Title

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Abstract
As domestic affluence increases, nations advocate for conservation policies to protect domestic biodiversity that often curtail natural resource production activities such as fishing. If concomitant consumption patterns remain unchanged, environmentally-conscious nations with high consumption rates such as the U.S. may only be distancing themselves from the negative environmental impacts associated with consuming resources and commodities produced elsewhere. This unintended displacement of ecosystem impacts, or leakage, associated with conservation policies has not been studied extensively in marine fisheries. This paper examines this topic, drawing on case studies to illustrate the ways in which unilateral marine conservation actions can shift ecosystem impacts elsewhere, as has been documented in land use interventions. The authors argue that the U.S. should recognize these distant ecological consequences and move toward greater self-sufficiency to protect its seafood security and minimize leakage as well as undertake efforts to reduce ecosystem impacts of foreign fisheries on which it relies. Six solutions are suggested for broadening the marine conservation and seafood consumption discussion to address U.S.-induced leakage.

Keywords: Imported seafood; international trade; leakage; marine conservation policy; seafood security

1. Introduction
The implementation of biodiversity conservation policies usually translates into improved environmental quality but often at the expense of curtailed production activities. If concomitant consumption remains unchanged, environmentally-conscious consumer nations may only be isolating themselves from the environmental impacts associated with consumed resources and commodities produced elsewhere [1-4]. Globalized trade moves agricultural products, natural resources, and manufactured goods from the producing but relatively low-income countries to consuming and relatively high-income countries [5-7]. One result of this demand for resources and commodities produced elsewhere is that consumer countries with strong environmental oversight can cause biodiversity threats to species located in the producer countries [7, 8].

Due to the spatial separation of production from consumption activities, residents of higher-income countries may be unaware or otherwise fail to account for the full environmental costs caused by the production of goods they utilize [9]. These negative environmental externalities or impacts which manifest themselves outside existing borders are referred to as "leakage,"[1] recognizing there are four types: conservation, production, consumption, and trade. Conservation leakage results when domestic measures to conserve resources lead to negative environmental impacts from an increase in foreign production to meet persistent demand; production leakage arises when regulation of domestic producers results in a transfer of production effort to foreign producers; consumption leakage results when unmet internal consumption demand is satisfied by external supplies (e.g., imports); and trade leakage results when an import ban from particular industries causes a redirection in the flow of trade to other consumer markets [11].

[1] Leakage refers to the displacement of environmental impact occurring when use policies aimed at reducing environmental pressure in a particular locale lead to a countervailing effect in another locale, offsetting the intended benefits of the initial policy [10]. Other terms characterizing this concept include "unequal ecological exchange," "displaced environmental load," "market transfer effect" and "spillover."

Leakage related to land use including forest conservation policies has been well documented at local and national [12-16] and at international [17-20] scales. Similar efforts to evaluate leakage caused by marine conservation policies affecting U.S. fishery production systems (*i.e*., the capture or culture of finfish and shellfish resources) are limited (i.e., [21-25], even though the U.S. continues to be a major importer of seafood [26], ranked second only to Japan for all fishery and fishery product imports [27].

A recent debate has emerged over whether U.S. marine conservation policies[2] that curtail fishing activities externalize negative environmental impacts of U.S. seafood consumption to other jurisdictions. Some conservation policy advocates argue that marine conservation efforts in the U.S do not redistribute ecosystem impacts[3]. However, the potential for transnational leakages seems probable when U.S. consumers rely on fishery production systems beyond the reach of U.S. management authority. Given international trade in seafood products, a unilateral conservation regulation that reduces production in one nation's fishery can be met by increased production in another nation where such conservation measures may be less stringent, thereby offsetting the environmental protections in the regulated fishery. Furthermore, the limited availability of information on such conservation leakage impacts makes it difficult to detect - much less address - them [28, 29].

This paper seeks to broaden the conversation about U.S. marine conservation policy to encompass the implications of leakage caused by outsourcing fishery production. The examination is set against the backdrop of U.S. seafood security, especially seafood self-sufficiency, that is, producing the food a nation needs or that which its population demands. Section 2 of this paper summarizes general U.S. consumption patterns on a global scale. Section 3 focuses on seafood consumption trends in the U.S. with particular attention to two examples of U.S. reliance on foreign imports. Section 4 discusses studies that have addressed the unintended external conservation, production, consumption, and trade impacts resulting from unilaterally imposed policies on U.S. fisheries. Following discussion in Section 5, Section 6 highlights potential solutions for addressing policy-induced leakage and provides concluding remarks.

