Global Ecology and Conservation 26 (2021) e01455

Contents lists available at ScienceDirect

Global Ecology and Conservation

journal homepage: http://www.elsevier.com/locate/gecco

Original Research Article

CITES and beyond: Illuminating 20 years of global, legal wildlife trade

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ARTICLE INFO

Article history:
Received 30 April 2020
Received in revised form 5 January 2021
Accepted 5 January 2021

Keywords:
Wildlife trade
UN COMTRADE
Commodities
HS Codes
Monitor
Biodiversity

ABSTRACT

Nature has the potential to provide wide-ranging economic contributions to society – from ecosystem services to providing income to communities via fair trade of resources. Unsustainable trade in wildlife, however, threatens biodiversity and its ability to support communities and a functioning planet. It is therefore important to have clear systems in place for tracing traded wildlife. Monitoring legal wildlife trade in all species is as important as it is for trade in protected species, since flows of the legal trade correlate with, and provide cover for, illegally traded wildlife. The majority of wildlife trade research is focused on species listed in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The concurrent, considerably larger legal wildlife trade in both CITES and non-CITES-listed species, however, remains unexamined – despite the fact that if mismanaged, it can lead to over-exploitation. Here we analyzed 20 years of data from the UN Comtrade database, aiming to detail the scale, composition, and trends across all taxa of wildlife traded legally, and to indicate opportunities for improvement. From 1997 to 2016 the value of this trade totaled between US$2.9 and 4.4 trillion. Of this, $2.9 trillion wildlife was traded under "specific" codes that specify taxonomic Order and below, while around $1.4 trillion was traded under "broad" codes that declare wildlife to taxonomic Class and above. The top 10 trading nations/territories accounted for 51.4% of the total value of wildlife traded. The top commercial categories for wildlife trade were seafood (82%), furniture (7%), and fashion (furs and hides) (6%). In these three major categories, vague commodity codes such as "Fish", "Tropical wood", and "Other furs" were used to declare 23%, 24% and 26% of items traded, respectively – despite encompassing thousands of species. This lack of granularity imperils biodiversity as trade cannot be comprehensively monitored. We recommend a review of what species are traded under these broad code descriptions, and a distillation of codes to taxonomic Family or Genus level in the next HS Code review period, particularly in the pet, traditional Chinese medicine and furniture categories. In addition, interdisciplinary research into legal wildlife trade should be increased to provide forensic, policy, economic and social solutions to improve trade management.

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https://doi.org/10.1016/j.gecco.2021.e01455
2351-9894/

1. Introduction

International wildlife trade is a sizeable economic sector, and its impact on global biodiversity is widely documented (Sutherland et al., 2009; Harrison 2011). If unmonitored, unsustainable legal wildlife trade can go unnoticed, threatening the survival of the species involved, the natural systems they are part of, as well as the humans that rely on wildlife to survive (ten Brink et al., 2012; Robinson 2016; Brondizio et al., 2019). Environmental income provides economic security to millions of people, particularly low-income households in less economically developed countries (Vedeld et al., 2007; Angelsen et al., 2014). Andean communities, for example, actively protect wild vicuña (*Vicugna vicugna*) populations due to revenue generated by commercial trade in their wool (MacMillan et al., 2015; Bulte et al., 2003). Similarly, sustainable butterfly farming initiatives support people economically from Papua New Guinea to Costa Rica (New 1994; Slone et al., 1997), as does abalone farming in Japan (Cook 2016). But there are a number of requirements that have to be met for this to be successful, such as precise trade management (Tensen 2016; Phelps et al., 2014). Therefore, having traceable, high-resolution data on natural resource exploitation is important to secure sustainable livelihoods, as well as to protect biodiversity.

Much research has focused on global legal and/or illegal trade of species listed in the Appendices of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (e.g. Nijman 2010; Bush et al., 2014; D'Cruze and Macdonald 2016; Cheng et al., 2017; Harfoot et al., 2018; Scheffers et al., 2019). While some studies have documented domestic trade in non-CITES-listed species (Anadu et al., 1988; Anderson et al., 2011; Nijman et al., 2017), less effort has concentrated on understanding the trends of international legal trade in non-CITES-listed wildlife, despite its scale and scope (Fig. 1) (Fuller et al., 2019). By addressing this knowledge gap, we can address the ecological and sociological implications associated with unmonitored wildlife trade, such as unnoticed overexploitation of species (Fain et al., 2013; Warchol and Harrington 2016; Frank and Wilcove 2019) and sudden loss of income for those dependent on a particular natural resource (e.g. Hopping et al., 2018). Given that legal wildlife trade correlates positively with illegal trade (Olsen et al., 2019; Tittensor et al., 2020), understanding global patterns of legal trade will also add to our understanding of whether and where wildlife trade poses a threat to biodiversity.

The sheer scale and complexity of global legal wildlife trade makes comprehensive monitoring a challenge. There are no species-specific reporting mechanisms in place to track the volumes, trends, or routes for species that are not listed on CITES, but traded legally. In this unregulated scenario, it is possible for irregularities to go undetected, such as trade in excess of quotas, misdeclaration, fraudulent licensing and laundering of protected species (Wyatt 2009; Wu and Sadovy de Mitcheson 2016; Cardeñosa et al., 2018). Studies that do examine patterns of legal wildlife trade in non-CITES-listed species either focus on specific taxa and regions (e.g. Fuller et al., 2019) or the links between source and consumers (Kastner et al., 2011; Moran and Kanemoto 2017). Likely in part due to the difficulties in deciphering the current reporting mechanisms for legal trade, to date there has been little effort to characterize the long-term overall trends and major importers, exporters and re-exporters of all wildlife traded legally across the globe.

