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Original research article

Where did all the pangolins go? International CITES trade in pangolin species

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ABSTRACT

The pangolin is greatly sought after for its various body parts, largely driven by demand from China. The mammal has been driven to the edge of extinction in Asia, with two Asian species listed as Critically Endangered in the International Union for Conservation of Nature Red List. With declining Asian pangolin populations, a shift in trade from Asian to African pangolin species has been suggested. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Trade Database provides a unique opportunity to investigate global trends in pangolin trade at the species level, across a broad temporal scale (1977–2014). We found that CITES trade in Asian pangolin species decreased through time, whilst trade in African species increased post 2000. The total number of incidents involving Asian species declined since 2000, yet they were still being traded in large volumes (more than 17,500 estimated whole Asian pangolins were traded from 2001 to 2014) despite a zero export quota for all wild sourced Asian species, traded for primarily commercial purposes. In 2014 all eight pangolin species were recorded in the CITES trade for the first time. An increasingly complex international network was identified through time, with the United States of America (US) being the dominant player in the global pangolin trade that was reported to CITES. The US was the most frequent trade country throughout the entire period and was the greatest importer of pangolins, and their products; measured both in volume as well as frequency. We hope that identifying these global trade network characteristics, and pangolin trade dynamics will help to inform pangolin conservation efforts, and guide enforcement and legislative changes in the future.

1. Introduction

Wildlife trade is a key threat to biodiversity conservation, with billions of specimens being traded globally every year (Broad et al., 2003; Smith et al., 2009; Rosen and Smith, 2010; Nijman and Shepherd, 2011). To ensure sustainability of wildlife trade, especially in threatened species, an international agreement between governments (currently 183 Parties) entered into force in 1975 (www.cites.org). The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) aims to ensure that international trade in specimens of wild animals and plants does not threaten their survival. Each country ('Party') is a voluntary member to the Convention, and all imports, exports and re-exports of

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CITES listed species are regulated, by each Parties designated Management Authority, through a licencing system (https://cites.org/eng/disc/text.php). Roughly 5600 animal- and 30,000 plant species are classified into one of three Appendices (I, II, and III) according to the level of threat that international trade poses upon them (CITES, 2013a).

The Management Authorities of each Party authorise trade by issuing permits for shipments. The issuance of permits is dependent on the status of the traded species, its CITES Appendix listing, and are sometimes subject to additional individual quotas. Parties are required to report their annual trade to the CITES Secretariat and the data is then centrally stored in the CITES trade database (accessible at http://trade.cites.org). Historically, the annual reports have only contained legally permitted transactions (but see the Discussion). However, Parties were additionally requested to report on illegal trade for some species, such as elephants (Resolution 10.10: CITES, 1997) and pangolins (Decisions 16.41/16.42: CITES, 2013b). From October 2017, all illegal trade detected by the Parties must also be included in the new illegal annual reporting system (see Notification 2016/007: CITES, 2016b).

Illegal wildlife trade (hereafter referred to as 'wildlife trafficking') is often reported in the media, and through research and non-Government organisations (e.g., www.healthmap.org; www.traffic.org), or via enforcement agencies and government reports (e.g., UNODC, 2016). Wildlife trafficking is of particular global concern, as it has become one of the largest and most profitable organised criminal activities, alongside trafficking in drugs, arms and people; and threatens the continued existence of an ever-growing list of species (Wyatt, 2013). The distinction between the regulated trade in wildlife (i.e., CITES permitted trade) and wildlife trafficking is often blurred (Wyatt, 2013). Whilst reports on wildlife seizures provide a unique opportunity to estimate trade flows (Shepherd et al., 2016), reported seizures may only represent a fraction of the actual trafficking amounts, and it is difficult to reliably estimate the volumes being traded, or the impact that trafficking is having on specific populations. Due to the illicit nature of wildlife trafficking, seizure records can be difficult to acquire and curate, particularly when information is sensitive and different enforcement agencies (i.e., countries) provide variable levels of reporting. The trade recorded in the CITES trade database (hereafter referred to as 'CITES trade') is the primary source of international wildlife trade data at the species level, which provides a consistent mechanism for estimating legal trade dynamics through time, and allows investigation of variability in trade around specific changes in international trade regulations. Whilst we acknowledge the inherent biases associated with the CITES trade data (see the Discussion), there is no comparable data available at this scale.