2. Global Consumption

The relationship between domestic economic growth and improved environmental quality was first hypothesized to follow the trajectory of the Kuznets curve where environmental degradation was predicted to decrease as national affluence increased (see review in Yandle et al. [30]. Rothman [31] was one of the first to argue that when international trade is considered, the behavior of the end-consumer rather than the producer is the principal driver of associated environmental impacts.

Various consumption-based approaches have been used to quantify ecological accountability among nations based on their consumption patterns and related impacts. Dietz et al. [32] used an ecological footprint[4] assessment for attributing environmental stresses to the country where consumption occurs. Of the 20 nations evaluated, the U.S. had the largest footprint, followed closely by China. Bradshaw et al. [35] assessed nations' relative environmental impacts on their rankings for seven environmental

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[2] U.S. marine conservation policies are embodied in and implemented through numerous statutes including the National Marine Sanctuaries Act, the Magnuson-Stevens Fishery Conservation and Management Act, the National Park Service Organic Act, the National Wildlife Refuge System Improvement Act, the Endangered Species Act, the Marine Mammal Protection Act, and more recently, the Antiquities Act.

[3] http://www.pcouncil.org/wp-content/uploads/K5c_SUP_PC_PPT3_TIRN_MAR2014BB.pdf (slide 9)

[4] Ecological footprint is one of many types of assessments used to assess the environmental impacts of production and consumption; other assessments include carbon and water footprints (see review by Galli et al. [33]). Life-cycle assessments are another tool used to measure such impacts [34].

variables and concluded that Brazil, the U.S., China, Indonesia, Japan, Mexico, India, Russia, Australia and Peru had the highest absolute impact (i.e., total resource use, emissions produced, and species threatened). Consistent with Bradshaw et al. [35], Selles [36] ranked China, the U.S., India, Brazil, Russia, Indonesia, Mexico, Australia, Japan and Germany as having the highest overall impact based on their contributions to global resource consumption and ecological degradation. Using a material footprint approach, Wiedmann et al. [37] determined that by absolute value, the U.S. is the largest importer and China is the largest exporter of primary resources embodied in trade. Using a species-threats approach based on net trade balances and foreign consumption (i.e., biodiversity footprint), Lenzen et al. [8] concluded that out of 187 countries, the U.S., members of the European Union (primarily, Germany, France, U.K., Italy and Spain), and Japan were the top final destinations of traded commodities whose production posed the greatest threats to biodiversity.

3. U.S. Seafood Consumption

Fish and shellfish imports into the U.S. have accounted for an average of over 17 percent of animal food product imports annually since 1999[5]. Seafood imports have constituted up to 90 percent[6] by weight of domestically consumed seafood in recent years compared to 61 percent in the early 1990s (**Fig. 1**, **Table 1**). One reason for this increase is that while total U.S. seafood consumption has increased over the last two decades from an annual average of 4.2 million metric tons (mt) during the period 1990-1995 to 5.4 million mt for the period 2010-2013, production has not matched U.S. preferences and buying habits.

Fig. 1. HERE

Table 1. HERE

Two examples of imported seafood favored by U.S. consumers underscore this point. Average annual consumption of shrimp in the U.S. has increased from about 265,000 mt in the mid-1970s to about 670,000 mt in recent years, far exceeding U.S. production (**Fig. 2**). Wild-caught shrimp used to account for nearly all shrimp consumption in the U.S., but imported cultured shrimp increasingly has substituted for this commodity over the past decade. Imports now make up the largest proportion of shrimp consumed whether captured or cultured having increased nearly six-fold from about 91,000 mt in 1975 to 509,000 mt in 2013. Similarly, imported swordfish satisfies the majority of U.S. demand, accounting for more than 80 percent of U.S. swordfish consumption by weight (**Fig. 3**). Both per capita and total consumption of swordfish peaked during the late 1990s, with total U.S. consumption tapering off to half at around 20,000 mt over the last several years.