There are a number of challenges involved in tracking and understanding the various dimensions of wildlife trade. Illegal trade analysis is encumbered by the clandestine nature of its operations and resulting unavailability of complete data (Harrison et al., 2016; Van Uhm 2016; de Mitcheson et al., 2018). Shortcomings in CITES data, meanwhile, include inconsistent reporting practices across parties, the use of multiple un-standardized measurement units, no value declarations, and reporting to different taxonomic levels (Green and Hendry 1999; Blundell and Mascia 2005; Russo 2015; Foster et al., 2016; Robinson and Sinovas 2018). Monitoring other international legal wildlife trade presents a different challenge – one of scale,

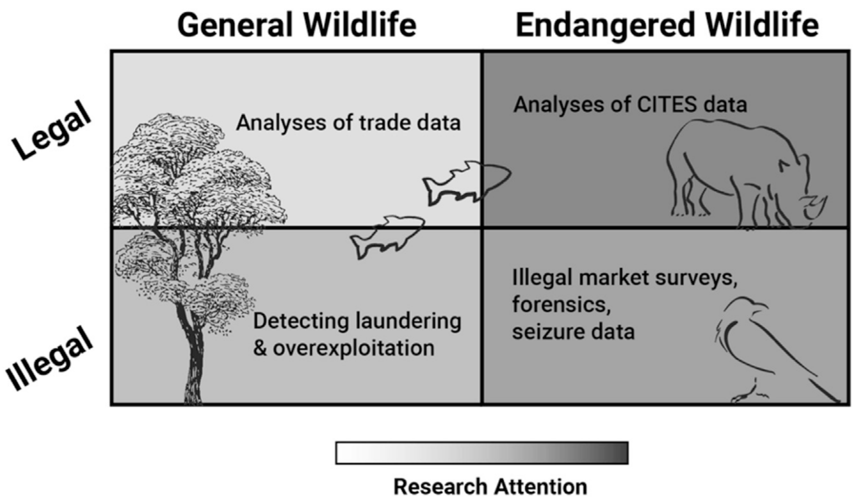

Fig. 1. Figure illustrating unbalanced research efforts for legal/illegal wildlife trade.

and lack of finite data (Janssen and Shepherd 2018). All UN member states are required to report all commercial trade annually to The United Nations International Trade Statistics Database (UN Comtrade). While the primary mandate of this database is tax-keeping purposes rather than the ecological considerations examined here, it remains the most comprehensive global dataset for tracking legal wildlife trade. This centralized database is relatively homogenous in terms of reporting systems, monetary unit declarations and commodity descriptions, but it is to some extent beleaguered by the same issues related to self-reporting as the CITES trade database – with countries occasionally failing to report (see Appendices Fig. A1), and the inevitable variation in reporting standards across Parties. Nevertheless – UN Comtrade represents the main database for international legal wildlife trade available.

Since the primary function of the UN Comtrade Harmonized System (HS) Codes are to provide data for statistics and tax purposes, most analysis conducted using this database has had an economic perspective (Goldberg et al., 2009; Ahn et al., 2011). Research utilizing codes related to wildlife has been focused on specific categories such as seafood (Gephart and Pace 2015), flora (Wu and Chen 2009; Negrelle et al., 2012; Masiero et al., 2015; Ghimire et al., 2016; Vasisht et al., 2016; Brendler et al., 2018), or certain taxa/geographic regions (Clarke 2004; Blundell and Machia 2005).

In order to provide a systematic overview of the global legal wildlife trade, we analyzed 20 years of UN Comtrade data pertaining to legal wildlife trade (which includes both CITES and non-CITES-listed species) for animals and other organisms. We refer to this trade here as "legal wildlife trade" and aim to describe the scale, trends, major traders, and categories of wildlife/wildlife derivatives traded therein. This analysis highlights areas where monitoring can be improved in order to avoid over-exploitation and to facilitate the sustainable management of wildlife populations – since this, in turn, can promote economic security and incentivize the protection of species. To this end, we suggest refinements to the HS Code system which would improve record-keeping, monitoring and traceability in legal wildlife trade, targeted resources to support enforcement in strategic wildlife trade hubs, and greater collaboration between scientists, economists, and policymakers in understanding legal wildlife trade trends.

2. Methods

Every year, countries report commodity trade to the World Customs Organization using six-digit codes that follow a global HS Codes. There are approximately 5300 codes encompassing all commodities, including wildlife and its derivatives. These HS Code data are publicly available online at UN Comtrade (comtrade.un.org), a repository of international trade statistics. We downloaded HS Code data that relates to wildlife (see methods section 2.1 and 2.2) from UN Comtrade. The number of countries that reported trade in each year fluctuated (Fig. A1); the average number of countries/territories reporting trade annually in the period is 162, and the aggregate total number of countries that reported trade to UN during this period is 201.

The HS Code system was designed to facilitate statistical record keeping and taxation. Neither the system, nor its codes, were designed to facilitate investigation of the trade in wildlife or the biological considerations we examine here. Therefore, the codes do not differentiate or distinguish farmed from wild-sourced organisms. This means our analysis inevitably includes farmed animals, plants or fungi, since it is not possible to separate wild-sourced individuals. The broad nature of the codes – which encompass species of varied threat level, provenance (regional, wild/farmed/artificially propagated), and laundering risk – is what makes it difficult to exclude products primarily derived from farming/artificial propagation. Vague code descriptions, such as "440728 Other tropical wood lumber" and "30199 Other live fish" prevent the separation of plantation from wild-sourced wood or wild marine animals from aquaculture, for example. These types of wildlife trade data issues, and the difficulties they introduce for analysis, have been acknowledged in research pertaining to this topic (Chan et al., 2015; Gerson 2008). Given that UN Comtrade constitutes the most comprehensive data on legal wildlife trade available, we examine it here – despite its shortcomings – and suggest improvements. In order to address some of these challenges, we have not included codes that relate to heavily domesticated animals or livestock, and we have analyzed different subsets of the overall dataset (see section 2.1 and 2.2). An additional consideration when including farmed wildlife was that commercial farming can affect wild populations negatively in a number of ways, by providing a potential avenue for laundering/mis-labelling, complicating enforcement/traceability procedures, stimulating parallel illegal trade, as well as serving as a potential source for the introduction of alien species in wild populations via farm escapees. See supplementary materials methods text for a more detailed justification for including codes that may include farmed as well as wild-sourced wildlife.

Our analysis of the trade data was based on the declared value of traded products rather than volume due to inconsistencies in how volumes are reported. The standard value measurement for UN Comtrade data is US Dollars (US$), while quantities/volume are reported in many different measurements (kg, cubic meters, volume in liters) which are not readily comparable (Berec et al., 2018; Russo 2015). Analyzing monetary values has its own limitations, relating mainly to the value added at each stage of the trade chain and under-reporting of trade value to minimize tariffs. We acknowledge these limitations and have attempted to mitigate their impact by correcting US$ values according to year-on-year inflation (using 2006 as the base year) with statistics sourced from the US Department of Labor Bureau.

