Of cowboys, fish, and pangolins: US trade in exotic leather

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Abstract
Illegal wildlife trade is a lucrative business, which is driving many species towards extinction. Pangolins (Manis spp.) and arapaimas (Arapaima spp.) are two CITES listed genera coveted in the leather fashion industry for their unique skin pattern. The US has contributed to the decline of pangolin species and was historically a large market for pangolin leather products. While the US trade in pangolin products has declined since 2000, we suspect that pangolin leather may now be substituted by arapaima products. Arapaima leather trade has increased significantly since the year 2011. We found a strong positive correlation between the US states trading in both arapaima and pangolin leather products. The US states that were most involved in this trade had a lower population density and were comparatively wealthier than others. Leather items of both arapaima and pangolin were found for sale on eBay, with 75% of incidents in breach of eBay policy, and potentially illegal. Pangolin leather products were also falsely advertised as arapaima products. We conclude that arapaima leather is increasingly used to satisfy the persisting demand for exotic leather, and further research is urgently needed to determine the effect of the trade on wild arapaima populations.

KEYWORDS
arapaima, CITES, endangered species, LEMIS, Manis, overexploitation, species substitution, sustainability, wildlife trade

1 | INTRODUCTION

The global wildlife trade is a lucrative business (Broad, Mullicken, & Roe, 2002; UNODC, 2016), and sometimes species are exploited so heavily that they become threatened or extinct (Courchamp et al., 2006). However, less availability does not necessarily reduce the demand for wildlife, and reduced availability can even stimulate trade and increase consumer demand (Courchamp et al., 2006; Rivalan et al., 2007). When a taxa declines, or becomes unavailable through either overexploitation or increased enforcement, wildlife products can be substituted. This includes substitution from other populations (including captive-breeding) (Broad & Burgess, 2016; Rowcliffe, Milner-Gulland, & Cowlishaw, 2005), or by a different species with similar utility (Broad & Burgess, 2016; Tensen, 2016; Williams, Loveridge, Newton, & Macdonald, 2017). Here, we investigate the potential substitution of leather products of a threatened group of mammals, by an entirely different taxonomic group. We describe the declining pangolin leather trade in the US, and its potential replacement by the skins of an underappreciated freshwater fish: the arapaima.

Pangolins are among the world’s most heavily trafficked wild mammals (Challender, Waterman, & Baillie, 2014). All eight pangolin species are listed as threatened on the IUCN Redlist of Threatened Species (IUCN, 2017), and since 2017
they have been listed in Appendix I of CITES; the Convention on International Trade in Endangered Species of Wild Flora and Fauna (UNEP-WCMC, 2014). Demand for pangolins exists mostly for their meat and scales; and especially for use in traditional medicines (Challender et al., 2014; Nijman, Zhang, & Shepherd, 2016; Pantel & Chin, 2009). However, the consumption of pangolin leather, particularly in the US and prior to 2000, is estimated to have contributed significantly to the historical decline of pangolins (Heinrich et al., 2016). This trade consisted mostly of the importation of skins for use in the leather industry; to manufacture exotic cowboy boots, wallets and belts (CITES, 1992, 1999). Today, illegal pangolin trade still occurs in the US, although in much smaller volumes compared to both the legal trade before 2000, and the continuing trafficking conducted in Asia and Africa (Heinrich et al., 2017).

Pangolins are covered in keratinous scales, giving their underlying skin a very particular look, which is much coveted in the leather industry (Figure 1). Their skin pattern is unique in the mammalian world, however, it closely resembles the skin pattern that certain fish species with large scales exhibit, such as arapaimas (Class: Actinopterygii, Order: Osteoglossiformes, Family: Arapaimidae, Genus: Arapaima). Arapaimas are one of the world’s largest freshwater fish, and they are endemic to the Amazon Basin (FAO, 2012). They have been listed in CITES Appendix II since 1975 (UNEP-WCMC, 2014), and are currently recorded as data deficient on the IUCN Redlist of Threatened Species (World Conservation Monitoring Centre, 1996). Their global population status is largely unknown, however, due to exploitation, illegal fisheries, and trade, it is suspected they are decreasing in the wild, and local extinctions have been recorded (Castello, Arantes, Megrath, Stewart, & Sousa, 2015; Castello & Stewart, 2010). Arapaima biomass is predicted to be significantly reduced in the future should current fishing rates continue (Capitani, 2017), and there are efforts underway to strengthen aquaculture in arapaimas (FAO, 2012). Arapaimas are commonly traded in South-east Asia (Nijman, 2010), and recently Sinovas, Price, King, Hinsley, and Pavitt (2017) reported on a relatively new trend in arapaima skins and leather products, being exported predominantly to the US and Italy.