Fig. 2. HERE

Fig. 3. HERE

4. Leakage Related to U.S. Fisheries

Leakage occurs in a given fishery or fisheries when production impacts such as overfishing, habitat degradation, or bycatch are curtailed by regulations resulting in reduced supply in one area and a shift in production to other less regulated areas. For example, regulatory policies to address sea turtle bycatch in the Hawaii swordfish fishery provide an example of multiple types of leakage occurring concurrently. Both swordfish and sea turtles are transboundary (transnational) resources and vulnerable to multiple

[5] http://www.ers.usda.gov/data-products/us-food-imports.aspx#25418, accessed June 9, 2016.
[6] A portion of these imports are caught by U.S. fishermen, exported overseas for processing and then reimported.

fleets serving global seafood markets. Concerns about domestic bycatch of leatherback and loggerhead sea turtles led NOAA's National Marine Fisheries Service (NMFS) to close the Hawaii swordfish fishery in 2001, pursuant to the U.S. Endangered Species Act (ESA). The fishery was reopened in 2004 with several additional, permanent technological and administrative requirements. Sarmiento [21] measured trade leakages (i.e., transfer effects) generated by the closure and determined that imports of swordfish from other nations, primarily Ecuador and Panama, increased appreciably. Rausser et al. [22] calculated conservation leakage resulting from the closure, with an estimated increase of 1,602 mt of swordfish imported annually due to the closure, resulting in an estimated 2,882 additional (net) sea turtle interactions from the swordfish fisheries of foreign nations combined.

In a similar study, Chan and Pan [24] examined the period when the Hawaii shallow-set longline swordfish fishery reopened (2005-2008), and estimated that the increase in average annual Hawaii swordfish production contributed to 1,841 fewer turtle interactions worldwide by displacing imports from fisheries that had higher sea turtle bycatch rates. They concluded that the regulatory changes reducing Hawaiian swordfish production did not reduce total region-wide sea turtle bycatch because the Hawaii fleet has one of the lowest sea turtle bycatch rates among the fleets fishing in the region [41]. Instead, with the reduced swordfish production from Hawaii's fleet, foreign fleets increased their harvests to maintain overall production, resulting in a net increase in sea turtle bycatch.

Squires et al. [25] provide another example of leakage associated with a time-area closure in the West Coast drift gillnet (DGN) swordfish fishery. In an effort to reduce fishery interactions with the endangered leatherback sea turtle, NMFS established the Pacific Leatherback Conservation Area (PLCA), which overlaps substantially with the DGN fishing grounds along the U.S. West Coast. Since 2001, this time-area closure has prohibited DGN fishing for three months during the prime swordfish fishing season. The authors' benefit-cost analysis of the regulation's impacts determined a U.S. production leakage of $27.5 million due to lost producer and consumer surpluses in the West Coast fishery with increased imports. In addition, the transfer of swordfish effort to other Pacific Rim nation swordfish fleets is estimated to have caused a conservation leakage of an additional bycatch of 1,457 endangered leatherback sea turtles compared to 45 turtles had the U.S. fishing grounds remained open.

Policy-induced leakage is not limited to international contexts; it also can occur domestically. Cunningham et al. [42] reportedly found evidence of production leakage between two adjacent regions subject to management by two separate U.S. fishery management councils (FMCs) resulting from a catch share program The authors assert that such leakage is most acute in fisheries with low institutional barriers, similar gear, and high market substitutability for managed stocks with other species.

5. Discussion

While documented examples in fisheries are rare, the foregoing examples suggest that market-driven, economically-based leakage can occur in fisheries when unilateral conservation policies are put in place similar to land use interventions. Marine conservation policies can stimulate resource production or exploitation activities in other locations, leading to production leakages in foreign [25] or neighboring jurisdictions [42]. This finding is not surprising as a regulated decrease in production at one location coupled with unchanged demand is expected under standard economic theory and assumptions to shift demand to other locations, stimulating increased production and increasing producer revenues elsewhere. Wear and Murray [12] documented the case where ESA-driven restrictions on federal timber harvests in the Pacific Northwest implemented to protect northern spotted owl habitat redirected production to southern U.S. and Canadian lumber producers. Mayer et al. [17] demonstrated how the increasing demand for wood products along with new forest conservation programs in Finland increased pressure on forests in neighboring Russia through wood imports.