Pangolins (Order: *Pholidota*; Family: *Manidae)* have become "*the most heavily trafficked wild mammal in the world*" (Challender et al., 2014a). Eight species are extant — four in Asia and four in Africa. The pangolin is a medium sized, nocturnal, and elusive mammal that is covered in scales. Its various body parts, especially their scales, but also its foetuses, blood, bones and claws are believed to have healing properties in traditional medicines (Bräutigam et al., 1994; Katuwal et al., 2013; Boakye et al., 2014; Mohapatra et al., 2015; Soewu and Sodeinde, 2015). Their meat is considered a delicacy in restaurants, where its consumption is also a symbol of status (Soewu and Sodeinde, 2015; Shairp et al., 2016). All pangolin species are consumed as a local source of protein in their native range countries (Bräutigam et al., 1994; Sodeinde and Adedipe, 1994; Pietersen et al., 2014b; Mohapatra et al., 2015; Soewu and Sodeinde, 2015), although it has been suggested that this local use is in decline, due to increasing demand and high prices paid in China (Conniff, 2013). Prices for pangolin scales in China have increased tenfold in the last decade (Challender et al., 2015), and the demand from China is believed to be driving much of the global trade (Pantel and Chin, 2008; Challender, 2011; Harrison et al., 2015; Nijman et al., 2016).

Largely due to the ongoing trade, the once widespread mammal has been driven to the edge of extinction in Asia, and both the Sunda (*Manis javanica*) and the Chinese pangolin (*Manis pentadactyla*) are now listed as Critically Endangered in the International Union for Conservation of Nature (IUCN) Red List (Challender et al., 2014b,c). The remaining two Asian species, the Indian (*Manis crassicaudata*) and the Philippine pangolin (*Manis culionensis*) are listed as Endangered (Baillie et al., 2014; Lagrada et al., 2014), while the four African species — the White-bellied pangolin (*Manis tricuspis*), the Giant pangolin (*Manis gigantea*), Temmincks Ground pangolin (*Manis temminckii*) and the Black-bellied pangolin (*Manis tetradactyla*) are listed as Vulnerable (Pietersen et al., 2014a; Waterman et al., 2014a,b,c). Information on population status in the wild is largely unknown for all eight pangolin species, as they are notoriously difficult to monitor, however, all are believed to be in decline (Baillie et al., 2014; Challender et al., 2014b,c; Lagrada et al., 2014; Pietersen et al., 2014a; Waterman et al., 2014a,b,c). All pangolins are particularly vulnerable to habitat destruction, high poaching rates and overexploitation as they have a very slow reproduction rate, with female pangolins usually only bearing one offspring per year (Yang et al., 2007; Lim and Ng, 2008; Thapa, 2014; Van Thai et al., 2014; Hua et al., 2015).