2.1. Overall trade

For analysis of overall trends in global legal wildlife trade, we created a comprehensive import/export dataset, for which we selected 347 codes that relate to, or are sourced from, wild plant, fungi and animal species (Table A2). In June 2018 we downloaded all import and export data reported by all countries over the 20-year period between 1997 and 2016 under these codes. We then sorted all 347 selected codes into eight major wildlife trade categories based on the purpose of the items traded, enabling us to compare and analyze trends in different categories. The eight purpose categories we designated were: seafood, fashion (primarily furs and skins), furniture, Traditional Chinese Medicine (TCM), ornaments and jewelry, pets, wild meat, and exhibition. Exhibition relates to all wildlife traded with the intention of being exhibited in zoos, wildlife parks or entertainment such as riding/racing, etc. A complete list of selected codes, code descriptions, and the categories they were classified into can be viewed in detail in Table A2. HS Codes are not divided solely by taxa; they are broadly aligned with products or the commercial area within which the product is used. Camels, for example, have a code which we included in the “exhibition” category “10613 Live camels and other camelids (Camelidae)” and also a separate code which we included in “wild meat”, namely “20860 Meat and edible offal; of camels and other camelids (Camelidae), fresh, chilled or frozen”. This enabled us to include species that may be traded for different purposes in our analysis.

For the purposes of this paper we defined wildlife as aquatic and terrestrial animals, plants, and fungi that can grow in the wild and are not heavily domesticated. Specifically, we did not select codes pertaining to horses, cows, pigs, goats, poultry, rabbits, bees and sheep − with the exception of codes in the fashion category that relate to Astrakhan, Broadtail, Caracul, Persian and similar lamb, Indian, Chinese, Mongolian or Tibetan lamb. We selected these codes by consulting the broader list of UN Comtrade HS Codes (available at comtrade.un.org), and separating the codes we assessed to represent wildlife. A list of the selected codes are in Table A2.

Processed wildlife products were included in this dataset if the fauna or flora which the products were sourced from were still recognizable. Highly processed items or final goods where product ingredients were obscured or difficult to differentiate were excluded (e.g. mixed materials in coats and jackets, chairs and tables). We did however conduct a separate analysis which excluded processed items (see methods section 2.2).

As many of the codes included in the overall dataset were very broad (i.e. taxa only identified to Class or above), this could represent an overestimate in the total amount of wildlife traded, due to the inclusion of large quantities of farmed animals or organisms. Therefore, we created four subsets of the original dataset for separate analyses to more clearly delineate trade flows and declarations. These include:

- “**broad**” codes which specify taxonomic Class and above;

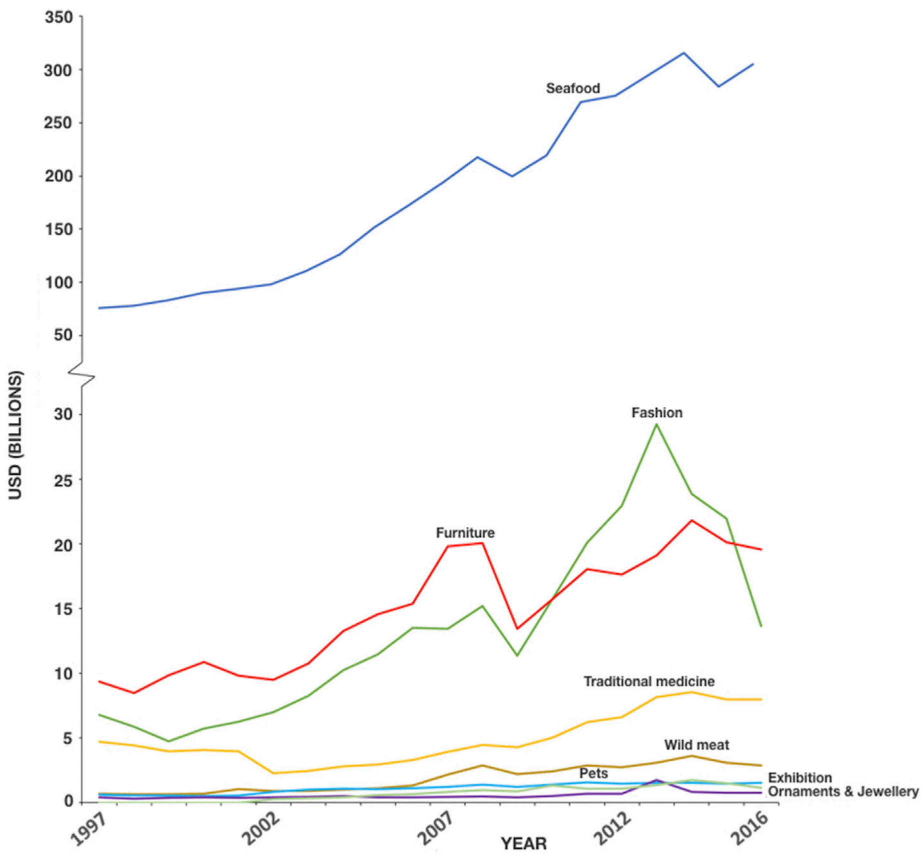

Fig. 2. US$ value of total wildlife traded (imports and exports) between 1997 and 2016 for all wildlife trade categories. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

- "**specific**" codes which specify taxonomic Order and below;
- "**processed**" codes which include terms associated with processing, such as (but not limited to) "pieces, legs, offal, preserved, powdered, sawn, minced" in the description;
- "**raw**" codes which include terms such as "live" "whole" "raw" "unworked" "frozen" "fresh" or "chilled" in the description.

Codes selected for the "broad" and "processed" subsets are indicated in Table A2, and the criteria/terms which qualify these codes as belonging to each subset are visible in bold in their corresponding code descriptions. Analyses of these data subsets enables a more nuanced characterization of trade and identification of target areas for improvement.

