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Estimates of illegal and unreported fish in seafood imports to the USA

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ABSTRACT

Illegal and unreported catches represented 20–32% by weight of wild-caught seafood imported to the USA in 2011, as determined from robust estimates, including uncertainty, of illegal and unreported fishing activities in the source countries. These illegal imports are valued at between $1.3 and $2.1 billion, out of a total of $16.5 billion for the 2.3 million tonnes of edible seafood imports, including farmed products. This trade represents between 4% and 16% of the value of the global illegal fish catch and reveals the unintentional role of the USA, one of the largest seafood markets in the world, in funding the profits of illegal fishing. Supply chain case studies are presented for tuna, wild shrimp and Chinese re-processed Russian pollock, salmon and crab imported to the USA. To address this critical issue of unintended financing of illegal fishing, possible remedies from industry practices and government policies may include improved chain of custody and traceability controls and an amendment to the USA Lacey Act.

1. Introduction

Illegal, unreported and unregulated (IUU) fishing is a significant global problem jeopardizing ecosystems, food security, and livelihoods around the world. As our protein-hungry planet faces an unprecedented crisis of overfishing – 85% of all commercial stocks are now fished up to their biological limits or beyond [1] – fishing practices that violate domestic or international laws, evade reporting requirements, or simply escape management altogether pose a major challenge to the sustainable use of ocean resources. IUU fishing distorts competition, harms honest fishermen, weakens coastal communities, promotes tax evasion, and is frequently associated with transnational crime such as narcotraffic and slavery at sea. Moreover, the total extractions of living resources from marine ecosystems are needed in order to understand the sustainability of fisheries both in terms of ecology and economics since catches reported to national and international agencies (FAO) exclude IUU, discards and often small-scale and recreational fishery catches [2].

Recent estimates of IUU extent by country and region have revealed substantial IUU world wide between 13% and 31% of reported catches, and over 50% in some regions. This illegal catch is valued at between $10 and $23.5 billion per year [3]. The 1995 FAO Code of Conduct for Responsible Fisheries [4] and the 1992 UN Agenda 21 (chapter 17) initiated an international framework for addressing this problem, recently termed 'fishery crime' [5]. Attempts at control have focused on fishery management through improving Monitoring, Control, and Surveillance (MCS), through a UN Port State agreement to restrict chandler support for suspect vessels [6], and by national and Interpol tracking of suspicious vessels including transshipment at free ports. These activities have substantially improved the prospects for addressing IUU fishing and associated crimes, but significant profits are still being made from illegal fishing.

Fishery markets, increasingly global, and, despite increasing use of chain of custody documentations [7], notoriously opaque at the distribution level, provide another opportunity to reduce profits from illegal fishing by isolating trade. Therefore there is a growing need to understand not only where IUU fishing takes place but also where and how illegal products ultimately enter the markets. In this paper, we investigate one key dimension of the global IUU problem by estimating the amount of illegal and unreported fish entering the US seafood market, one of the largest in the world. Any major destination market for illegal seafood will thus be a major source of revenue for illegal fishing.

2. Methods

2.1. Scope of analysis

This study is limited to estimating the percentage and approximate amounts and values of illegal and unreported products

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entering the United States as imports. It does not include products that may originate in "unregulated" fisheries. As with previous studies, although "unregulated" fishing remains a significant obstacle to sustainable livelihoods, this paper does not cover the full gamut of IUU fishing, but is restricted to "illegal and unreported" (IU) or more simply "illegal" fishing, since unreported fishing is technically illegal because reporting is mandatory for all UNFAO countries.

Second, this work does not include domestic products landed by USA flag vessels and processed and sold entirely in the United States. It is possible that it may include some products that, after originating with USA vessels and even possibly landed in the USA, have been exported for processing in other countries and then re-imported into the USA. Although the United States has a strong regulatory structure for monitoring and controlling illegal fishing activities, particularly when compared to a number of the countries exporting seafood to the United States, illegal fishing is known to occur in U.S. domestic waters [8,9] with some estimates as high as 10–20% [10]. However, no effort is made here to estimate IUU in domestic fisheries of the USA.

Finally, this study looks only at edible seafood imports, fish products imported into the USA for human consumption. It excludes fish products imported for animal consumption or for use in industrial products, though almost all of those imports are from wild-caught fisheries that also experience some level of illegal fishing.

2.2. Estimation methods

The analysis depends on knowing the amount and constituents of seafood imported into the USA, the proportion that derives from wild caught fish and the provenance profile of these imports by country and region. Second, the total amount of illegal fishing for all major fishing countries has been estimated [11] and these figures have been refined here by fish species and region using additional information. Imports of key products to the USA market in 2011 are identified and estimates made using the 'anchor point and influence table' approach [12] and some estimated product flow scenarios.

2.2.1. Estimation of seafood imports to the USA

The United States and Japan have been essentially tied in recent years as the largest single country import markets for seafood, both importing between 13% and 14% of the global total. The EU is the largest overall market, importing about 27% of the total. Together these three markets account for about 55% of global seafood imports.

Seafood consumption in the USA totaled about 2.1 million tonnes, second only to China [13] representing 6.8 kg per capita in 2011 [14]. (This includes domestic production that is consumed inside the USA.) American consumers spent an estimated $85.9 billion on fish products in 2011, with about $57.7 billion spent at foodservice establishments, $27.6 billion at retail, and $625 million on industrial fish products [15]. Table 1 shows that tuna, crab, pollock and cod are the most consumed wild-caught seafood products.

According to NOAA, in 2011 roughly 90% of seafood consumed in the United States was imported, and about half of this was wild-caught [16]. The percentages for both imports and wild caught origin are estimates by NOAA. According to personal communications with NOAA staff, no detailed examinations of the origin of imports to the USA have been conducted by NOAA, USDA or others. At least two factors complicate efforts to calculate these numbers. First, NOAA estimates may not fully account for "re-imported" fish products – i.e., products of U.S. origin that are exported for processing and then re-imported into the U.S. market. However, since illegal fish products are often mixed into supply chains at the processing stage, the foreign locus of processing makes it appropriate to consider even re-imported products as "imported" for purposes of this paper. Second, U.S. trade data often does not differentiate between farmed and wild-caught catches entering the USA market and so additional work was undertaken to estimate this proportion from the key supplier countries.

Table 1
Wild-caught marine seafood consumption in the USA. Note this table does not include shrimp, the most popular consumed seafood (1.9 kg annual consumption per person) or salmon, the third most popular consumed seafood (0.88 kg annual consumption per person) despite the fact that a portion of this seafood is from wild-caught fisheries National Fisheries Institute. Source: Top 10 U.S. consumption by species chart. http://www.aboutseafood.com/about/about-seafood/top-10-consumed-seafoods.