The case studies also illustrate examples of trade leakages from increased imports [21], and conservation leakages from increased bycatch [22, 24]. Consequently, reducing domestic production to achieve a particular conservation objective can lead to unintended negative consequences, reducing the net gains – and possibly increasing net losses – globally. Such outcomes suggest the need for multiple within- and across-border policy instruments to reach an optimum regulatory strategy. The need for global cooperation has been recognized in fishery [43] and forest conservation efforts [18, 44]. At the local and regional scale, policy-makers should be mindful of negative consequences that may arise from unilateral actions especially in the context of global markets and possibly weaker environmental governance in other locations. In particular, as part of the ESA consultation process, federal managers need to take leakage into account as part of the net effects analysis for any proposed Federal action that may affect a listed marine species.

The disproportionate contribution of a small group of countries – including the U .S. – to global resource consumption and ecological degradation is not unexpected. Populations in high-income countries have far higher purchasing power compared to those in lower income countries [33, 45]. Further, as countries become more affluent, domestic environmental protection becomes a regional and national priority [8, 17, 46, 47]. However, when consumption levels remain high amid protective domestic environmental policies that reduce domestic output, external resources are increasingly depended upon to meet demand. The intertwined relationship among demand, environmental protection, and reliance on imported resources is closely analogous to the “Netherlands Fallacy.” Ehrlich and Ehrlich [48] used this term to describe how Dutch standards of living are made possible only through reliance upon imported goods, meaning that the Dutch population was not self-sufficient. The complex relationship among these production and consumption factors is depicted in **Fig. 4**.

Fig. 4. HERE

In terms of marine biodiversity, conservation leakage is of particular concern because much of the seafood imported into the U.S. is believed to be harvested under less stringent conservation requirements than imposed on U.S. fisheries [49-51]. Such leakages could be minimized if there were greater reliance on countries with sustainable fishing practices and more importantly, on U.S. capture and culture fisheries. However, efforts for greater self-sufficiency can only succeed if there is a fundamental change in U.S. attitudes that reconciles marine conservation goals with the reality that eating fish means harvesting seafood somewhere, just as Berlik et al. [44] reasoned that using wood means cutting trees somewhere.

Such changes in attitude could begin with shifting from excessive or outright fishing prohibitions to finding ways to minimize domestic biodiversity impacts. For example, the PLCA closure was implemented as an avoidance strategy to prevent interactions between DGN gear and leatherbacks sea turtles. A more effective alternative might have been considering other gear types that produce a comparable volume of swordfish catch with lower sea turtle interaction rates. Such a tactic would have reduced the negative economic impacts to fishermen and the reliance on imported swordfish while still achieving conservation goals. Another approach could include transitioning from static management regimes to dynamic ones where fisheries are managed in real or near-real time in response to shifting oceanographic, biological and ecological conditions [52-55]. The use of adaptive tactics also could be adopted by other nations to enable compliance with proposed NMFS regulations prohibiting seafood imports that do not meet U.S. standards for marine mammal protection.

6. Solutions

Global demand for food is expected to continue increasing well into the second half of this century corresponding with continuing population growth [45]. Seafood consumption is expected to continue to rise at a faster rate than freshwater fish consumption in both industrial and developing countries [56]. Environmentally concerned U.S. consumers can distance themselves from leakage concerns by reducing their seafood consumption, albeit at the expense of foregoing the known health benefits derived from seafood [57]. Further, limiting consumption of fish may generate leakage into agricultural production systems, which can create other environmental externalities such as fertilizer and pesticide runoff, which degrades terrestrial, freshwater, and marine ecosystems. Alternatively, the U.S. can consider its own seafood security by moving toward greater self-sufficiency as well as undertaking efforts to reduce biodiversity threats in foreign fisheries it relies upon to meet domestic seafood demand. To meet these challenges, several approaches for addressing leakage are suggested:

1. *Increase awareness of U.S. fisheries*. Most Americans remain unaware of the high environmental standards by which U.S. federal marine fisheries – and many state fisheries - are managed, in compliance with multiple state and federal laws. These standards conform to or exceed internationally accepted guidelines for sustainable fisheries adopted by the Food and Agriculture Organization of the United Nations [58]. Sea Grant Extension Programs in U.S. coastal states and territories have carried out such work, with NOAA Fishwatch and a number of nongovernmental organizations also helping to bridge this gap. However, further efforts to address this lack of understanding are needed.

2. *Develop U.S. domestic aquaculture to complement capture fisheries*. The global status of marine capture fisheries is considered stable; however, increased catches are considered unlikely [59], suggesting that aquaculture will need to play a greater role in seafood security [60]. Aquaculture is considered the fastest growing animal food production sector and supplies more than half of the world's seafood for humans [61]. While there has been a reluctance to embrace aquaculture more enthusiastically in the U.S. because of its own set of externalities (e.g., environmental impacts of fish feed, waste, disease control substances), it is a form of seafood production that can be managed for ecological and economic sustainability.