Given that Asian pangolin populations are declining, and the supply is unable to meet the demand (especially in China and Vietnam), it has been suggested that there is a proportional market shift to the four African species, trafficked to supply the Asian market (Bräutigam et al., 1994; Challender, 2011; Challender and Hywood, 2012; Pietersen et al., 2014b). Prior to 2008 there were no known records of pangolins being trafficked from Africa to Asia (Challender and Hywood, 2012). Since then, increasing numbers of trafficked shipments coming from Africa have been intercepted on their way to Asia (Challender and Hywood, 2012; Gomez et al., 2016). Shipments of pangolin derivatives have been recorded as coming from Angola, Cameroon, Central African Republic, Republic of Congo, Côte d'Ivoire, Guinea, Kenya, Mozambique, Nigeria, Sierra Leone, Uganda, Zimbabwe and Zambia (Challender, 2016). Most recently, four tons of pangolin scales, worth more than 10 million US-Dollars, were seized in Hong Kong from a single shipment originating in Africa (Andersen, 2016). Apart from the decline in Asian pangolin populations (Wu et al., 2004; Baillie et al., 2014; Challender et al., 2014b,c), one major reason believed to be facilitating this shift from Asian to African species is the growing economic ties between the two continents (Challender and Hywood, 2012; Baker, 2014; Challender, 2016).

Since the Convention entered into force in 1975, pangolin species have been variously listed in all three CITES Appendices. Since 1995 all species have been listed in Appendix II, and a zero export quota for all wild-caught Asian species, traded for primarily commercial purposes was established in 2000 (CITES, 2000). This quota does not apply to African species, which are still allowed to be legally traded under the provisions of Appendix II species (see Article IV of the Convention). More recently, pangolin listings are under further pressure to change. At the Seventeenth Conference of Parties (Johannesburg, South Africa: September 24th until October 5th 2016), 19 countries have submitted proposals for the up-listing of all eight pangolin species from Appendix II to Appendix I (Proposals 8, 9, 10, 11 and 12: CITES, 2016a).[1]

To our knowledge, no studies have investigated the global pangolin trade network reported to CITES for all eight pangolin species, nor investigated the relative proportions of African to Asian species involved in CITES reported trade in relation to these trade networks, especially following the zero export quota in 2000. To address this, we have analysed global pangolin trade as reported by CITES Parties. We have quantitatively compared the temporal dynamics of this international trade, among all Asian and African pangolin species. In addition, we have documented the key trading partnerships and characteristics of the global pangolin CITES trade network. We hope that quantifying these trade dynamics and identifying key trading partners will inform better decision making around existing (and future) CITES regulations, national legislation, and pangolin conservation measures.

2. Methods

The CITES Trade Database (www.trade.cites.org: UNEP WCMC, Cambridge UK, downloaded on the 20th of May 2016) was queried for all pangolin species (*Manis* spp.) trade data between the years 1975 and 2014 for all 'Sources', 'Purposes', 'Trade Terms', 'Importing Countries', and 'Exporting Countries', as a comparative tabulation report. The resulting data included 1485 trade incidents; noting that incidents in comparative tabulations are summed by CITES when the trade details in a particular year are identical across all of the variables listed above, and are not necessarily reported on a shipment-by-shipment basis (CITES, 2013c).

All identified species were assigned to their respective native home continent; being either 'Africa' (*M. tricuspis, M. gigantea, M. temminckii, M. tetradactyla*) or 'Asia' (*M. crassicaudata, M. javanica, M. culionensis, M. pentadactyla*). Unidentified species, which were reported to originate from an Asian or African native range country (see Table S1) in the 'origin country' field, were assigned their respective home continent, or otherwise flagged as 'unknown'.

CITES trade terms were consolidated into six groups for analysis: (i) whole animals (live and bodies); (ii) specimens/medicine (medicine, powder and specimens); (iii) scales; (iv) body parts (trophies, feet, claws, tails, skulls, skeletons); (v) leather/skins (leather, leather items, leather products large and small, shoes, skins, skin pieces, skin scraps, and garments); and (vi) miscellaneous (derivatives, carvings, bone pieces, meat, and unspecified). Trade sources were grouped into five categories: (i) captive (captive and ranched); (ii) wild; (iii) seized; (iv) pre-convention; and (v) unknown. Finally, trade purpose was grouped into five categories: (i) scientific (biomedical research, scientific); (ii) miscellaneous (circus, zoo, educational, law enforcement, captive breeding); (iii) commercial; (iv) personal (personal, hunting trophy); and (v) unknown.