Overall rank	Wild-caught marine species group	Annual per capita consumption, kg	% of USA consumption
2nd	Canned Tuna	1.18	17
4th	Pollock	0.59	9
8th	Crab	0.26	3
9th	Cod	0.23	3
Total		2.27	33
Overall consumption		6.80	100

The majority of these wild-caught imports to the USA are from 10 countries: China, Thailand, Indonesia, Ecuador, Canada, Viet Nam, the Philippines, India, Mexico, and Chile. For all the countries that exported catch into the USA in 2011, freshwater, non-edible, and declared farmed seafood product catches were excluded from total catches to get estimated total imported marine capture [17]. These top 10 countries (out of a total of around 120 countries exporting fish products to the U.S. that year) represented approximately 80% of 2011 seafood imports to the USA by volume and value [18]. Total imports of edible seafood products to the USA in 2011 were 2,379,940 t, valued at $16.5 billion. Seafood imports from the top 10 countries exporting to the U.S. were 1,914,610 t of edible seafood products valued at US$13 billion. The 30 products examined for this study (see below) represented about 45% of U.S. 2011 wild-caught seafood imports by volume; NOAA estimates that about half of total imports are from aquaculture.

2.2.2. Estimation of illegal caught fish imported

Estimates of the total level and value of illegally caught fish entering the market in the USA as imports are estimated using the following scheme, as illustrated in Fig. 1.

1. For each of the top 10 countries as sources of imports, the top three wild-caught seafood products (by species groups and volume) exported to the United States were identified, resulting in 30 import streams identified by country and species group. The species groups were defined by the statistical categories available in the NMFS trade database. In two cases (Ecuador and Mexico), the top three products exported to the USA included shrimp. Since data from NMFS do not distinguish wild from farmed shrimp, additional analyses were performed to estimate the proportion attributable to wild shrimp in each case.
2. For each of the 30 country and species product categories, the originating fisheries were identified. Although no precise definition of a "fishery" was employed (again, due to the form and organization of available data), fishery sources were generally identified by some combination of vessel nationality, geographical location and jurisdiction of fishing, gear type, and target species.

Fig. 1. Methodology diagram: estimating wild caught marine imports into the USA.

3. Information was gathered and analyzed regarding IU practices associated with the 30 country/species product categories and their source fisheries. Based on multiple sources and data types, quantitative estimates of IU fishing were assigned.
4. Combining data from multiple sources, and using the statistical method applied in widely accepted studies of global IUU prevalence (see "anchor point and influence factor" approach, below), a range of IUU infection was estimated for each of the top three exports for each of the top 10 countries, using a 95% confidence interval. These ranges were then combined to produce a trade-weighted average of IUU infection for each of the top 30 country/species product categories.
5. Considering that the 30 country/species combinations examined for this report account for 45% of wild caught seafood imports to the USA, and appear likely to be broadly representative of IU levels across all import categories, total IUU infection in U.S. wild seafood imports was calculated via linear extrapolation.

2.2.3. The "anchor point/influence factor" method

Previously published analyses [19,20–22] have established the "anchor point and influence" methodology to examine illegal and unreported catches. This method is adapted to focus on illegal and unreported catches for specific fisheries from which products were exported to the United States in 2011. A brief explanation of this methodology is as follows:

First, empirical data from a wide variety of sources were used to establish "anchor point" estimates of the upper and lower bounds of illegal and unreported fishing in each fishery. Monte Carlo simulations were used to investigate the effects of uncertainty, with 1000 simulations across the distribution of uncertainty. The estimates are presented with a 95% confidence interval.

Qualitative and quantitative data were subsequently used to generate "influence factors" that then scale the interpolations between anchor point estimates. The influence factors for each analysis reflect the overall and relative incentives and disincentives to misreport catches. This work extends previously published methods by estimating IUU catches for each of the products caught from within EEZs, the High Seas and Regional Fisheries Management Organizations (RFMOs). This technique is more appropriate for analyzing illegal catches for products exported to the major markets of the United States, Japan and Europe. The methodology applied here is more robust than previous analyses in using product flow scenarios that incorporate where the product is sourced and caught by domestic and foreign fleets.

A deeper examination of illegal catches for each product was necessary for this study, as fish products exported to the United States from the top 10 countries in the current analysis actually come from different jurisdictions. Pollock and salmon exported by China, for example, were not caught within its Exclusive Economic Zone (EEZ), but largely sourced from the Russian EEZ. The IUU analysis should therefore reflect the IUU risk for the product from various jurisdictions within the Russian EEZ. Similarly for tuna exported by several of the top 10 countries, the IUU estimate varies by jurisdiction (EEZ, high seas, RFMOs, re-processed trade, etc.) and the aggregate IUU estimate will reflect the various sources.

2.3. Data and information sources

More than 180 different sources were consulted, including academic papers, fisheries association reports and articles, national government or provincial authorities' reports, official RFMO data or publications, industry data, NGO publications, and press reports. In some cases, information gathered through confidential interviews with knowledgeable individuals was also used: these are cited here as anonymous where necessary.

Linking U.S. imports of wild-caught seafood products and IU fishing in the source fishery required a thorough examination of global seafood supply chains. The analyses in this report employ a wide variety of data inputs, with each estimate of IU infection derived from multiple sources. This work builds on primary data sources and IU estimates developed in 2009 [23], peer-reviewed composite and country-specific studies, government data sources including surveillance data, trade data, stock assessments based on fishery-independent (survey) data, and expert opinion. The work is supplemented with additional and updated information.

New data sources include recent peer-reviewed literature, regional commission reports, fisheries association data, illegal fishing vessels apprehended in fisheries, in-country press reports of illegal fishing and catch seizures, U.S. Congressional Research Service reporting, governmental publications, NGO (e.g. Marine Stewardship Council) research and reports, and personal interviews. Catch data have been obtained from monitoring agencies such as the Food and Agriculture Organization of the United Nations (FAO), which maintains global statistical databases.

The categories of data sources used for each country/product combination are presented, along with the overall confidence of the data in each source category. Some sources contain information on multiple fisheries in different jurisdictions, and may be cited multiple times.

Not all fisheries have robust empirical data for analysis. In data-poor fisheries, we have supplemented existing information with interviews with industry experts and government officials to provide a more robust estimate of the IU catches for the products concerned. In some cases, these sources provided information – sometimes including documentary information – of a non-public nature. A total of 41 interviews were conducted, of which 32 were confidential. While never preferred by researchers, the limited use of confidential information sources is accepted practice in fisheries research. Even the most widely used data on wild fish catches, the data published biannually by the FAO, depends in part on expert

opinions privately expressed to researchers. Under current circumstances, it is impossible to perform comprehensive and reliable research into IU fishing without including "leaked" confidential information. For this study, however, only a small fraction of the inputs underlying this study come from private, personal communications. These interviews supplemented trade flow documents, furthered the understanding of trade flows, and aided in extrapolating the percentage of catches coming from different fleets, routes and countries in the re-reprocessed trade.

In total, these sources offer an unprecedented examination of illegal and unreported fishing around the globe in 2011, allowing the production of the most accurate IU estimates to date.