The US is one of the largest markets for leather products of both pangolins (Heinrich et al., 2016) and arapaimas (Sinovas et al., 2017). Yet this is likely to be a niche market, and the trade dynamics remain unquantified in the scientific literature. Here, we address this important information gap. First, we analyzed the historic international trade of leather products entering the US from 1999 to 2015, using Law Enforcement Management Information System (LEMIS) data from the US Fish and Wildlife Service (USFWS). We compared the source of the animals in the trade and tested whether arapaima leather trade increased, once the trade in pangolin leather declined. We then analyzed contemporary trade in pangolin and arapaima leather products, from 2017 and 2018, which were offered for sale on the US eBay website. Specifically, we compared the characteristics of the eBay advertisements, and leather products for sale, and focussed on the spatial characteristics within the US, to determine from which states demand for arapaima products originated. We were particularly interested to assess whether the states in which trade

![Figure 1](image-url)
in pangolin leather products persists, were the same as those where arapaima products are being traded.

2 | METHODS

2.1 | Data

We collected data on pangolin and arapaima leather trade from the US eBay website (www.ebay.com; 2017–2018) and USFWS LEMIS data (1999–2015). We chose to use LEMIS data rather than CITES data, so that we could compare the eBay and LEMIS data on a state level basis, and in order to reliably estimate the number of incidents; these are summed in CITES as opposed to being presented on a shipment-by-shipment basis in the LEMIS data (CITES, 2013). We also checked the number of incidents in the CITES data, and found there were less compared to the number of incidents in the LEMIS data. LEMIS data predominantly reflected international trade whereas the eBay data provided a more detailed picture of the domestic trade. For further information on the interpretation and use of LEMIS data see Rhyne et al. (2012) and Romagosa (2014).

The USFWS LEMIS data includes both legal and illegal trade incidents for any wildlife shipment entering or exiting the US. We collated LEMIS data for all pangolin and arapaima incidents for the years 1999–2015 (with the exception of the year 2014; which was not made available). The data were subsequently filtered to include leather products only. The commodities of both arapaimas and pangolins were consolidated into the categories presented in Table 1.

| TABLE 1 | Traded commodities of arapaimas and pangolins in the US and their corresponding consolidated commodity categories |
|----------------|-----------------------------------------------------------|
| **Consolidated category** | **Original commodities** |
| **Pangolin spp.** | **Leather** | Skins, skin pieces, large and small leather products, trims, garments, shoes |
| **Medicinals** | **Medicinals (not further specified)** |
| **Other** | **Bone pieces, scales, specimens (not further specified), live and dead animals, feet, meat, skulls, skeletons, tails, claws, trophies, other unspecified items** |
| **Arapaima spp.** | **Leather** | Skins, skin pieces, large and small leather products, trims, garments, shoes |
| **Live** | **Live** |
| **Other** | **Meat, scales, not further specified jewellery (not further specified), other unspecified items (not further specified)** |

Pangolin and arapaima listings were accessed from the “Clothing and Accessories” section of the US eBay website for 9 months from the beginning of September 2017 to the end of May 2018. Products for sale that matched any of the chosen keywords, and additionally displayed the characteristic diamond-shaped pattern of pangolin and arapaima skin (Figure 1), were entered into a bespoke SQL database (Microsoft Access, Version 2016). We scanned the website five times a week and entered the data into the database immediately. The following keywords were chosen based on preliminary observations and searches of the eBay website: “Piranucu;” “Arapaima;” “Pangolin;” “Anteater;” and “Exotic.”