We assigned units to all incidents where the unit for the trade term was blank, following the 'preferred unit' according to the *Guidelines for the preparation and submission of CITES annual reports (February 2011)*. Where the units were provided, they were standardised from centimetres to metres, grams to kilograms, millilitres to litres, boxes and flasks to cartons, pairs and pieces to number of specimens. Where both the importer and the exporter reported a quantity, the larger of the two quantities was used in all cases; the correlation between importer and exporter reported (log10) quantities was extremely high (Pearson's $r = 0.94$, 95% CI $= 0.90, 0.96$), and the slope of the linear regression between exporter quantities and importer quantities was not significantly different from one (slope $= 0.94$, 95% CI $= 0.87, 1.02$).

All traded quantities were then converted into an estimated minimum and maximum number of whole pangolins. Where the unit was defined as the 'number' of specimens, the minimum and maximum quantity of whole pangolins was assumed equal to the traded quantity provided, with the exception of small leather products and leather items where the maximum number of whole pangolins required to make the product was instead assumed to be double the quantity provided. For large leather products, it was assumed that at least two whole animals were required to construct each product, and a maximum of four. Up to eight claws were estimated to belong to at least one pangolin and a maximum of eight pangolins. Up to four feet were assumed equal to a minimum of one whole pangolin, or a maximum of four. Shoes were reported in pairs (UNEP-WCMC *Guide to using the CITES Trade Database Version 8, October 2013*: CITES, 2013c) and it was assumed that a minimum of two or a maximum of four pangolins were needed for a pair of shoes. Meat, reported in kilograms, was converted to whole pangolins according to the average weight of each pangolin species (Gaubert, 2011). Weight for scales and skins were converted to whole pangolins using known body mass ratios and actual scale weights (Heath, 1992a,b; Zhao-Min et al., 2012; Mohapatra et al., 2015). Skins reported in metres were converted by using length measurements for each species (Heath, 1992a,b; Gaubert, 2011). As data was only available for *M. javanica, M. pentadactyla*, *M. crassicaudata* and *M. temminckii*, it was

[1] Post-acceptance of this paper, all eight pangolin species have been accepted for up-listing to CITES Appendix I at the Seventeenth Conference of Parties (30-September 2016).

assumed that *M. tricuspis* and *M. culionensis* would be similar to *M. javanica* and *M. pentadactyla* as they have a similar average weight (Gaubert, 2011). It was also assumed that *M. gigantea* had similar proportions as *M. temminckii*. If the species was not identified, the numbers for conversion from the largest pangolin species were used to calculate the minimum number of whole pangolins and the maximum number was assumed to be that of the smallest pangolin species. Derivatives, bone pieces, carvings, garments, medicine, powder, specimens, unspecified shipments, as well as all shipments that were reported in cartons, boxes, flasks or other non-standard units were omitted from the calculation of whole pangolins (18.72% of total incidents), as it was impossible to unambiguously convert them into an estimated number of whole pangolins.

A comparison between CITES and LEMIS (Law Enforcement Management Information System) data was conducted *post-hoc* after it became apparent that a large number of CITES trade incidents were being reported by the United States of America (US) as source 'seized'. Given that the CITES metadata (CITES, 2013c, pg. 12) states that the source column relates to the "original source of the species being traded", we interpreted a 'seized' source as a species that is re-exported from a previous seizure event (i.e. legally redistributed). However, the large number of US seizure events led us to investigate whether the source column was being misused. CITES and LEMIS data were compared for seized shipments imported into the US from 1999 to 2013. LEMIS is a database administered by the US Fish and Wildlife Service (USFWS), reporting on all shipments being imported to or exported from the US. Furthermore, LEMIS provides detailed information about the recorded shipments, including if they were seized or not. The source column in CITES trade data was filtered to 'seized' and the Disposition Code column (indicating the final action that was taken by US Authorities) in LEMIS was filtered to 'I' (seized), 'R' (refused) and 'A' (abandoned). As a rule, exact matches were required in the quantity, exporter, year and species columns. Varying matches were allowed for the wildlife description ('term' in CITES), the 'purpose', 'origin country' and 'unit' columns. The number of matches between the two datasets, for seized shipments imported into the US, were then compared.