3. Results

From each of the top 10 countries exporting to the U.S., the top 3 wild-caught products exported to the United States in 2011 (Table 2) comprised more than 0.5 million tonnes of seafood worth about US$ 3.7 billion.

The results from this analysis of wild-caught imports (Table 3) indicate that 20–32% by weight of wild-caught seafood imported by the United States in 2011, with a value between $1.3 billion and $2.1 billion (or 15–26% of total value of wild-caught seafood), were from illegal and unreported (IU) catches. This suggests that the amounts of illegal fish entering the market in the USA lie within the range of earlier estimates of global illegal fishing of 13–31% [24] implying that USA sourcing practices do not preclude entry of illegal products.

Shrimps represented 24% of imports by volume and 31% by value in 2011. Although shrimps comprise the largest category of seafood imported to the USA both in volume and value, such products were excluded from the analysis for Thailand, China, Indonesia and Vietnam as much was of farmed origin. There is some evidence that wild-caught shrimp is on occasion illegally exported mislabeled as farmed shrimp and this issue is discussed in detail below.

Of the 30 country-product combinations investigated for the study, tuna from Thailand had the highest estimated volume of illegal and unreported sourced fish (32,000 t to more than 50,000 t, representing 25–40% of total tuna imports from Thailand). This was followed by illegal and unreported pollock from China with an estimated volume of potentially more than 30,000 t (30–45% of pollock imports from China). Wild-caught salmon imports from China were the next largest illegal import (28,000 t, representing 45–70% of salmon imports from China). Tuna from the Philippines, Vietnam, and Indonesia represented the next largest illegal import with 25,000 t (up to 35% of all tuna imported to the USA in 2011). Other illegal fish imports higher than the 20–32% average were octopus from India (35–50%), snappers from Indonesia (35–50%), crabs from Indonesia (20–45%), tuna from Thailand (25–40%), wild-caught shrimps from Mexico (25–40%), and Indonesia (20–35%), wild-caught shrimps from Ecuador (25–35%), and squids from India (20–35%). Issues concerning pollock, tuna and shrimp imports are discussed in more detail below.

Imports from Canada all had estimated levels of illegal and unreported fish imports below 10%, with lobsters and herring representing the lowest (2–5%). Imports of clams from Vietnam (5–10%) and toothfish from Chile (5–7%) also had 10% or less sourced from illegal or unreported fishing.

Table 2
30 Wild Seafood Products Selected for the IUU Seafood Analysis.

	Country	Species	Quantity imported in 2011, t	Value, US$
1	China	Pollock	71,752	187,040,539
		Salmon (Atlantic and Pacific)[a]	39,296	242,943,956
		Squids	38,786	159,849,675
2	Thailand	Tuna	128,381	529,266,770
		Squids	4252	26,175,308
		Crabs	4000	69,907,417
3	Indonesia	Tuna	19,443	128,719,468
		Crabs	8913	186,067,659
		Snapper	759	4,780,908
4	Ecuador	Tuna	21,510	113,672,292
		Shrimps[b]	7378	51,222,278
		Dolphin fish ('Mahi mahi')	5382	45,812,827
5	Canada	Lobster	42,652	809,552,579
		Crabs	39,964	501,797,917
		Herring	11,488	29,618,952
6	Vietnam	Tuna	24,513	119,073,957
		Crabs	2977	50,471,458
		Clams	2311	6,974,450
7	Philippines	Tuna	30,931	134,922,569
		Octopus	5552	23,672,673
		Crabs	2915	65,149,419
8	India	Squids	5506	20,407,172
		Crabs	1599	28,769,431
		Octopus	1679	4,883,770
9	Mexico	Shrimps[c]	10,423	96,523,445
		Snappers	3529	20,061,748
		Tuna	4213	16,598,001
10	Chile	Toothfish	3727	62,249,823
		Squids	819	1,823,495
		Hake	66	415,828
	Total		**544,716**	**3,738,425,784**

[a] Most of this catch is sourced from Russian wild fisheries.

[b] According to industry sources, approximately 10% of the 73,789 t of shrimps exported to the U.S. from Ecuador in 2011 was from wild capture fisheries, while the rest came from aquaculture.

[c] In 2006, 95% of Mexican shrimp was exported to the USA, followed by 3% to China and 0.7% to Spain. Using CONAPESCA estimates of farmed and wild shrimp catches in 2011, a breakdown of farmed vs. wild reveal that 108,890 t (66%) of farmed and 56,746 t (34%) of wild shrimp was landed by Mexico in 2011, of which 30,748 t (19%) was exported to the United States. Therefore, 10,423 t of wild caught shrimp, and 20,055 t of farmed shrimp were estimated as exports from Mexico to the United States. http://www.conapesca.sagarpa.gob.mx/wb/cona/consulta_especifica_por_produccion.

4. Discussion

This discussion covers the scope of the results, and describes three pivotal issues underlying the trade in illegal fish products such as the opaque seafood supply chain, extensive and poorly-documented seafood reprocessing in China, and weak legislative control of seafood entry to the USA. Specific details of Russian pollock, salmon and crab, tuna and shrimp imports to the USA are also presented to illustrate the extent of some of the supply routes for illegally caught fish. Possible actions to control the trade in illegally sourced seafood products are reviewed.

4.1. Scope of results

It is worth noting that the overall volume and value of illegal imports would be greater if inedible products were included in the study. It is also important to note that although a significant portion of the fish consumed in the United States comes from illegal origins, it does not suggest that importers, distributors, retailers, or consumers of fish in the USA or elsewhere are aware of this situation. As discussed below, seafood supply chains are notoriously opaque such that

Table 3
Estimated illegal and unreported catches for 30 seafood products exported in 2011 for the top 10 countries (in t and % by weight). Column 2 reflects the estimated trade-weighted average IU for the 3 species evaluated in the present study for this country. Column 3 is the estimated illegal catch percentage for the top 3 products and the actual amounts in tonnes are given in Column 5. The rightmost two columns (column 3 by column 5) are the estimates of illegal imports to the USA in tonnes.

Country	Average estimated % of IU catches	IU catches range by product (%)	Product	2011 Exports to the USA (t)	IU catches (t)	
					Lower limit	Upper limit
China	29–44	30–45	Pollock	71,752	21,526	32,288
		45–70	Salmon	39,296	17,967	27,948
		10–15	Squids	38,786	3879	5818
Thailand	24–39	25–40	Tuna	128,381	32,095	51,352
		15–30	Squids	4252	638	1276
		10–15	Crabs	4000	400	600
Indonesia	20–38	20–35	Tuna	19,443	3889	6805
		20–45	Crabs	8913	1783	4011
		35–50	Snappers	759	266	379
Ecuador	12–19	10–15	Tuna	21,510	2151	3226
		25–35	Shrimps	7378	1839	2575
		5–15	Mahi Mahi	5382	269	807
Canada	3–7	2–5	Lobsters	42,652	853	2133
		5–10	Crabs	39,964	1998	3996
		2–5	Herring	11,488	230	574
Vietnam	22–31	25–35	Tuna	24,513	6128	8579
		10–15	Crabs	2977	298	446
		5–10	Clams	2311	115	231
Philippines	19–32	20–32	Tuna	30,931	6186	9898
		15–30	Octopus	5552	833	1666
		15–30	Crabs	2915	437	874
India	21–36	20–35	Squids	5506	1101	1927
		10–25	Crabs	1599	160	400
		35–50	Octopus	1679	588	839
Mexico	20–33	25–40	Shrimps	10,423	2606	4169
		10–20	Snappers	3529	353	706
		15–25	Tuna	4213	632	1053
Chile	6–10	5–7	Toothfish	3727	186	261
		10–20	Squids	819	82	164
		15–25	Hake	66	10	16
Total	**20–32%** (weighted average)			**544,716**	**109,498**	**175,017**