We collected ancillary information on all of the products and sales, which included: (i) location of the seller (US State); (ii) the type of commodity (boots, belts, wallets, or handbags); (iii) quantity and price of the product; as well as, (iv) the condition (new or used); (v) region of manufacture (if known); and, (vi) whether or not the product was available for international shipping. We were interested in where demand within the US originated, so only advertisements from sellers within the US were retained; all advertisements from international sellers were disregarded. Sellers were classified as “commercial” if they had an eBay store, otherwise they were classified as “private”. We collated data for genuine, as well as imitation (“print leather”) pangolin and arapaima leather products, and noted whether the product for sale had been advertised as being either imitation or genuine, and being either pangolin, arapaima, or unclassified (i.e., not advertised as either arapaima nor pangolin). Finally, the products for sale were classified as being either genuine or imitation, pangolin or arapaima products, regardless of what was advertised by the seller; this classification was based on our own expert visual assessment of the pictures provided in the advertisements (Figure 1).

For both datasets, we converted all pangolin and arapaima leather products into whole estimated animals. In all cases, the minimum and maximum number of whole estimated animals were calculated, and the arithmetic average (rounded up to a whole animal) was used in subsequent analysis as a measure of volume. For both taxa, we assumed that a minimum of one and a maximum of two animals were needed for a shoe, boot, garment and large leather product. For smaller leather products, and individual skins, we assumed that only one animal per product was needed. For skin pieces and trims, we assumed that a minimum of one and a maximum of the reported number of products was needed.

2.2 | Analysis

All analyses were conducted in the R software environment (version 3.4.3) for statistical and graphical computing.
We used contingency-type frequency tests to assess the independence of categorical variables, using the mosaic function of the “vcd” package (Meyer, Zeileis, & Hornik, 2017). The homogeneity of the frequencies was evaluated with Wald χ² tests for independence. To rule out that the trade in arapaima leather was increasing simply due to an overall increase in leather products traded in the US, we tested for a change in the log₁₀ frequency of incidents of all non-arapaima leather products traded in the US from 2010 to 2015 (generalized linear model), and compared this with the trade in arapaima leather.

To evaluate the change in the proportion of animal sources and commodities through time we used multinomial logit regression models from the “nnet” package (Venables & Ripley, 2002). Bootstrapped predictions through time were calculated for each category and used to calculate 95% Confidence Intervals (CI) for the predictions. The “trade activity” was calculated by multiplying the volumes and frequency of incidents per state. The involvement of US states based on the trade activity was mapped using the “usmap” package (Di Lorenzo, 2018). To test for a correlation of the trade activity in the different datasets on a state level basis, Pearson’s correlations were used, including zeros for states where no trade had occurred.

We tested the effect of different predictors (outlined below) on the involvement of US states (excluding Puerto Rico) in domestic arapaima leather trade (i.e., the US eBay data; note that the LEMIS data only had incidents in seven states). We used the volumes as well as the frequency of incidents of arapaima leather products from the eBay data as response variables. As the data was highly over-dispersed we used negative binomial generalized linear regression models. Because of the apparent fashion for cowboy boots, we predicted that arapaima trade would predominately occur in states with comparatively low population densities and a higher percentage of rural population. Both pangolin and arapaima boots can fetch high prices in the US (e.g., the maximum price for a pangolin product found on eBay was almost US$13,000, while the maximum price for an arapaima product was almost US$2,000) and we predicted that the states most involved in this trade would be comparatively wealthier than others.

State level data were downloaded from the US government census webpage (www.census.gov), using data from the last centennial census of 2010. The only exception was the GDP per state, for which data for the year 2017 were retrieved from the Bureau of Economic Analysis (BEA) (www.bea.gov) of the US Department of Commerce. We tested if the predictors were correlated and included the following (non-correlated) predictors: Population Density (defined as number of people per square mile and using the log₁₀ transformed value); Rural population (the proportion of people living in a rural environment, including everyone who was classified as not living in an urban or urbanized area); and GDP (the Gross Domestic Product in millions of current US Dollars for the year 2017, using the log₁₀ transformed value). We also hypothesized that states that were trading in pangolin products were more likely to be involved in arapaima trade, due to the similar visual qualities of the skin in both genera. We therefore initially included pangolin data as a binary predictor variable (i.e., whether or not we had found pangolin leather products being traded within a given state). However, since the trade activity per state was highly correlated with the trade activity of arapaima per state (Pearson’s correlation r = 0.94), this was uninformative and ultimately discarded from the final model.