2.2. Source countries and processing hubs

We created the separate "processed" and "raw" datasets in order to discern what specific roles the trading countries had in the network (whether they were primarily export, import, or transit/processing countries). The "processed" subset was used to identify major transit/processing hubs, and the "raw" subset was used to determine exporters of primary products. In addition to these, in July 2020 we downloaded a separate "re-exports" dataset, which included data on re-exports for the same 347 wildlife codes from 1997 to 2016. However, the UN Comtrade website states that reporting re-exports as a separate category is optional, and that items considered re-exports must also be included in the mandatory export category. As a result, only 86 countries declared re-exports separately during the period examined. In the import/export datasets, the exports encompass all exports *and* re-exports. By comparing reported re-exports with exports, we are able to achieve an idea of re-exports, but it is not a complete picture since not all parties will have reported trade in the voluntary re-exports section.

We then compared the results from the analysis of re-exports data with Gross Domestic Product (GDP) data to further elucidate major re-exporters and identify processing hubs. Since GDP is a measure of goods produced in a country/territory, a low GDP yet simultaneously high involvement in international trade is characteristic of transit/processing/re-export hubs, since trade involvement is centered around goods that are not produced in the country itself. We selected GDP as a measure because it is a standardized overall global economic trade parameter, and a widely used, broadly accepted indicator of international economic positioning. Other measures such as population or country size have a less direct relationship with economy and trade. The GDP data were downloaded from the online UN data repository (unstats.un.org/unsd/snaama/Downloads) and was limited to GDP and its breakdown at constant 2015 prices in US$.

3. Results

3.1. Overall trade

Legal wildlife trade between 1997 and 2016 was worth between US$2.9 and 4.4 trillion. Of this, $2.9 trillion wildlife was traded under "specific" codes that specify taxonomic Order and below, and slightly more than $1.4 trillion under "broad" codes that declare wildlife to taxonomic Class and above.

In the overall dataset (including both "broad" and "specific" codes) the annual average wildlife trade was $220 billion. By comparison, the global trade in tea, coffee and spices in 2016 was $91 billion (UN Comtrade 2016). Seafood was by far the largest category under which wildlife was traded (encompassing 82% of trade, $3.6 trillion), followed by furniture (7%, $297 billion) and fashion (6%, $267 billion). Once seafood, furniture and fashion were removed, the remaining five categories combined accounted for <5% of the legal wildlife trade in the two decades examined ($183 billion, cumulatively) (Fig. 2).

The monetary value of trade in all categories increased during the period; trade in seafood and furniture rose steadily throughout, whereas fashion peaked in 2014 and declined thereafter (Fig. 2). The monetary value of trade in all categories combined increased, with dips in 2009 and 2015 and a plateau in 2011 (Fig. A3).

The 10 countries/territories with the highest value of imports and exports combined over the 20-year period were USA, China, Japan, Spain, France, Thailand, Germany, Hong Kong Special Administrative Region,[1] Norway and Italy (Fig. 3). These countries/territories alone contributed 51.4% of the overall total amount of wildlife traded in the last 20 years, while the top 15 contributed 64.7%.

The peak wildlife trade year in the dataset was 2014, when the total value of wildlife products traded was $377 billion (Fig. A3). In 2010 China surpassed USA to become the largest wildlife trader year-on-year, after which point overall wildlife trade value escalated considerably (Fig. A3). China was the second-biggest trader of wildlife globally overall for the whole time period (Fig. 3), and when considered together with its special administrative regions Hong Kong and Macau, China traded more legal wildlife per annum than any other country from 2004.

The top three wildlife traders (USA, China, and Japan) also ranked first to third in terms of GDP (Fig. 3). The GDP data in Fig. 3 shows three countries/territories that are among the top 10 wildlife traders, yet place above 20th in global GDP ranking. For example, Thailand is the sixth biggest wildlife trader but is 26th globally in GDP, Hong Kong is the eighth biggest wildlife trader but 34th in GDP, while Norway is ninth for wildlife trade and 28th in GDP.

[1] Hereafter "Hong Kong".

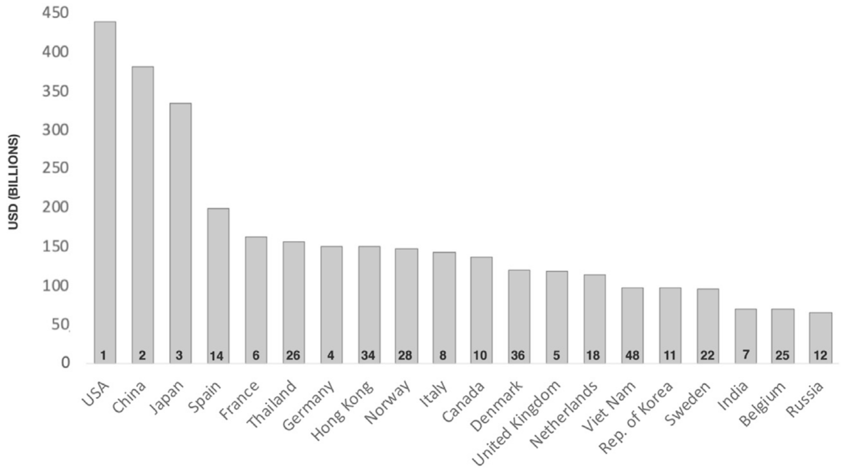

Fig. 3. The top 20 countries/territories for global wildlife trade between 1997 and 2016, the US$ value of wildlife trade overall for those countries over that 20-year period, and their ranking in terms of GDP in US$ for 2015 (numbers on bars, UN).

3.2. Analysis of “specific” codes

Analysis conducted on the “specific” import/export dataset, with broad codes removed (Table A2), found that wildlife trade trends followed those of the overall import/export dataset, and top traders therein (Fig. 2; Fig. 3). Moreover, this analysis shows that 66% ($2.9 trillion) of the total trade was declared using specific HS Codes that indicate taxonomic Order and below, while 34% ($1.4 trillion) was traded using broad codes that only describe taxonomic Class or above, such as “fish”, “plants” and “tropical wood”.