3. *Support sustainable fishing practices in other nations*. Efforts for capacity-building including transferring best fishing practices, technologies and monitoring practices to nations whose fisheries continue to supply U.S. markets. A few examples include NMFS programs for training Columbian fishermen on the effective use of turtle excluder devices in Caribbean and Pacific coast shrimp fisheries, instructing fishery observers in Ghana, Senegal, Sierra Leone, Liberia, and Gabon, and providing circle hooks to South American countries

4. *Multilateral cooperation*. Overarching World Trade Organization-consistent trade laws and regulations can help address production and trade leakages and their negative impacts across the entire ranges of affected stocks. Policy instruments and harvest strategies addressing information requirements (e.g., eco-labeling, certification, standards, consumer awareness campaigns and similar approaches) on bycatch reduction can be designed to create market prices and conditions that address external costs and benefits. U.S. delegations participating in

international regional fishery management organizations and other fora can initiate that dialogue.

5. *Recognize the externalities of management decisions*. Leakage occurs when the spatial scale of intervention does not match the scale of the targeted problem [62]. Ignoring environmental impacts associated with goods produced elsewhere creates what Berlik et al. [44] described for U.S. timber management as the "illusion of natural resource preservation." Policy-makers need to be mindful of and evaluate the challenges and trade-offs among the full range of impacts, including those beyond their jurisdictions, as part of the decision-making process.

6. *Treat wild capture and aquaculture fisheries as part of the food system.* Seafood represents a part of the nation's food system [63, 64]. Nonetheless, within the context of managing marine resources and ecosystem impacts, seafood rarely is acknowledged as a component of the human diet, despite its recognized importance as a source of nutrition and sustenance. Olson et al. [64] argue that treating seafood as a food production system provides a different frame of interpretation that does not end with harvesting but also includes distribution and use. Such a broader conceptualization can reestablish the connection between consumption and production behaviors, which underlies the reality that humans are part of the marine ecosystem.

7. Concluding Remarks

The title of this paper plays on the popular 16th century English proverb questioning whether people can both have their cake and eat it too. This aphorism describes the challenge confronting fishery management decision-makers and seafood consumers. Reckoning with the inherent tradeoffs between conservation goals and seafood consumption demands may be a more practical approach rather than assuming "win-win" outcomes, where both are fully satisfied [65]. Decision-makers cannot dismiss this - tactic especially in the context of climate change and a growing human population [60]. Unilateral marine management policies that force greater reliance – and biodiversity impacts – on distant ecosystems call into question their global effectiveness and conservation ethicality.

Rothman [31] questioned whether wealthy nations were merely "passing the buck" when distancing themselves from the environmental degradation associated with their consumption habits. The full impact of U.S. seafood consumption patterns needs to be considered at the global level in light of continuing efforts to further marine biodiversity protections. Failing to do so only serves to counteract the effectiveness of domestic actions by externalizing negative environmental costs to others.

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Table 1. Annual average U.S. landings, trade, and consumption of edible fishery products in the U.S. by round weight, for periods 1990-95 through 2010-14. (Sources: NOAA National Marine Fisheries Service [26, 38, 39])

Period	**Landings**	**Imports**	**Exports**	**Consumption**	**Imports/ Consumption (%)**
1990-95	3,433,757	2,597,005	1,794,465	4,236,298	61%
1995-00	3,302,178	3,012,069	1,887,387	4,426,860	68%
2000-05	3,334,483	4,005,626	2,522,868	4,817,241	83%
2005-10	3,281,307	4,765,517	2,578,040	5,468,784	87%
2010-14	3,398,934	4,874,546	2,871,143	5,402,223	90%