consumers and vendors of fish are generally unaware of the role they play in buying and selling illegally caught products. Without routine transparency of fishing practices and traceability of seafood products, it is nearly impossible for concerned consumers or responsible businesses to avoid commerce in illegal products, unless they exclusively purchase seafood with chain-of-custody certifications [25] or from suppliers with highly reputable transparent purchasing practices.

Any effort to quantify levels of infection with illegal products in markets anywhere in the world faces a number of significant data limits and methodological challenges. Illegal and unreported fishing itself is hidden by its nature. Once taken from the water, illegal and unreported fish products enter a highly complex stream of commerce, involving diverse supply chains that may include trans-shipments at sea, landing and transit between countries for various stages of processing, and the division and combination of lots. Official statistics about trade in fish products is often available only at significant levels of data aggregation, so that correlation of trade flows with specific fisheries often requires an intensive primary research. Moreover, in the seafood industry today, full chain traceability is often lacking – or, where it does exist, is often held confidentially within proprietary systems. And information about illegal fishing practices may be concealed even when held by public authorities as it is often considered sensitive or confidential.

The nature of the available data and the statistical methods employed for this study support estimates by species and general region at relatively high levels of aggregation. Hence, the results estimate the overall scale of illegal product infection in imports to the USA, not specific illegal fishing hotspots or specific instances of illegal fishing. Moreover, we report only on import flows to the USA identified by the final country of export.

4.2. Seafood supply chains

The highly internationalized seafood supply chain feeding imports into the United States and other major markets is one of the most complex and opaque of all natural commodities. It involves many actors between the fisherman and the consumer, including brokers, traders, wholesalers and other middlemen, often distant from the consumer markets they supply. This complicated network is characterized by bulk shipments of seafood of mixed origin that include illegal fish. While some control mechanisms for the assurance of food safety are in place, there is a lack of monitoring, transparency and accountability as to the sources of the seafood. There are no trace-back procedures to help companies avoid handling the products of poaching and illegal fish products enter the supply chain at multiple points. Once hauled from the water, fish products take a multiplicity of routes to reach the USA: exported directly after harvest; exported after only primary processing; or exported as a store-ready product after both primary and secondary processing (Fig. 2).

A significant amount of fish is imported to the USA by first passing through one or more intermediary countries for post-harvest processing and subsequent re-export. These additional steps introduce additional challenges to traceability and allow for

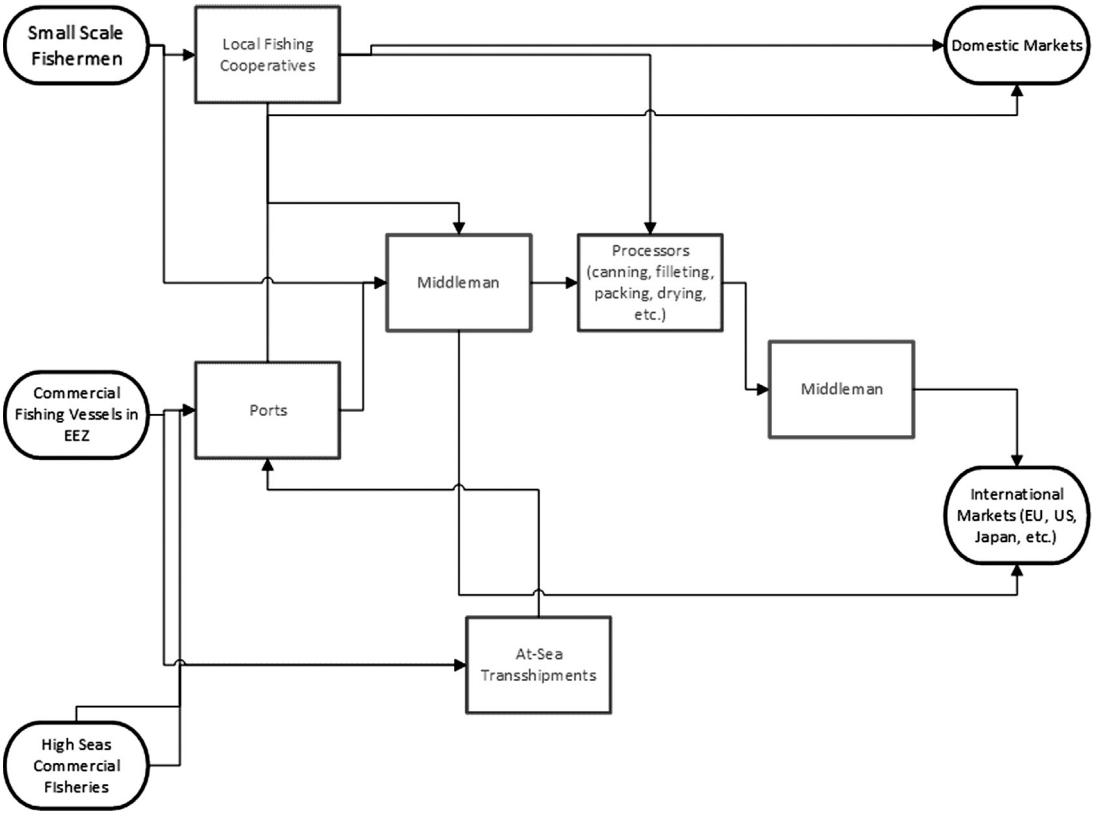

Fig. 2. Diagram of a typical seafood supply chain.

the mixing of legally- and illegally-sourced fish, where illegal fish may be essentially 'laundered' in the processing countries, and subsequently enter international trade as a 'legal' product of the exporting nation.

Irrespective of the route to market, products may be combined from different sources or different species that are often difficult to distinguish and be mislabeled; for example Atlantic cod fillets labeled as haddock or blue whiting during exports [26] in mixed shipments. Multiple species from multiple jurisdictions may all bear the same packaging for export, masking the origins and actual extent of fishing for the species [27]. Current practices thus allow illegal fish to be concealed, mixed indistinguishably into legal product flows. Additionally, fish caught illegally may be used as fishmeal in farmed products and hence enter the market indirectly in farmed seafood; for example seafood retailers and suppliers in the UK have acknowledged a problem with fishmeal produced from illegal practices, after a major supplier was identified as using "trash fish" caught in protected Thai waters as fishmeal for farmed prawns [28]. Regardless of a product's route, the absence of adequate catch documentation and reliable traceability is a serious impediment to establishing the legal origin of fish products entering the market in the USA. The result is that consumers are nearly always unaware of the precise identity and source of the seafood that they purchase.

