amounted to just 3% of the maximum catch wrested from its waters as recently as 1991 [6]. Over 1986–1997, a crucial period of tuna depletion, Japan alone caught 16 times as much as Tuvalu did in Tuvalu's waters [6]. In addition, the illegal, unreported and unregulated (IUU) catches in Pacific islands' EEZs were estimated to be four times as valuable as the island nations' earnings from access fees [41], despite extensive participation of observers [33]. Recently in a bold move, eight Pacific island nations joined to ban fishing with purse-seine nets, capable of capturing whole schools of tuna, from a 3.2 million square km area of international waters called the Eastern High Seas [42].

In contrast, the catch losses estimated here for Australia and New Zealand have stabilized somewhat since the mid-1990s after periods of stepwise increase. These countries also scored well for their current fishery management practices [28,29]. New Zealand, having widely implemented a system of individual transferable quotas (ITQs) that gives fishermen a long-term stake in stewardship, reported recently that only 15% of quota-covered stocks are significantly below target levels [33]. ITQs have shown promising results in preventing overfishing [43], but Mora et al. note that their success for a country relies on the scientific value of the underlying quotas [29]. Approximately half of Australia's stocks are managed, 40% of which have been deemed overfished [33]—a statistic hidden by the dramatic growth in total landings until the 1990s.

4. Conclusions

By examining catch trends at the country and species level over a critical period in the history of fishing, it is clear that overall reported landings hide the spread of overfishing throughout the world's oceans. Early losses appeared for countries exploiting the North Atlantic and North Pacific Oceans (e.g., Norway, the US, the former USSR). Within decades, however, the technological intensification and southward movement of fishing effort had depleted stocks in the EEZs of South America, Southern and West Africa, and China. Despite increasing catch trends for many countries bordering the Indian Ocean at present, there is no reason to expect that the stocks there will escape a similar fate in a fishing-as-usual scenario.

For wild fish to remain an abundant food source, there must be concerted action to significantly curtail fishing effort so that stocks may rebuild to higher biomass levels. The analysis in this article has shown that countries such as Norway, Iceland, the US, Canada, Australia and New Zealand which have implemented sustainable fishery management practices have stabilized or even reversed their losses to overfishing (although in some cases increased imports also helped reduce fishing pressure). There have been several international mechanisms and proposals to improve management in a sustainable direction [10] but change must be decisive; global fishing effort may need to drop 20–50% [18,44].

Still, demand for seafood continues to rise [9], and ecolabeling is not the norm. In the past few decades, tastes have gone global, so that tuna sushi is a commonplace item in restaurants and even supermarkets of the industrialized world. Regional tastes can be decisive, too; the appetite for shark-fin soup in China, Singapore, Hong Kong and Taiwan has contributed to shark populations plummeting worldwide [45]. Consumers are often unaware when tastes outlast a species' commercial viability. After the depletion of cod stocks in the North Atlantic, fisheries moved on to Alaskan pollock, and then to farmed African tilapia and Vietnamese tra in order to supply the firm, white-flesh fish with which consumers of fish sticks and battered-fish sandwiches were already familiar [46].

Thus, in addition to real changes to fishery management on an international level, helping consumers make informed decisions is also crucial. Otherwise, overfishing, like other ecosystem degradation, will continue to disproportionately burden the poor [47], and global commerce will draw increasing exports from food-deficit, Southern countries to sustain the diet preferences of those who can afford it.

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