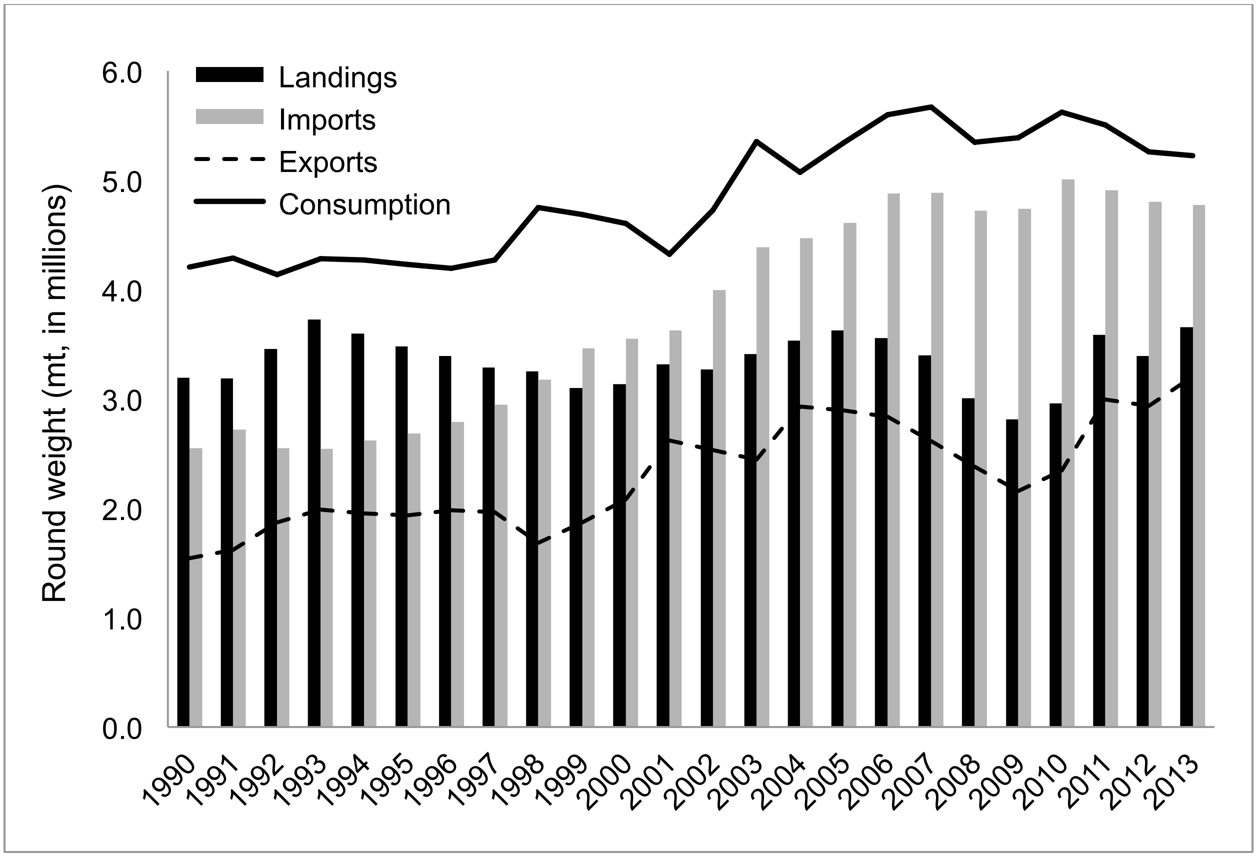

Fig. 1. U.S. consumption, landing and trade of edible fishery products by round weight, 1990-2013. (Data source: NOAA National Marine Fisheries Service [26])