4.3. Regulatory deficit: the absence of effective trade controls in the USA

Unlike the European Union, which has begun to implement direct trade controls through regulations requiring seafood traceability and certification of the legal origin of imported wild-caught fish products, the USA does not yet have a robust system to exclude illegal products from its market, except for special mechanisms in place for particular species groups such as toothfish.

The main law in place in the United States to discourage imports of illegally caught fish is the Lacey Act (16 U.S.C. Section 3371–3378). First enacted in 1900 and subsequently amended in 2008 to address illegal logging, the Lacey Act is intended to stop imports and sale of products that are extracted in violation of the source country's conservation provisions or international law. In theory, regular prosecutions and strong penalties should deter potential violators. And because the Lacey Act can be applied to distributors and retailers in the USA, and not merely to importers, it can also serve as an incentive to seafood merchants to avoid products of dubious origin. The largest penalty ever handed out for violations of the Lacey Act involved a case of South African rock lobsters that were illegally caught and smuggled out of South Africa to the United States between 1987 and 2001. In addition to being sentenced to jail, the defendants were ordered to pay $54.9 million in restitution to the government of South Africa [29].

However, while the Lacey Act has resulted in a few significant convictions in the seafood arena, it prompts investigations in only a small portion of fish imports. And the Lacey Act as currently implemented does not include any proactive mechanisms for detecting illegal fish products as they enter the United States; it can only be used to sanction violators once they have been discovered. Moreover, USA border officials inspect only about 2% of all shipments of fish products and focus on species identification and food safety standards [30]. In short, current border routines are not oriented towards distinguishing illegally caught from legally caught fish products.

4.4. Chinese reprocessing: obscuring the supply chain

Chinese re-processing of seafood products is staggering in its scale, highly complex in its patterns of sourcing, and characterized by lack of transparency and traceability. An absence of species-specific commodity codes for exported products, and a growing trade of unspecified frozen fish imports (~400,000 t in 2006) create problems in identifying and tracking fish products imported

into China and processed for re-export [31]. In 2009, around 97% of China's total imports of whitefish, salmon and tuna were sourced from 10 countries, with 57% of it coming from Russia. Nearly 70–85% of tuna processed in China is of foreign origin. About 90% of seafood exported by the USA to China is re-processed and exported by China to other countries or re-exported back to the United States [32]. Third-country intermediaries (e.g., Chinese products exported to Canada and then exported from Canada to the United States) also generate problems in traceability of seafood products from China.

Potential problems in tracing seafood products may be exacerbated where companies own fishing vessels and quotas in Russia but these vessels are flagged to Russia or other Flags of Convenience nations. Chinese companies or their subsidiaries own many of these companies in Asia-Pacific countries but they are often registered under a different national company or flag [33,34]. The Russian Federal Antimonopoly Service (FAS) has undertaken court proceedings for corruption issues in this matter [34].

Illegal transshipment of catches directly from Russian fishing grounds to foreign ports is widely suspected, and prevents identification of such IUU catches from within the Russian EEZ. Recent changes in Russian laws make it mandatory for catches to pass through Russian Customs before export and a reduction of illegal catches may have ensued, although there has been no formal study of this. However, the extent of illegal transshipments is still considered by multiple sources to be high in the Russian EEZ, with Russian vessels routinely switching off VMS before entering neighboring nations' ports or transshipping catches to Flags of Convenience vessels within the Russian EEZ [34].

Collectively, supply chains for seafood products transiting China are rife with opportunities for obfuscation and the laundering of illegal catches into legitimate trade flows.

4.4.1. Russian seafood processed in China

Russian pollock, crab and salmon are significant imports to the seafood market in the USA. All three species undergo transshipping and are processed in China before re-export to the United States and all three have been linked to high levels of illegal fishing. Until 2009, there were no mandatory requirements for seafood harvested in Russian waters to be landed and processed by Russian customs before export. Consequently, operators used this loophole to trade unregistered exports of seafood not declared to the customs territories.

4.4.2. Russian pollock processed in China

The bulk of Russian-caught pollock becomes a double frozen product exported to Europe and the United States: it is frozen first in Russia, sent to China where it is thawed, processed and frozen again. Most of the frozen blocks imported by the USA and Europe from China are composed of Russian pollock.

The Russian pollock fishery has had low transparency due to the lack of observer coverage, the absence of adequate data on by-catch of marine mammals and discards of juvenile pollock. According to both the Government and Russian seafood industry officials, restrictions are rarely complied within this fishery [35]. Investigation into the current situation for Russian pollock exports to China for re-export to the United States found that illegal catches likely remain high, as officials rely on Daily Vessel Reports (DVRs) to assess official landings and TAC in this fishery. Catch reporting is also affected by inaccurate reporting of raw-to-processed fish conversion coefficients and poor monitoring of transshipments at sea. Discards of undersized pollock are in direct contravention of regulations stipulating the allowable by-catch of undersized pollock. Prevailing low scientific observer coverage [36] and enforcement presence means that this regulation is rarely enforced, and seems to be further compounded by low wages and corruption among the enforcement staff [37].

In the Sea of Okhotsk pollock fishery, enforcement efforts have reportedly led to declines in illegal fishing since 2008, with violations from inspections reduced from 3.4% in 2008 to 1.7% in 2010 [38,39]. However, this data should be treated with caution as landings of illegal catches of Russian origin continue to be reported in neighboring countries [40].

When violations occur, the Russian industry has claimed them to be administrative violations rather than an IUU crime – an atypical interpretation of IUU reporting. Notably, there appears to be no routine at the government level in the Russian Federation to compare illegal catches against the TAC for Russian pollock. The impact for Russia is mainly biological and scientific, in that for robust assessment and TAC-setting, scientists need to incorporate unlawful discards of undersized pollock and discards from roe harvest, a task made difficult while Russian industry denies that violations exist.

Russian legislators recently approved a national plan of action (Government of the Russian Federation decree of 25 December 2013 no. 2534p, Moscow) and legislative changes to create sanctions against illegal fishing, but these efforts have been held up by prevarications from the fishing industry [41] and the Russian government has been diverted into trying to establish definitions for specific violations [42]. Recent Marine Stewardship Council certification of the Russian pollock fishery requires increased observer coverage [43] that hopefully will mesh with these legislative changes.

4.4.3. Russian crab processed in China

Most Russian crab is caught in the Russian Far Eastern EEZ (Sea of Okhotsk) and the Russian EEZ sector of the Barents Sea north of Murmansk. Illegal crab is either overharvested by companies that have legitimate quota share or is caught by vessels fishing without quota share or licenses, with the latter reportedly being primarily an activity of Russian organized crime [44].