3 | RESULTS

3.1 | International trade from 1999 to 2015

The LEMIS data included a total of 163 pangolin leather trade incidents, involving an estimated 21,411 pangolins from 1999 to 2015. The US trade in pangolin leather has decreased over time, with an abrupt decline after the year 2000 (Figure 2a,b); while the trade in medicinals constituted the biggest proportion of trade incidents since c. 2007 (Figure S2a in Data S1).

There were 130 arapaima leather trade incidents reported, involving an estimated 5,524 arapaimas from 1999 to 2015. Trade in arapaima leather only commenced in 2011 and has since increased significantly (Poisson regression slope estimate = 0.89, standard error [SE] = 0.08, p < 2e-16, 95% CI = 0.75, 1.05; Figure 2a, Figure S1b in Data S1); despite the overall leather trade in the US (excluding trade in arapaima leather products) remaining effectively constant from 2010 to 2015 (Estimate = −0.024, SE = 0.021, p = .335, 95% CI = −0.06, 0.02; Figure S1a in Data S1).

Arapaima trade before the year 2011 was mostly comprised of live animals, but was quickly superseded by the number of leather trade incidents (Figure S2b in Data S1).

Most arapaima and pangolin leather originated from wild-caught animals (Figure 2c,d). For pangolins, the number of wild-caught animals declined after the year 2000, while increasingly the source was declared as “unknown”. The proportion of wild-caught animals increased again after 2007. The proportion of reportedly captive bred pangolins was negligible (i.e., <2%) (Figure 2c). Arapaimas predominantly originated from unknown sources until approximately 2012. Since then, the biggest proportion of traded arapaimas originated from wild-caught animals. The proportion of incidents involving captive bred arapaimas was also very small (i.e., <5%) (Figure 2d).

From 2001 to 2015 the leather products for pangolins originated from 15 different countries across 17 different international trade routes (Figure 3). US imports from non-
range countries (i.e., Mexico, Canada, and the United Arab Emirates) comprised 85% of the total trade activity for pangolins. Incidents originating in Africa comprised 14% and incidents originating in Asia comprised 1% of the total trade activity for pangolins. For arapaimas, all trade incidents originated in Brazil and the four different international trade routes involved five countries, namely Brazil, Mexico, Canada, Italy and the US (Figure 3).
3.2 | Current domestic e-commerce trade

We discovered 478 incidents on eBay from September 2017 to May 2018 with leather products that had been manufactured in at least seven different countries (Figure 4). Leather products that had been manufactured in Indonesia and China consisted exclusively of imitation leather (i.e., “print leather”), while leather products that had been manufactured in Canada, France and South Korea included only genuine pangolin products. Leather products manufactured in the US included genuine arapaima (26% of incidents) and genuine pangolin (74%). Leather products offered for sale, which had been manufactured in Mexico, included a mixture of genuine arapaima (41%), genuine pangolin (13%), and pangolin print leather (45%).
The mean starting price for pangolin products was US $544 (SE = US$84.58), with the maximum starting price being for a handbag, which was advertised for US$12,895. The mean starting price for arapaima products was US$390 (SE = US$20.23), with the maximum starting price being US$1,800 for a pair of boots. Pangolin leather products were more likely to be used items, whereas arapaima leather products were more likely to be new (n = 322, χ² = 193.98, degrees of freedom [df] = 1, p < .001; Figure S3 in Data S1). Arapaima products were also more likely to be offered in a “buy now” auction, whereas pangolin products were significantly more likely to be offered in a bidding auction (n = 469, χ² = 31.53, df = 3, p < .001; Figure S4 in Data S1). Furthermore, we found that genuine leather was significantly more likely to be offered in private auctions, whereas print leather was more likely to be offered for sale by commercial sellers (n = 473, χ² = 95.74, df = 3, p < .001; Figure S5 in Data S1). Some of the leather items for sale were mis-advertised (Figure S6 in Data S1). For example, genuine pangolin products were sometimes advertised as genuine arapaima (10%) or print leather (3%), and we found a number of pangolin products unclassified (28%). We also found print leather advertised as genuine pangolin (4%) or arapaima (5%). There were, however, no incidents where arapaima products were advertised as pangolin products, and arapaima products were also less likely to be unclassified (Figure S6 in Data S1).