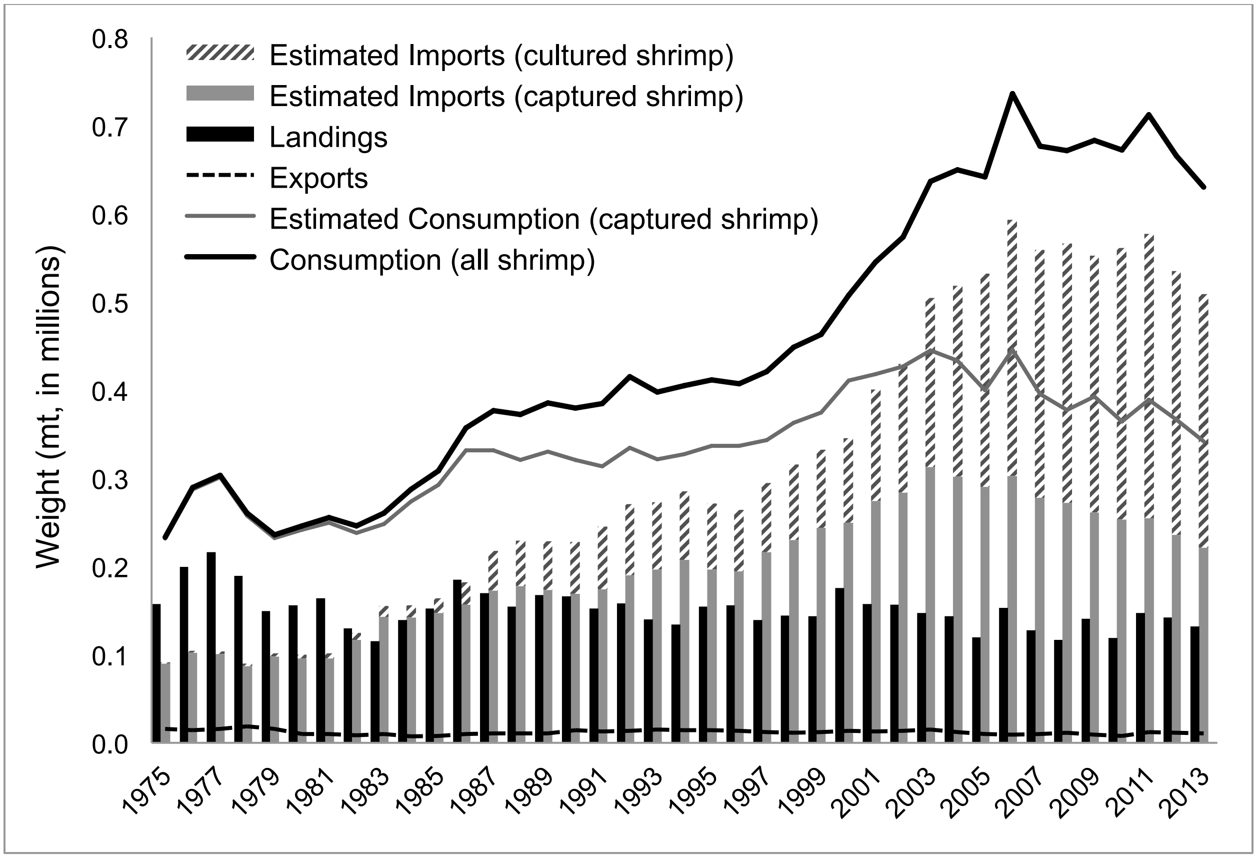

Fig. 2. U.S. consumption, catch and trade of shrimp, by weight, 1975-2013. Estimates of U.S. imports of captured and cultured shrimp were calculated as the ratio of captured shrimp to total shrimp production using NMFS and FAO data. (Data sources: NMFS Office Science and Technology: www.st.nmfs.noaa.gov/commercial-fisheries/commercial-landings/ and FAO Fisheries and Aquaculture Statistics: http://www.fao.org/fishery/topic/16140/)