Illegal live crab is generally landed in Japan or Korea. Crab landed in Japan is processed and consumed in that jurisdiction, while the crab landed in Korea is processed and may be provided with counterfeit Certificates of Origin and Certificates of Heath [45]. Russia and Korea recently discussed the unloading of king crab in Korea without the required Russian certificates. Korea argued that an international documentation scheme was needed, and noted that there was a powerful group in Russia that benefited from poaching. The crab is then shipped to China for repackaging (sometimes including reprocessing), where it may be mixed with legal crab. From China, significant amounts of this product are exported to the United States. “Once the IUU crab is in the U.S. supply chain, the routes into the marketplace are the same as that for legal crab, and because of false documentation, repacking and obfuscation of traceability, it is currently undetectable” [46].

From 2000 through 2010, for every legal crab caught in Russia, 2.6 crabs were caught illegally [47]. In three of those years, the amount imported into the United States alone exceeded the Russian catch quota [48]. Several reports published by different regulatory bodies in Russia corroborate that estimates of the overall volume for illegal trade of crab are not consistent and grossly incomparable [49]. Unreported exports and transshipping to foreign ports without declaration persist, leading to unaccounted illegal catches. In recent discussion over the 2013 crab quota by Russia’s fisheries agency (RosRybolovstvo), it was observed that although progress is being made in interdicting illegal crab fishing, the total amount of Russian crab unloaded in Canadian, Chinese, Japanese, Korean, U.S. and European ports still significantly exceeds, by 1.8 times, Russia's allowable catch quota

for crab (86,600 t landed versus the allowable catch quota of 48,300 t for all Russia's fishing grounds [50]).

Since 2004, crab fisheries globally have been depleted by fishing for export demand, and the stocks have been severely overfished [51]. The biological and economic impact of illegal fishing for Russian red king crab is that most of the fisheries have been depleted and are closed, with only two remaining open legally today. Moreover, the volume of illegally caught Russian crab depressed prices for Alaskan king crab by an estimated 25% in 2012 [52]. There have been some recent improvements in that "Russia's stricter monitoring policies are noticeably impacting the fishery sector and especially crab" [53].

4.4.4. *Russian salmon processed in China*

Illegal fishing for salmon in Russia comes in several forms, ranging from fishing permit holders who exceed their quota to rampant poaching for salmon roe in Russia's rivers, often leading to the discard of chum salmon bodies. It includes the illegal setting of traps [54] and the misreporting of catch as lower value species (for example pink salmon reported as chum salmon). There are also problems in monitoring the status of Pacific salmon stocks in the Russian Far East [55,56]. In the Sakhalin region, the pink salmon fishery has interactions with endangered species such as Kaluga sturgeon, Sakhalin sturgeon and critically endangered Sakhalin taimen (Siberian salmon).

Widespread corruption and the lack of patrolling make it difficult to reduce illegal fishing in Russia [57,58]. In the Kamchatka region, for example, salmon quotas are exceeded by 15–25% [59] and estimates suggest that illegal catches are 2–2.7 times more than reported harvests [60]. Illegal harvest from the Sakhalin region is estimated at 20–25% of the reported catch [61]. In the Chukhotka region, unreported catches of sockeye salmon can range from 20% to 30% [62]. Since controls were introduced in 2009, there have been no follow up studies to show changes in illegal fishing rates and trade flows for Russian salmon exported to China.

Salmon products from the large-scale driftnet fishery carry the highest risk of having been caught illegally [63]. Fishing techniques such as discarding and high-grading of pink salmon appear to be common in the driftnet fisheries [64], where the reported catch composition diverges from the species makeup seen in nature. The large-scale driftnet fishery also causes an estimated mortality of 150,000 sea birds each year, including three endangered species [65]. There are no consistent scientific observers in the fishery and interactions with threatened and vulnerable species are unmonitored. Russia's large-scale driftnet fishery for sockeye salmon is the only remaining driftnet salmon fishery in the North Pacific, as this fishing equipment has been banned by international treaty on the high seas (United Nations General Assembly Resolutions U.N. Resolution 44/225 and U.N. Resolution 46/215, 1991), and banned by the United States in their territories (High Seas Driftnet Fisheries Enforcement Act 1992 – Public Law 102–582), which bans any USA sales and trade in products caught by this technique.

Imports to the USA are predominantly pink salmon and some chum salmon, with much of it processed in China for fresh and frozen fillet products. These are important products to major retailers in the USA, who regularly buy pink salmon from Russia. During trans-shipment at sea, illegally fished salmon are mixed in with legal Russian salmon exports to China.

There is also a lack of traceability for Russian wild salmon products that are trans-shipped or held in South Korea, for example, where products may be stored in duty free warehouses and not recorded. Passage through these facilities increases reputational risk for buyers by reducing possibilities for verification that products are legal, such as validation of the Certificates of Origin. Sendai, Japan is another major port of landing for Russian salmon, where product mixing may occur for shipments traveling without certificates of origin or with packaging not clearly marked with origins [66,67]. Illegally fished products may also be mixed into shipments at their sources, unless the source – such as the Ozernaya River region – is geographically isolated.

In an effort to reduce IUU fishing on Russian wild stocks, Russia has negotiated bilateral agreements with South Korea, North Korea and Canada and in 2012 was in discussions with Japan [68]. An agreement with the United States has not yet been implemented. The draft agreement with Japan includes provisions to reduce fishing access for foreign fleets that do not fully cooperate with the terms of the bilateral agreements. Until strengthened observation and regulatory frameworks are in effect, the multiple forms of illegal Russian salmon fishing threaten not only the salmon stocks themselves, but also other species and food webs. The role of additional countries in shipping and processing further convolute already complex trade flows, and raise the risk of illegal products reaching consumers.

4.5. *Tuna*

Tuna enters the USA market as canned tuna for retail, large cans for food service establishments and as imports of fresh or frozen tuna species. The vast majority of these tuna imports are caught in the Indian and Pacific Oceans. Imports from the top four exporters of tuna to the United States (Thailand, 44%; the Philippines, 10%; Vietnam, 8%; and Indonesia, 7%) accounted for almost 70% of tuna imports in 2011, and the top 10 countries accounted for 90% of total imports [69] (See Table 4).

In 2011, canned tuna represented about 63% of total tuna imports into the USA by volume but just over half of the value, while the remaining tuna imports are fresh or frozen tuna products [70]. Canned tuna imports to the U.S. in 2011 totaled 187,198 t valued at $719,293,937, while fresh and frozen tuna imports totaled 107,679 t valued at $651,366,670 [68]. The identified species for fresh/frozen tuna products on Customs codes are albacore, bigeye, bluefin, skipjack, and yellowfin tuna. The species in canned tuna are primarily skipjack tuna, although this may also include species of frigate and bullet tunas. Customs codes only distinguish albacore. Non-specified tuna is the current Customs tariff designation for all other canned tuna that is traded.