2.1. Analytical methods

Generalised linear models were fitted to test for a change (e.g., increase) in the number of CITES reported incidents through time (Poisson variance and log link function), and the proportion of incidents identified to species level (Binomial variance and logit link function) through time. Multinomial logit regression models were used to model the categorical response of the CITES nominal outcome variables (i.e., 'purpose' and 'term') through time (using R package 'nnet': Venables and Ripley, 2002). We used low-order natural splines (degrees of freedom $= 2$) to capture non-linearity in the temporal trends in the relative number of occurrences in each category of the multinomial responses. Bootstrapped predictions ($B = 1000$) of temporal trends were calculated for each response category and were used to calculate 95% confidence intervals for the predictions (based on temporal block bootstrap resampling; block length = 3 years). We also estimated the average linear trends in the relative number of incidents for each response category within the pre- and post-2000 time periods based on the first derivatives of the bootstrap spline predictions (with 95% confidence intervals).

Contingency-type frequency tests were used to visualise and assess the independence of categorical variables (using the R package 'vcd': Zeileis et al., 2007; Meyer et al., 2013). The homogeneity of frequencies was evaluated with Wald Chi-square tests for independence ($\alpha = 0.05$). When assessing the independence of CITES categorical variables, body parts were omitted from the CITES trade 'term' category, and the unknown and miscellaneous categories were omitted from the CITES trade 'purpose' category as they made up less than 5% and 10% of the total ($n = 422$) incidents since 2000, respectively.

To visualise the network of pangolin trade, and how this has changed over time, we constructed network diagrams representing the flow of pangolin products between countries which we classified as: (1) within the native range of Asian pangolin species; (2) within the native range of African species; or (3) outside the native range of any pangolin species (using the R package 'igraph': Csardi and Nepusz, 2006). We constructed circle networks to illustrate the annual number of trade incidents between exporting and importing countries for: (1) all pangolin species over the entire period (1977–2014); and (2) African pangolin species before and after the year 2000. A web application (https://taaprowse.shinyapps.io/pangolins/) was developed to facilitate visualisation of these trade networks for different data subsets and different time periods (using the R package 'shiny': Chang et al., 2016). All data analyses were conducted in the R-software environment (version 3.2.2) for statistical and graphical computing (R Core Team, 2015).

3. Results

Trade in pangolin species is globally widespread (Fig. 1). We found a total of 1485 trade incidents reported to CITES and an estimated 809,723 whole pangolins (not accounting for 18.72% of 'inconvertible' incidents) to be involved in the trade for the entire period between 1977 and 2014. Trade has been conducted across all major inhabited ice-free continents, and between 74 countries (Fig. 1). Among these countries, 218 unique trade partnerships were identified (Fig. 2), and the number of new partnerships formed per year ($mean = 5.7$, Standard Error (SE) $= 0.52$) has not decreased (nor increased) significantly through time (slope $\pm$ $SE = -0.02 \pm 0.05$, t-value $= -0.54$).