Notably, trade in certain wildlife trade categories was predominantly conducted under broad HS Codes, particularly TCM (83%, $82 billion) and pets (95%, $21 billion). In the dataset with specific codes only, the TCM category is reduced to just four plant products – ginseng ($16 billion), liquorice roots ($559 million), poppy straw ($120 million) and coca leaf ($62 million), since all TCM codes involving animal products were too broad to be included, e.g. “51000 Ambergris, castoreum, civet & musk; cantharides; bile, whether/not dried; glands & other animal products used in the preparation of pharmaceutical products”. The vast majority of trade in the TCM category ($72 billion, 74%) is conducted under the generic 121190 “plants” code. Specific codes in the pets category is limited to parrots ($777 million) and birds of prey ($333 million), which are greatly surpassed by the value of wildlife traded under the broad codes such as “ornamental fish” ($17 billion), “reptiles” ($1.9 billion) and “other birds” ($1.7 billion). Eliminating these broad codes would lead to a major underestimation of the total value of the legal wildlife trade, so we have used the “overall” dataset for the analysis of trade value of different use categories, and to rank the top trading countries (see methods section 2.1).

3.3. Categories

3.3.1. Seafood

Seafood is the largest wildlife category traded and its major trading nations correspond to the dominant global traders for all wildlife (Fig. 2; Fig. 3). The top exporter, China, conducted most of its seafood trade through a variety of codes describing unspecified “Fish” prepared or stored in different ways (e.g. “30429 fish fillets & other fish meat”, “30420 Fish fillets, frozen”), followed by cuttlefish/squid, shrimps/prawns, other mollusks/aquatic invertebrates, and eels. Second-largest seafood exporter Norway’s role centered around salmon. Thailand, the third-largest exporter, mostly traded tuna/skipjack/Atlantic bonito (*Sarda sarda*), shrimps/prawns, and cuttlefish/squid (Table 1). The top importer, USA, mostly received shrimps/prawns, and “30429 Fish fillets & other fish meat” as did second-largest importer Japan. Third-largest importer Spain has a similar commodities’ profile – with octopus appearing as a relatively more important seafood import.

3.3.2. Furniture

Top exporters of furniture were USA, Malaysia and Germany, and top importers were China, Italy and India (Fig. 4). Top commodities imported by China and India fall under vague, all-encompassing HS Code descriptions such as “440349 Other tropical wood” or “440391 Logs, tropical wood not elsewhere specified (n.e.s.)”. The most commonly used species-specific wood codes were for oak, red meranti (a Southeast Asian hardwood) and beech (Table 1). Italy imports mostly “440729/24-6 Wood”, as well as oak and beech. USA, Malaysia and Germany all mostly export “wood” and “tropical wood” (as above), with mahogany and maple being important exports for USA, and oak for Malaysia and Germany.

Table 1
The top five traded commodities in each wildlife trade category.

CATEGORY	COMMODITY	%[a]	US$[c] (97–16)
SEAFOOD	Fish[b]	23%	843 bn
	Shrimps/prawns[b]	16%	572 bn
	Salmon[b]	11%	400 bn
	Tuna, skipjack and bonito[b]	7%	266 bn
	Cuttlefish and squid[b]	3%	111 bn
FURNITURE	Oak[b]	27%	81 bn
	Tropical wood[b]	24%	70 bn
	Beech[b]	15%	45 bn
	Wood[b]	10%	31 bn
	Meranti (red)[b]	5%	16 bn
FASHION	Mink fur[b]	60%	159 bn
	Other furs[b]	26%	69 bn
	Reptile leather/skins/hides[b]	5%	14 bn
	Other leather[b]	4.4%	12 bn
	Fox fur	3.9%	11 bn
TRADITIONAL CHINESE MEDICINE	Plants[b]	74%	72 bn
	Ginseng	16%	16 bn
	Ambergris, castoreum, civet and musk, cantharides, bile, glands/other	7%	7 bn
	Whalebone, tortoise-shell, horns, antlers etc.	1.5%	1.5 bn
	Liquorice roots	0.5%	559 mn
ORNAMENTS & JEWELRY	Corals, shells of mollusks/crustaceans etc.	36.5%	4 bn
	Natural pearls[b]	26%	3 bn
	Ivory[b]	14%	1.5 bn
	Bone, tortoise-shell, horn, antlers, etc.	16%	1 bn
	Other animal carving material	7%	754 mn
WILD MEAT	Meat and edible offal, other[b]	97%	36 bn
	Frog's legs	2%	715 mn
	Meat and edible offal, cetaceans, manatees/dugongs, seals/sealions/walruses[b]	0.7%	247 mn
	Meat and edible offal, reptiles, including snakes and turtles[b]	0.2%	73 mn
	Meat and edible offal, camels[b]	0.09%	33 mn
PETS	Ornamental fish[b]	79%	17 bn
	Reptiles, including snakes and turtles	9%	1.9 bn
	Other birds	7%	1.7 bn
	Parrots	3%	777 mn
	Birds of prey	1%	333 mn
EXHIBTION	Mammals	59%	8 bn
	Primates	22%	3 bn
	Camels	16%	2 bn
	Cetaceans, manatees/dugongs, seals/sealions/walruses	2%	317 mn
	Birds – ostriches and emus	0.05%	7 mn

[a] All percentages in all tables rounded to nearest numeral.
[b] Various forms/codes merged.
[c] billion (bn) and million (mn).

3.3.3. *Fashion*

Hong Kong was the number one importer and exporter of fashion, accounting for 20% of total imports and 30% of exports, mostly in mink and various "Other furskin" codes. China and Italy were the second-and-third largest importers of wildlife for fashion, while exports show Denmark and China being second and third (Fig. 4). Major commodities include raw mink, fox, and "Other furskins" coming out of Denmark, whilst China imports raw furskins and exports tanned/dressed furskins. Italy imports a higher proportion of reptile skins than other countries.

3.3.4. *Other categories*

China was the biggest exporter of wildlife products for use in TCM, followed by Hong Kong and USA – while imports were dominated by Hong Kong, USA and Japan (Fig. 4). The top commodity exported by China, Hong Kong and USA was "Plants and parts, including seeds and fruits used in pharmaceutical items, perfumes, insecticides, fungicides" (hereafter "Plants"), followed by ginseng – which has a dedicated commodity code. It should be noted that this "Plants" code also includes plant uses other than medicinal, such as for perfumes or insecticides, but it is not possible to separate these into different uses since they are currently combined under one HS Code. This commodity code is excluded from the separate analysis of specific codes, results for which can be seen in section 3.2.