Across the two datasets, we found a total of 18 US states where trade in arapaima leather had occurred, and 29 states in which pangolin leather trade had occurred (Figure 5). There was overlap in the states trading in both arapaima as well as pangolin leather, with 13 states trading in leather of both genera. Only 17 US states did not trade in any of the two types of leather (Figure 5). For the states involved in the eBay trade there was a very strong positive correlation for the trade activity of arapaima and pangolin leather products traded per state (Pearson’s correlation r = 0.94).

The states that were most involved in arapaima leather trade were characterized by a significantly higher GDP (Frequency: Estimate = 4.68, SE = 1.60, p = .003, 95% CI = 2.27, 8.13; Volumes: Estimate = 6.73, SE = 2.22, p = .002, 95% CI = 2.27, 12.96; Figure S7 in Data S1) and a lower population density (Frequency: Estimate = −2.65, SE = 1.06, p = .012, 95% CI = −5.49, −0.49; Volumes: Estimate = −5.22, SE = 1.45, p < .001, 95% CI = −9.81, −1.33; Figure S7 in Data S1).

4 | DISCUSSION

There are strong indications that arapaima may be substituting pangolin leather trade in the US. Arapaima leather trade has increased significantly since 2011, and the increase in arapaima trade occurred after the decline of pangolin leather products. We also found a very strong positive correlation (r = 0.94) between the US states in which both types of leather are being traded today. In addition, 10% of pangolin products were falsely advertised as arapaima products on eBay. These findings, combined with the fact that the two types of leather have such obvious similar physical patterns, are consistent with arapaimas acting as a substitute for pangolin leather products in the US. Substitution of wildlife products has been reported previously, and published examples include: tiger bone being replaced with lion bone (Williams et al., 2017; Williams, Newton, Loveridge, & Macdonald, 2015); captive-bred crocodile skins being substituted for wild-caught animals (MacGregor, 2006); or, more broadly, fish being substituted by bushmeat when the
fish supply is low (Rowcliffe et al., 2005). The last example demonstrates that it is important to consider whether supply or demand is driving the trade, in order to develop successful conservation strategies (see also McNamara et al., 2016).

When one species is substituted by another, there is always the risk that a currently more common species may become endangered in the future, due to the increased trade activity and exploitation. In the case of arapaimas, these species were already threatened before any increase in the trade of their skins (Castello & Stewart, 2010). Increased efforts are underway to farm arapaimas for commercial purposes, as they have great potential for aquaculture (FAO, 2012). They have the best growth rate among Amazonian fish species and are obligate air breathers, which makes them an ideal species for surviving in low-oxygen conditions (FAO, 2012). Additionally their meat is reported to be very nutritional and beneficial to human health (Cortegano et al., 2017).

Aquaculture may be an important tool to reduce the pressure on wild arapaima populations, which are threatened by illegal and unsustainable fisheries and trade, and habitat destruction (Castello et al., 2015; Castello & Stewart, 2010). However, loss of genetic diversity due to selective fisheries and translocation of specimens for aquaculture are also of concern, and existing aquaculture in Brazil may be unsustainable, as aquaculture enterprises are, for example, allowed to collect arapaimas from the wild to “support” captive populations (Castello et al., 2015; Castello & Stewart, 2010).

Of the incidents involving arapaima leather products reported to LEMIS, 89% were from wild-caught animals, and they all originated from Brazil. Arapaima management is determined by state-level legislation in Brazil (Castello et al., 2015; Sinovas et al., 2017) and exports of arapaimas are only allowed if they are either wild-caught from management areas, or captive bred (Sinovas et al., 2017). However, a study from Brazil revealed that almost 80% of arapaima landings were illegal (Cavole, Arantes, & Castello, 2015), which was observed to be the highest level of illegal fishing activity reported in the literature. In Brazil, arapaima leather yields higher prices per unit on international markets than arapaima meat, and the leather products are more likely to get exported (Sinovas et al., 2017). Concerns have been raised that Brazil’s national policies regarding freshwater fish management and insufficient monitoring may support the development of unsustainable aquaculture, and may be insufficient to effectively protect arapaimas (Castello et al., 2015; Castello & Stewart, 2010; Lima Junior et al., 2018). Yet, if sustainable aquaculture and management could be ensured, and arapaima skins were only obtained as by-products of the food industry, arapaima leather products may provide a substitution opportunity to reduce demand for “exotic” pangolin leather products in the US.