The same sources indicate that nearly 80% of Thailand's tuna exports by volume are canned tuna and Thailand alone accounted for 55% of the canned tuna imports by volume into the USA in 2011. Imports of canned tuna from Thailand in 2011 were 102,134 t valued at $393,859,488. Together with the Philippines (13%), Vietnam (10.5%), Ecuador (10%), Indonesia (5%), China (4%), and Mexico (1%), these seven countries accounted for 99% of the canned tuna imports into the U.S. in 2011. (Imports of canned

Table 4
Estimated tuna imports to the USA in 2011.

Source	Estimated imports, t
Thailand	128,000
Philippines	30,700
Viet Nam	24,400
Ecuador	21,100
Indonesia	19,700
China	14,200
Mauritius	9400
Trinidad	8720
Colombia	6930
Fiji	6990
Others	26,800
Total	296,940

tuna from the Philippines were 25,162 t valued at $79,784,613; Vietnam, 19,605 t valued at $71,060,394; Ecuador, 18,848 t valued at $90,167,140; Indonesia, 9938 t valued at $42,771,461; China, 6958 t valued at $21,803,715; and Mexico, 2214 t valued at $8,223,366).

Almost all of the world's tuna stocks are nearly fully exploited and some are overexploited, while some of the stocks that are not yet overexploited are being overfished [71]. Proper management of stocks is threatened by increasing fishing capacity, not only of industrial fisheries but also small-scale coastal fisheries [72]. Efforts to control catch through catch quotas, effort controls size limits and other restrictions are difficult to enforce when there is excess fishing capacity and tuna processing facilities that demand increasing amounts of raw material. These same pressures add to the incentives for illegal and unreported fishing.

Recent steps taken to confront illegal fishing come in a context where it has historically been a significant component of tuna fishing worldwide. Illegal tuna fishing in the Indian and Pacific Oceans is facilitated by the lack of seafood traceability when supplies are consolidated during trans-shipping at sea. In particular, the frozen tuna market tends to trans-ship and re-supply at sea. Strong demand for tuna encourages brokers to amalgamate supplies from different origins to make orders. Because there is scant transparency at sea, even products carrying a traceability claim on the package could well derive from mixed shipments with mixed species fished by a mix of licensed and blacklisted vessels. This appears to be the case for tuna processed in Thailand, the hub of tuna seafood processing in Southeast Asia. Illegal activity by small and medium scale longliners and falsification of tuna documentation is also a concern.

Thailand imports about 85% of the raw material for its tuna canning industry, primarily frozen skipjack caught in the western central Pacific Ocean by fleets flagged to Taiwan, USA, South Korea and Vanuatu [73]. Foreign interests own the large tuna trading companies that supply the Thai canneries, and tracking the routing of seafood products through these companies remains a challenge for chain of custody and traceability issues [74]. In the fresh and frozen tuna market trading relationships are complex, changeable and generally between much smaller companies than in the cannery sector.

The Thai fleet consists of four industrial-scale purse seine vessels operating in the Indian Ocean and a small artisanal purse seine fleet targeting coastal tuna species (bonito) [75]. Thailand is the major port of landing for tuna fished in the Indian Ocean, where at least 50% of the tuna fishery is subsistence or small scale. Tuna vessels operating in small-scale fisheries in the developing world generate significant bycatch of sea turtles and marine mammals, where such tuna catches are also beset with under-reporting problems [76,77].

Data collection and detection of illegal activity has been a challenge, especially in the vast areas of operation in the Indian Ocean and the Western Pacific. A recent air, sea and electronic surveillance operation over an area of approximately 30 million square kilometers conducted by the Secretariat of the Pacific Community (SPC) and the Pacific Islands Forum Fisheries Agency (FFA) resulted in the boarding of 64% of 320 sighted vessels and 27 (13%) infringements. The operation included the Cook Islands, Micronesia, Kiribati, Marshall Islands, Nauru, Niue, Palau, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu and Vanuatu: regional estimates put lost earnings from activities such as under-reporting or misreporting to as much as over a billion dollars [78]. Under-reporting and misreporting of catches, even by European flagged vessels, [79] remain a significant challenge in the Indian Ocean where more than half of tuna catches are made by small-scale gears [80]. Gillnet fisheries continue to expand rapidly in the Indian Ocean, some of which use illegal large-scale pelagic driftnets [81].

A report on the global tuna supply chain stated that in June 2010 around 30% of Thailand's imported tuna had catch certificates to comply with EU fishing regulations designed to exclude IUU fish from the supply chain [82]. However, exports to the EU account for less than 20% of Thai canners' total production and Thai industry sources indicated that while "it would be ideal if all imports had EU catch documentation, market outlets still exist for canned tuna using fish supplies that do not have EU-compliant catch certificates,"[83] suggesting that the USA may remain a major market for tuna that does not have catch certificates.

The Philippines is the second largest canned tuna exporter in Asia after Thailand. Unlike the Thai tuna industry that largely depends on imports of tuna raw material for its canneries, the Philippines has a large domestic tuna fishing fleet that supplies most of the raw materials to its canneries. About 50% of landed tuna is consumed locally, and the other half is either exported as sashimi-grade tuna or sent to tuna processing plants [84]. The Philippines increasingly imports significant amounts of tuna from foreign fleets to top up supplies from domestic tuna fishing vessels. A recent report in the Philippine media noted that the declining fish catch in the inshore waters of the country has driven Filipino fishers further offshore, resulting in increased costs, higher safety risks and more difficulty in sourcing high-quality tuna [85]. There is under-reporting of tuna catches from smaller vessels operating in provincial waters and losses from illegal fishing by foreign operators may be as high as 10,000 t each year in the Philippines EEZ [86].

Vietnamese exports of tuna (about half of which are canned) have increased dramatically in recent years and the United States is the main export market for both canned and fresh/frozen tuna [87]. Vietnam relies heavily on imported raw material for processing. It is suspected that about 25% of the tuna caught by Vietnamese vessels originates from Indonesia's EEZ, illegally caught with no fishing agreement [88]. (Another 5–6% of unregulated catch comes from disputed waters of the Spratly Islands, claimed by China, Vietnam, Thailand, Indonesia, and Philippines, but as this arises from a territorial dispute and fishing in unregulated areas claimed by Vietnam it is not here included as IUU.) There is also significant under-reporting of tuna in domestic small-scale fisheries within Vietnam's own EEZ [89].

The supply of tuna to canneries in Indonesia is almost all local, sourced from a variety of vessels, including purse seine, pole and line and artisanal [90]. However, under-reporting of catches from numerous, dispersed landing centers remains a large problem in Indonesia, and catch from artisanal vessels is poorly quantified in national catch statistics [91]. Port sampling by government authorities is sparse, and significant gaps exist in monitoring interactions with protected, vulnerable and threatened species. Significant by-catch and discards of several non-target species occur in Indonesian tuna fisheries, but these are rarely quantified [92,93]. Moreover, tuna catches are not adequately monitored in Indonesian waters, especially for foreign owned fishing vessels operating under joint-venture agreements [94].