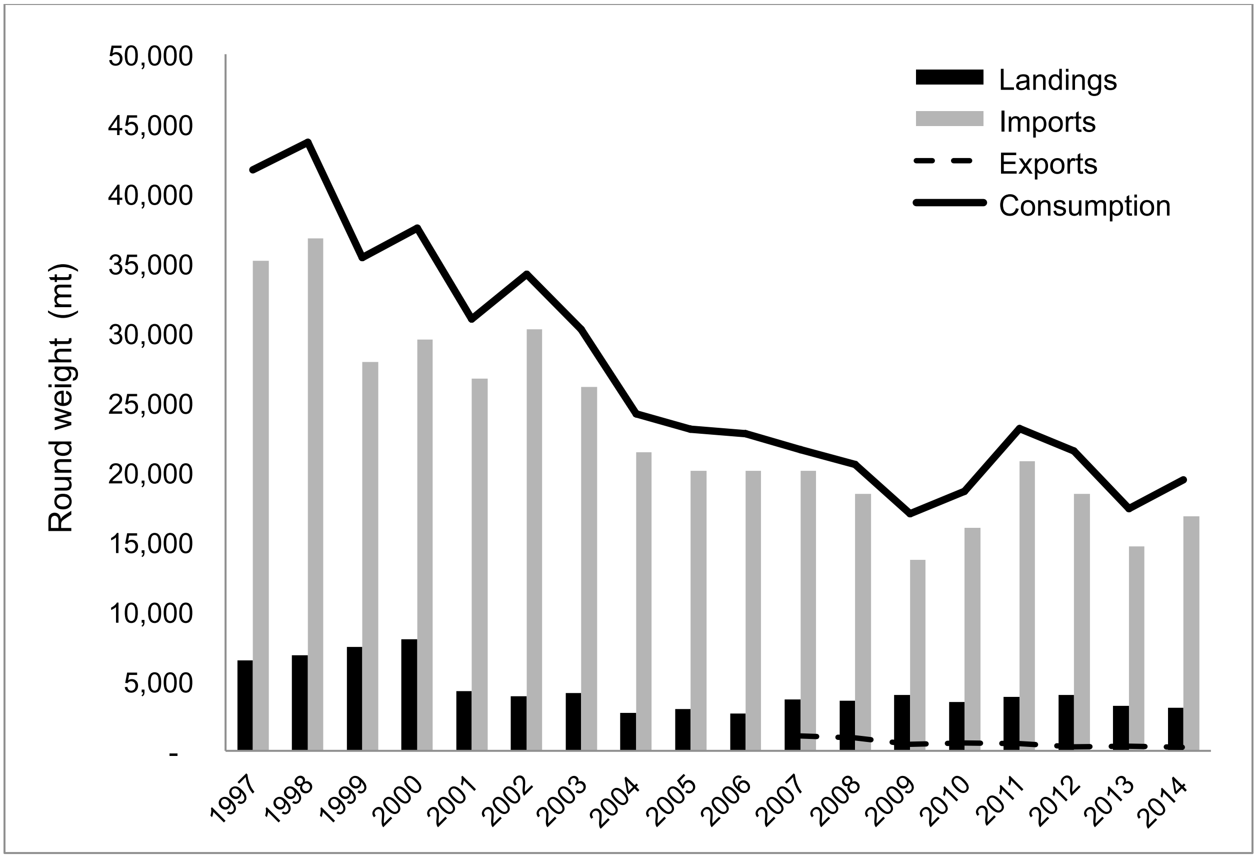

Fig. 3. U.S. landings, imports, exports and consumption of swordfish by round weight, 1997-2013. Data prior to 1997 are not included because U.S. swordfish imports before 1997 were not assigned a specific Harmonized System Code [22, 24], precluding the identification of imports of swordfish fillets and meats. Consequently, total U.S. swordfish imports prior to 1997 are under-reported [40]. Data on U.S. exports of swordfish prior to 2007 are not available. (Data source: NMFS Office Science and Technology: www.st.nmfs.noaa.gov/commercial-fisheries/commercial-landings/annual-landings/)

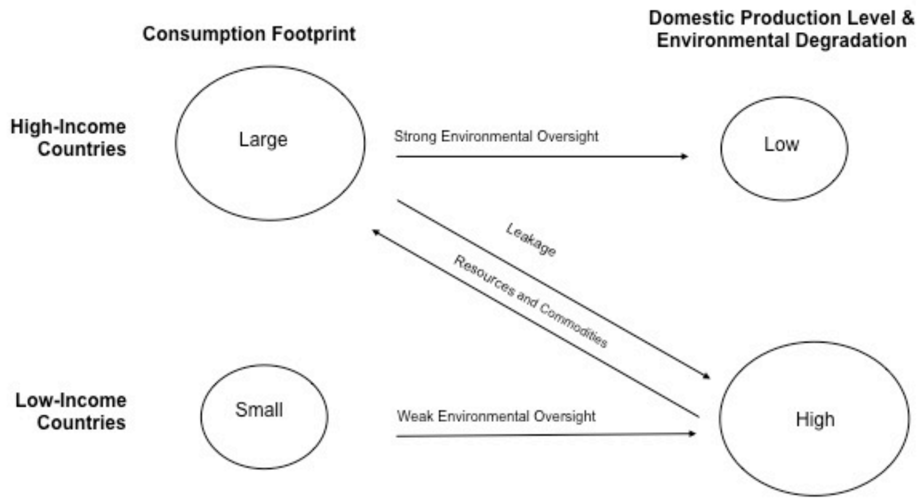

Fig. 4. Conceptual framework illustrating the relationship between high-income countries with high consumption footprints and corresponding stronger environmental oversight contributing to reduced domestic production (top horizontal line) and lower-income countries with low consumption footprints and weaker environmental oversight leading to higher domestic production (bottom horizontal line), with the latter providing resources and commodities to satisfy demand, leading to conservation leakage (diagonal lines).