Japan was the top exporter of wildlife products for use in ornaments and jewelry, followed by India and USA. Japan was also one of the top importers in this category, after USA and "Other Asia, not elsewhere specified" (Fig. 4). Animal carving products (other than ivory) such as corals, mollusk shells, cuttlebone, antlers, tortoise-shell, and bone (see Table 1) was the

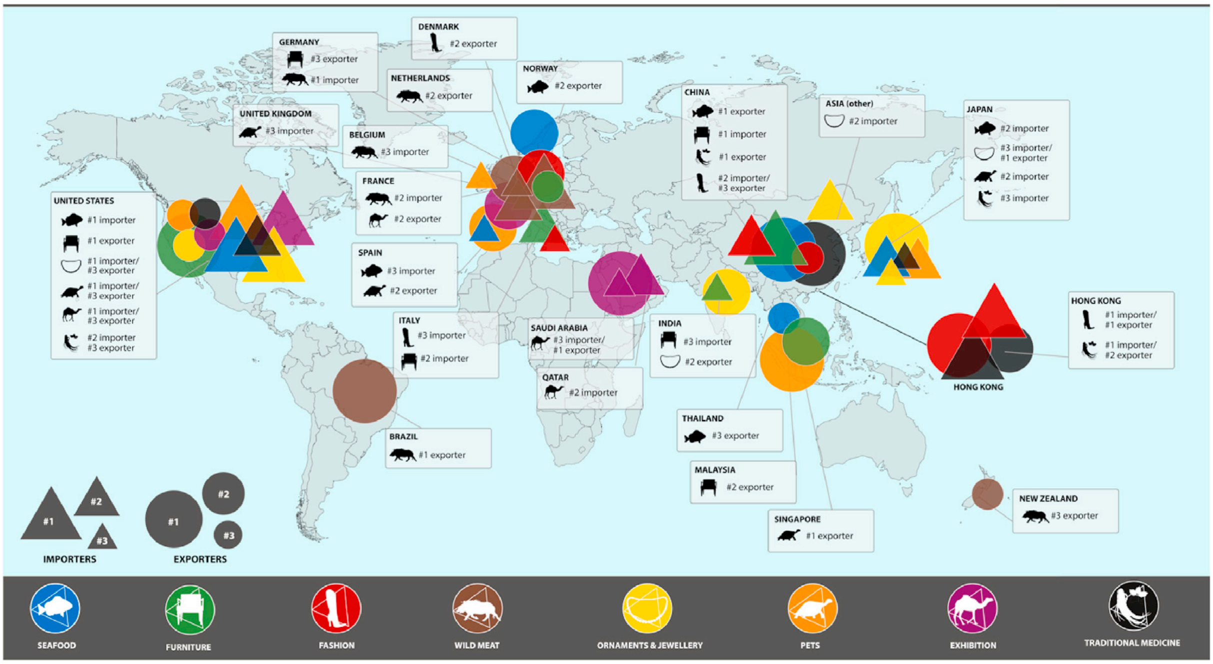

Fig. 4. Top three import and export countries/territories for each wildlife trade category from 1997 to 2016 by total US$ trade value. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

top export and import item for Japan, and the top import item for USA and "Other Asia, n.e.s.". India and USA exported mostly pearls.

In the wild meat category, Brazil, The Netherlands and New Zealand were the top three exporters, with Germany, France and Belgium responsible for most imports (Fig. 4). For all the top traders, various descriptions of the commodity "Meat and edible offal, other" was the most commonly traded form of wild meat (Table 1). Germany, France, and Belgium imported frogs' legs, but otherwise only trade wild meat under vague codes, such as "20890 Other wild meat and edible offal, n.e.s.". Brazil's second-biggest export was frogs' legs, followed by meat and edible offal of primates. The Netherlands and New Zealand had a more diverse commodity profile, exporting meat and edible offal of cetaceans, reptiles, primates as well as frogs' legs.

The value of global pet trade maintained a constant, modest incline throughout the period (Fig. 2). Top exporters were Singapore, Spain, and USA while top importers were USA, Japan and United Kingdom (Fig. 4). Ornamental fish was the top commodity traded by all major traders in this category (Table 1). After that, parrots were important for Singapore, birds of prey had a relatively high position on Spain's commodities list, and reptiles were the second-most exported item from USA. After ornamental fish, all three top importers mostly received reptiles, "10639 Other live birds, n.e.s.", and parrots.

Commodity codes specific to exhibition wildlife were only established in 2002. Since then, Saudi Arabia was the top exporter of exhibition wildlife, followed by France and USA. Top importers were USA, Qatar, Saudi Arabia (Fig. 4). For Middle Eastern traders in this category, trade in camels is central. Within the commodity codes for exhibition purposes, USA mainly imported primates, while its top exported commodities were "Mammals, other", primates, and "Cetaceans/manatees and dugongs/seals and walruses".

3.4. Source countries and transit hubs (raw vs processed wildlife products)

We used three subsets of the original dataset to identify major processing/transit hubs and source countries (see methods section 2.2). First, we separated our dataset into "raw" and "processed" wildlife (Table A2). This showed that 37% ($1.6 trillion) of overall wildlife trade was in raw, primary products and 63% ($2.8 trillion) in processed wildlife items. The top five exporters of raw products were Norway, China, USA, Denmark, Canada. The top five exporters of processed products, meanwhile, were China, Thailand, USA, Vietnam, and Canada.

The UN Comtrade re-exports data subset, meanwhile, totaled $58 billion for the two decades examined, which is 2.7% of overall exports declared by all parties ($2.1 trillion). This is likely reflective of low re-export reporting rates, since only 86 countries/territories reported re-exports voluntarily during the period, compared to a total of 202 (average 162) that reported the mandatory exports and imports (Fig. A1). Nevertheless, the five countries that reported highest percentages of re-exports compared to their declared exports include Hong Kong (94%), Jordan (78%), United Arab Emirates (65%), Macau (60%) and Montserrat (46%).