4.6. Shrimp

Wild shrimp from the South East Asian region, such as Indonesia, is often purchased at sea and trans-shipped to Thailand and China for processing, and is therefore not landed and reported in source country trade statistics [95]. Part of this catch is unreported but licensed through joint venture agreements with Thai, Taiwanese and Korean vessels. Part of the catch is also from unlicensed vessels selling supplies to trans-shipping vessels at-sea. This extra supply feeds the processing sector in Thailand, while simultaneously diverting the catch away from the Indonesian processing sector. As is seen for other products and regions, the

incentive for IUU fishing is the lack of transparency on trade flows at sea where supplies are amalgamated for large, shore-based processing interests.

In Mexico, illegal catches of shrimp may be as high as double the reported catches [96]. In the shrimp trawl fishery, a 2006 estimate by the Mexican navy revealed that nearly 50% of small-scale boats in the province of Sonora were operating illegally; of 8000 boats operating only 4000 were registered [97,98]. Illegal practices occur in all of the artisanal shrimp fisheries in the Gulf of California, but the negative interactions are focused in the upper Gulf of California, which includes landings for the ports of San Felipe (Baja California), Puerto Peñasco, and Golfo de Santa Clara, Sonora [99].

The Gulf of California shrimp trawl fishery results in very high bycatch discard rates. Forty-six species of crustaceans, fishes, gastropods and elasmobranchs were observed as by-catch, with more than 75% of species discarded and 25% retained. An artisanal fleet of about 800 skiffs operates year-round using gill nets to target shrimp (September–March), finfish (February–May), sharks, and rays (May–June) [100]. Several threatened and endangered species are caught regularly [101,102]. Moreover, by-catch in the shrimp fishery is the leading cause of death for the vaquita, a small porpoise endemic to the Gulf of California that is widely cited as the most endangered mammal in the world with a population of only around 200 individuals [103]. Adverse environmental impacts such as these are often symptomatic of fisheries that engage in illegal activities.

Overall transparency for catches by the artisanal fleets in Mexico is increasing due to a high level of community-based management for long-term stewardship. Transparency of wild shrimp exports to the United States, however, is very low, compounded by the failure of trade statistics in the USA to differentiate wild from farmed shrimp products in imports. One leading U.S. importer advertises a mix of wild and farmed shrimp from Mexico in their products, reflecting the generally poor transparency of sources in the U.S. market for shrimp.

4.7. Suggested remedies

A number of instruments that could control the trade in illegally caught seafood products already exist within the USA, but are not well designed for today's massive global seafood trade and are not sufficiently enforced. One example is the High Seas Driftnet Moratorium Protection Act, which clearly establishes that any commerce in products from drift net caught fisheries is illegal. Another instrument is the Lacey Act, which has occasionally been used in fisheries. However, the infrequency of Lacey Act actions, and their disconnection from routine border enforcement measures raises substantial questions about the ability of the Act as currently implemented to prevent or effectively deter the imports of illegally caught fish into the United States on the scale reported here. A Lacey Act process to parallel the 2008 amendment that inhibited the use of imported illegal logs may partly address the problem, but this too may well need to work in conjunction with a comprehensive seafood traceability process that excludes IUU products from entering the supply chain.

Indeed, these tools as currently implemented appear to be inadequate to address the large quantities of illegally caught seafood that are entering the market in the USA. In addition to more rigorous inspection and border controls aimed at detecting and deterring illegal imports, government and private sector systems are called for to address the lack of transparency and traceability in wild seafood supply chains. These could include the use of catch documentation, improved chain of custody procedures and certified product sources to ensure that seafood imports are traceable to verifiably legal sources. A catch documentation scheme for all seafood imports similar to that in force in the EU would encourage the flow of IUU-free products in the USA market. An effective improvement would be the barcodes that have been recently devised to document the supply chain and origins of seafood, and are readable by distributors, retailers, consumers and government agencies [104].

Many seafood companies honestly believe that no illegally sourced fish enter their supply chain, but the extensive mixing of product at-sea and at the processing stage means that they are almost certainly mistaken. Both catch documentation and verification are essential: even product entering the relatively well regulated EU market can have substantial illegally sourced fish – for example, Mediterranean blue fin tuna has over 40% of illegal catch. To successfully claim zero tolerance a company must operate a due diligence program to verify that illegally sourced seafood cannot enter its supply chains.

Some fisheries that were examined for this work, Russian pollock fisheries for example, have since 2011 established management measures that have reduced the level of illegal, unreported, and unregulated fishing occurring in the fishery. For most of the fisheries examined, however, the level of monitoring, control, and surveillance within the management regimes do not appear to have advanced; and the absence of traceability means that attempts to audit imports to determine legality remain difficult if not impossible.

5. Conclusions

The global seafood industry faces significant competitive pressures, and often operates on thin profit margins, a tough commercial environment that is made worse by the continued worldwide crises of overfishing and stock depletion. These economic pressures encourage a focus on securing cheap seafood supplies. Today, those supplies often arrive through production and marketing chains that lack transparency and accountability, thus providing opportunities for large amounts of illegally caught fish to reach retailers and consumers. The gaps in the system occur at many levels: at sea, where monitoring, control and surveillance remain frequently inadequate; in ports, where systems to document catch landings are often weak or non-transparent; and in market countries, where effective systems to require traceability and proof of legal origin are lacking. Coupled with the financial incentives to fish illegally, these gaps allow illegal fishing to remain profitable, with devastating effects on global fish populations, communities that depend on fish for food and the livelihoods of legitimate fishermen.

This paper presents a new effort to study and quantify the dimensions of the problem from the perspective of the United States as a major seafood market. Building on previously published data and new product flow estimations for the situation in 2011, this work reaches several key conclusions.

First, illegal fishing activities remain a major problem for the seafood industry and seafood consumers. Second, the lack of transparency in highly complex and diffuse wild seafood supply chains allows illegal and unreported catches to be easily laundered and mixed into legitimate supplies entering international trade. Third, very few tools currently exist to monitor and interdict illegal catches entering the United States through seafood imports. Fourth, significant quantities of illegal fish enter the USA. In 2011, an estimated 20–32% of the wild-caught marine imports into the USA (by weight) were from illegal and unreported catches, with a value between $1.3 billion and $2.1 billion. These findings are consistent with many other studies that show the prevalence of illegal fishing around the world and clearly reveal that

consumers in the United States today face a high risk of unintentionally purchasing illegal seafood.

The work reported here suggests that the United States funds significant profits from illegal fishing activities by providing major opportunities for marketing illegally caught fish, and this has three implications for the USA seafood trade. First, the USA is one of the world's biggest seafood markets, whose purchasing power has a significant impact on patterns of fishing and trade. Second, preventing the infiltration of illegal fish products into legitimate markets is inherently difficult as a result of the diffuse, complex, and opaque nature of seafood supply chains. Third, current regulations and border inspection practices in the USA are not effectively oriented towards the prevention or interdiction of trade in illegal fish products.

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Appendix A. Supplementary materials

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.marpol.2014.03.019.

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