Most of the genuine pangolin leather products we found for sale on eBay were predominately advertised as used items (91%), and it is possible that these were legally obtained at the time of import. However, none of the traders indicated having any accompanying paperwork (i.e., CITES permits or proof of origin), which is required to re-sell legally acquired pangolin leather products domestically. The international sale and offer for sale of these products is prohibited. It is also against eBay policy to offer CITES Appendix I (pangolins) products for sale, or CITES Appendix II (arapaima) products for international sale and thus 75% of all genuine leather listings were against eBay policy, and potentially in breach of US and international regulations.

The substitution of one taxa by another provides a case-book example of the complexity and diversity of the highly dynamic trade in wildlife products. Pangolins and arapaima are both found in regions highly threatened by unsustainable biological harvesting (Di Minin et al., 2019), and whilst native protection remains of paramount concern, complementary conservation strategies are urgently required to prevent further risk of extirpation. For example, global pangolin conservation and awareness is increasing, however, arapaimas are also threatened, and have attracted much less attention. Consequently, research and conservation action is needed to reduce consumer demand in the US for exotic leather, and promote sustainable use of substitute products. Legislation and enforcement of online marketplaces is a continuing issue, which needs to be addressed for all illegal wildlife trade. Finally, improved monitoring of arapaima aquaculture, and populations in the wild is needed. For the latter both the intensity of pressure from harvesting, and the abundance and trends in the wild need to be monitored closely. This will hopefully also inform an urgently required update on the IUCN Redlist status of arapaimas, which was last assessed in 1996 (World Conservation Monitoring Centre, 1996).

Wildlife trade, and biological use, is a highly complex and often controversial topic. We found that pangolin leather products were still being traded in the US, although to a much lesser extent since the establishment of the zero export quota in 2000. More recently, there has been an increase in the trade of arapaima leather products, which are potentially being used as a substitute for pangolin leather. There are examples where the use of exotic skins can be sustainable and even beneficial for species conservation (see, e.g., MacGregor, 2006). In most cases, however, it is still difficult to trace the origins of exotic skins to determine if they originated from captive bred or wild animals, and from animals sustainably harvested or not (Ziegler, Giesen, Van Schingen, Rauhaus, & Ziegler, 2018). Wildlife laundering remains a core issue. In many countries corruption, and enforcement and monitoring issues, as well as inadequate
protection of exploited species, increase the difficulties to assess the sustainability of the exotic skin trade (Janssen & Chng, 2017; Lyons & Natusch, 2011; Nijman, Shepherd, & Sanders, 2012). Ultimately, generalizations about this trade (see, e.g., Natusch et al., 2019) are unhelpful, as the potential for sustainably trading exotic leather is highly species (and country) dependent. In the case of arapaimas, almost 90% of the arapaima leather originated from wild-caught specimens, and the effects of this trade on wild populations is unknown. If it could be ensured that arapaima leather products originated from a sustainable source, they may provide a viable substitute to meet the persisting demand for pangolin leather products in the US. However, since arapaimas are also threatened, more research is urgently needed to identify the level of threat while this trade is still in its relative infancy.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interests.

AUTHOR CONTRIBUTIONS

S.H. designed the study, collated, analyzed, and interpreted the data and wrote the manuscript. J.V.R. contributed to the development and design of the study, and editing of the manuscript. P.C. supervised the development of the manuscript, and assisted with the study design, analysis and editing.

DATA ACCESSIBILITY STATEMENT

The eBay data are available through the Figshare repository (doi: 10.25909/5cebb560378516).

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Additional supporting information may be found online in the Supporting Information section at the end of this article.

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