4. Discussion

This analysis of 20 years of international legal wildlife trade data highlights that legal wildlife trade is a lucrative global economic trade – approximately double the international trade in tea, coffee and spices (UN Comtrade 2016). Legal wildlife trade, as defined in this paper, averaged $220 billion per annum 1997–2016. This eclipses – by an order of magnitude – annual trade in illegally traded wildlife, estimated to be worth between $7 billion and $23 billion each year (Nellemann et al., 2016). Our analysis also identified top wildlife traders (USA, China, Japan) and major wildlife traders with a relatively low GDP (Thailand, Hong Kong, Norway) – indicating their potential role as transit/processing hubs. This is verified by the findings of additional analyses, which identify Hong Kong as a major re-exporter, and Thailand as an exporter of processed goods. Finally, our analyses show that much legal wildlife trade is conducted under vague, all-encompassing codes with broad descriptions, some of which are used particularly frequently (26% of seafood trade declared as "Fish", 22% of furniture trade decalred as "Tropical wood", and 26% of fashion traded as "Other furs"). Trade under certain wildlife trade categories is conducted almost entirely with broad codes that only specify taxonomic Class or above – such as TCM (83%) and pets (95%), which inhibits monitoring and our ability to maximize the benefits of wildlife from sustainable resource use and ecosystem services.

4.1. Global patterns of legal wildlife trade

The top three legal wildlife trading countries overall (USA, China, Japan) are also the world's top three economies in terms of GDP (Fig. 3), reflecting the correlation between trade of CITES-listed species and GDP (Symes et al., 2018). This relationship is echoed in Olsen et al. (2019) which found that country area and species diversity (factors that can influence economic mass) correlate to volumes of legal/illegal wildlife trade flows into the USA. The top wildlife traders in our study (USA, China, Japan), are also typically countries deemed to be "net importers of biodiversity" (Lenzen et al., 2012), where a high proportion of a country's biodiversity footprint is caused by commodity imports (Kastner et al., 2011). This is aligned with findings by Scheffers et al. (2019), which indicate that most CITES-listed wildlife is exported from pan-tropical biodiversity hotspots, including South America, Indonesia, Malaysia – showing that legal trade (whether species are CITES-listed or not) mainly flows from the tropics to more economically developed, sub-tropical or temperate countries (e.g. USA, China, Japan), in both volume and value.

However, of the top 10 legal wildlife trade countries in our analysis, three were not in the 2015 UN top 20 countries/territories in GDP – Thailand, Hong Kong, and Norway (Fig. 3). This indicates that wildlife trade makes up a relatively large portion of overall economic activity for these three countries/territories relative to the proportion in the other major wildlife traders' economies. Hong Kong was a major re-exporter in two wildlife trade categories: fashion and TCM – indicated by its status as both a major importer and exporter simultaneously, in addition to 94% of its exports also being declared as re-exports. The pivotal role of this small territory to wildlife trade is apparent when the seafood category is removed from our legal wildlife trade value calculations, which leaves Hong Kong as the top wildlife trader globally, eclipsing China and USA, which both have much higher GDP in comparison (Fig. 3). Similarly, Thailand and Vietnam are important processing hubs – indicated by their status as top 20 wildlife traders with comparatively low GDP and validated by the fact that both are top five exporters in the analysis of "processed wildlife" (section 3.4).

4.2. Targeted enforcement action

Asia, and Hong Kong specifically, has been identified in other studies as particularly influential for volumes of CITES-listed and seized wildlife into USA – specifically for ornaments (ivory exported from Hong Kong, corals from Indonesia), furniture (wood from Indonesia and China), and pets (live birds from Hong Kong and Indonesia) (Olsen et al., 2019). This highlights the proportionately high impact that enhanced trade monitoring by Hong Kong authorities would have on wildlife trade generally, as well as other wildlife trade processing/transit hubs, such as Thailand and Vietnam. Targeting these locations for strategic resource allocation (financial, personnel, training, equipment) dedicated to customs inspections of wildlife imports could have a maximum impact relative to investment.

During inspections, customs officials would benefit from clear documentation of exactly how much material of what type is being imported, as this would improve their ability to detect irregularities (Gerson et al., 2008). Though CITES appendix listings track trade in around 35,800 species, our analysis shows that there are many thousands more species traded for which there is little-to-no traceability. CITES does not, for example, cover many of the songbirds, fish, trees or plants traded. Often, these species are traded as pets, furniture or TCM – the very wildlife trade categories our analysis identified as having particularly frequent use of broad codes; TCM (83%), pets (95%), and 22% of furniture trade declared as "Tropical wood", 26% of seafood trade declared as "Fish".

4.3. Case study: pets

Various reptiles, birds and fish are traded at high volumes and diversities across major markets, often without the accompanying licenses (Andrews 1990; Cheung and Dudgeon 2006; Nijman et al., 2017; Sung and Fong 2018), but this information is lost in such general codes. In the pets category, 5% of trade was in parrots and birds of prey, declared under their specific codes. The remaining 95% of trade was declared as "Live ornamental fish", "Other live birds" and "Live reptiles".

According to the International Ornithological Congress, there are 10,787 extant species of birds (IOC World Bird List v10. 2, 2020). As such, the "10639 Other live birds" code subsumes around 9800 species of birds (excluding 398 parrots, 333 raptors, 243 owls covered by the specific parrot/bird of prey HS Codes). Meanwhile, 617 "other" bird species are listed on CITES Appendices – excluding parrot, raptors and owls (CITES 2020), which leaves over 9000 bird species traded without CITES documentation and under the "10639 Other live birds" HS Code – with no traceability and monitoring.

Similarly, the "Live reptile" code must subsume all 3500 snake, 6000 lizard, 320 turtle/tortoise and 27 crocodilian species – none of which have a dedicated HS Code. CITES covers a total of 897 reptile species, leaving many species traded without detailed records. The situation for ornamental fish is even worse, with CITES only including 162 species of fish – which leaves thousands of fish also traded untraceably under the "Live ornamental fish" code, the most commonly used code in the pets category.

4.4. Recommendations

Though imperfect, the HS Code system is the most comprehensive extant global system for information on traded species. The analysis presented here provides useful insights into areas of refinement in HS Codes that would improve our ability to analyze, monitor and trace traded wildlife – since it is easier to modify an existing framework than it is to establish an entirely new system (Chan et al., 2015). However, revising HS Codes alone will not be sufficient and resources must also be directed towards supporting enforcement and capacity building, particularly for customs authorities which would require more funding, personnel, and training in species identification.

The current prevalence of broad HS Code descriptions provides a low-resolution trade landscape characterized by vague parameters preventing effective monitoring of trade. This impedes enforcement and results in undetected mislabeling of protected species by a number of means, including covert farming and trading in protected species, fraudulent declaration of wild-caught individuals within a farm-sourced shipment, and underreporting trade volumes (Haitao et al., 2008; Wu and Sadovy de Mitcheson 2016; Andersson and Gibson 2017; Janssen and Chng 2018). These issues would become more detectable if HS Codes relating to wildlife were broken down to genus or species level. CITES appendix listings are often applied retroactively, once a species is already over-exploited (Frank and Wilcove 2019). By including better documentation for unprotected, commonly traded species we improve our ability to preemptively identify over-exploitation of wildlife.

Customs inspection would also be simplified by distilling certain HS Codes, since suspicious shipments or mislabeled species could be more readily identified. Though the volume of data would increase, selective algorithms and strategic screening methods could be implemented to counteract this. Our analysis shows that priority areas for genus-level HS Codes would be ornamental fish, reptiles and "other birds" traded as pets, as this often involves rare species (many of which may not be covered by CITES) and should be a priority area for customs inspection. For the same reason there should be thorough examination of the more specific, domestic HS Codes (up to 13 digits) allocated by individual countries to certain products (these are not applicable throughout the global HS Codes). This could improve our understanding of what wildlife is traded under broad codes, so that more granular codes can be established therein. Additionally, the UN World Customs Organization (WCO) should establish purpose-specific genus-level codes for plants and animals traded as medicine, since TCM trade is also dominated by broad and processed commodity codes, including multiple taxa (tortoise shell, whalebone, antlers, beaks) and TCM plants which are currently indistinguishable from those traded as perfumery or insecticides. WCO should also continue to distill "fish" codes in seafood and "tropical wood" codes in furniture as both remain two of the most commonly used broad categories, contain many species not covered by CITES, and sustainable management of these resources is particularly important in terms of community livelihoods and ecosystem services. For the aforementioned items we should be moving towards full traceability (Gerson et al., 2008) and robust certification for all wild products – to which end more specific HS Codes would be an important step.

HS Codes are revised every five years (Kumakura, 2009). Chan et al. (2015) specifically indicate how taxonomic serial numbers and HS Codes could be applied internationally to increase traceability, and our study further demonstrates that this type of code refinement is indeed required across many of the wildlife trade categories. The last round of updates came into effect in 2017 and saw a distillation of codes relating to many trade sectors, of which trees and seafood were the only wildlife (WCO 2017). Seafood saw subdivision of codes for crustaceans, mollusks and other invertebrates, and for trees there was a creation of new subheadings separating tropical from non-tropical wood, as well as specific codes for bamboo and rattan.

A precise understanding of what wildlife is being traded is important from a regulatory point of view, for accountability, and to mitigate overexploitation in species. Achieving this level of diligence will require concerted resources to train stakeholders involved and facilitate international cooperation to ensure that species, source, and volume declarations are conducted with precision. Implementing these high regulatory standards should be afforded priority, given the role of overexploitation and wildlife trade in global biodiversity decline (Brondizio et al., 2019). The WCO has a particularly important role in bringing about improved standards for this and must work with countries to improve their capacity to maintain more detailed trade declaration systems.

Scientists should also contribute by communicating with authorities such as the WCO their findings on what species are at risk of laundering, over-exploitation, or accidental mis-declaration, as well as developing forensic tools to help customs identify these species and their provenance (Butchart et al., 2013; Hatten et al., 2020). In addition, interdisciplinary research on legal wildlife trade in collaboration with economists, sociologists, and policy makers would serve to increase our understanding of the various dimensions of trade, and facilitate successful regulation (Wilcove 1998; McNeely et al., 2009;

Ogden et al., 2009; Howes and Kemp, 2017). Finally, conservation biologists can make important inputs to indicate which species in what areas and under which particular conditions might be suitable for sustainable use (MacMillan et al., 2015) to help maximize benefits for both wildlife and people.

Unfortunately, the lack of HS Code granularity currently inhibits the detailed level of management and traceability required to scale responsible farming initiatives that enable sustainable use and incentivize conservation (Slone et al., 1997; New 1994). Though HS Codes are for statistics keeping and tax purposes, we have an opportunity within this framework to also conserve wildlife and support people. Species-specific, universally applied HS Codes with scientific names and the resulting increased capacity for community-led sustainable trade in wildlife products would also de-incentivize legal and illegal market interactions – such as quota violations and underreporting – and ultimately benefit global biodiversity conservation action ('t Sas-Rolfes et al., 2019).

5. Conclusion

Our study characterizes overall trends in legal wildlife trade for a two-decade period. More analysis is needed of this and other wildlife trade dimensions (Fig. 1), but our research constitutes a first step in uncovering the issues that are inherent in the current system and detailing how it can be improved to protect biodiversity, sustainable resource use, and ecosystem services. We identify countries/territories where targeted enforcement could be particularly impactful, and priority wildlife trade areas for additional code allocation.

Governments have placed increasing attention on tackling illegal wildlife trade in recent years. However, as this paper demonstrates, the legal trade in wildlife (non-CITES and CITES-listed) has considerable economic value, and there is a vested interest in effectively managing this, both for species protection and to sustain the economic value of trade that many countries and people rely on. Efforts to avoid unsustainable legal trade are essential for managing biodiversity, and should include processes and mechanisms ensuring regulatory compliance.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We would like to thank Yannick Kuehl, Yvonne Sadovy de Mitcheson, David Baker and members of the Conservation Forensics Lab at HKU for helpful discussions that planted the seed for this work. We thank Roland Melisch and James Compton for their insights and feedback which helped us to improve this manuscript. W Lau was supported by the U.S. Agency for International Development (USAID) Wildlife Trafficking, Response, Assessment and Priority Setting (Wildlife TRAPS) Project. The contents are the responsibility of the authors and do not necessarily reflect the opinion of USAID or the U.S. Government.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.gecco.2021.e01455.

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