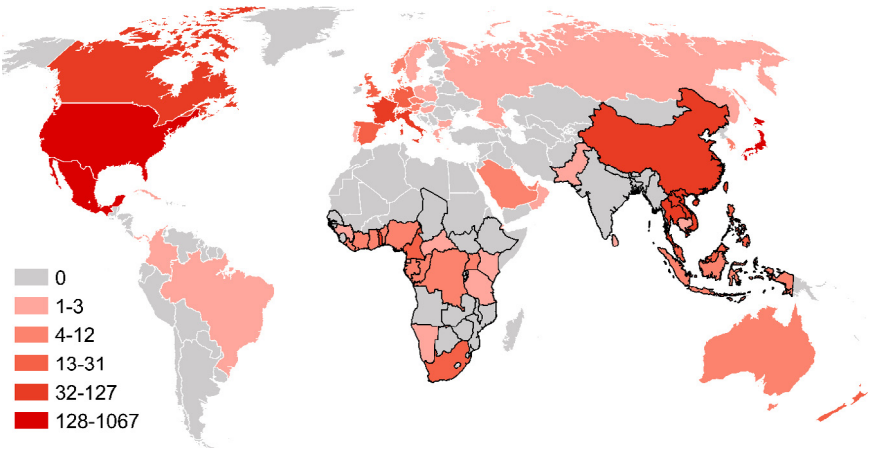

Fig. 1. Pangolin (*Manis* sp.) trade has been reported by CITES (number of import plus export incidents on $\log_{10}$ coloured scale) between 74 countries from 1977–2014, of which over half of the countries (58.11%) are outside the native African and Asian range states (thick black country borders) of all eight species. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

The top five trading countries contributed to 63% of the import–export trade links, with the US being the most connected country in the network (61 links/44 trading partners); followed by China (28/23), Japan (25/19), Italy (22/18) and Singapore (19/15). Of these five countries, only the US was primarily an importer of pangolin products, with 78% of pangolin trade incidents recorded as imported goods (Fig. 2).

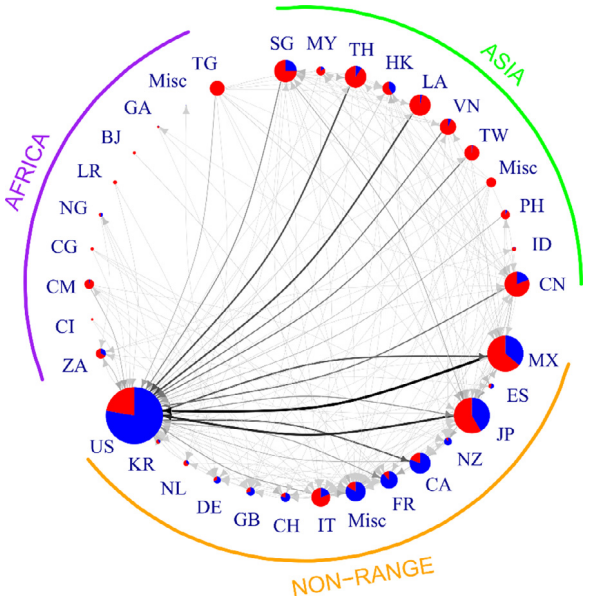

Fig. 2. All CITES trade incidents for all eight species from 1977 to 2014. Countries are classified by whether (or not) they are African, Asian, or non-range countries. Refer to Table S1 for corresponding country names associated with each country code. Miscellaneous ('Misc') includes countries that were involved in less than 5 incidents (Asian and African countries), or less than 10 incidents (non-range countries). The size of the nodes (and the coloured pies), and the directional trade arrows (Export [red pie] to Import [blue pie]), are natural-log transformed by the number of incidents represented. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

The trade network in African pangolin species has radiated substantially over time, with 24 trade-network links operating between 1977 and 2000 compared to 54 network links post-2000 (Fig. 3). The US was the dominant importer of African pangolin products over both periods, while export growth for these species has been driven largely by Togo, South Africa and Cameroon, for which the annually-averaged number of export incidents were 620%, 514% and 171% higher post-2000 (Fig. 3).

The greatest number of incidents (98 incidents; 6.6%) was in 1983, whereas the largest (estimated) number of whole pangolins traded was in 2000 (min = 109, 399, max = 118, 298; average percentage of total (estimated) whole pangolins = 12%; Fig. 4).

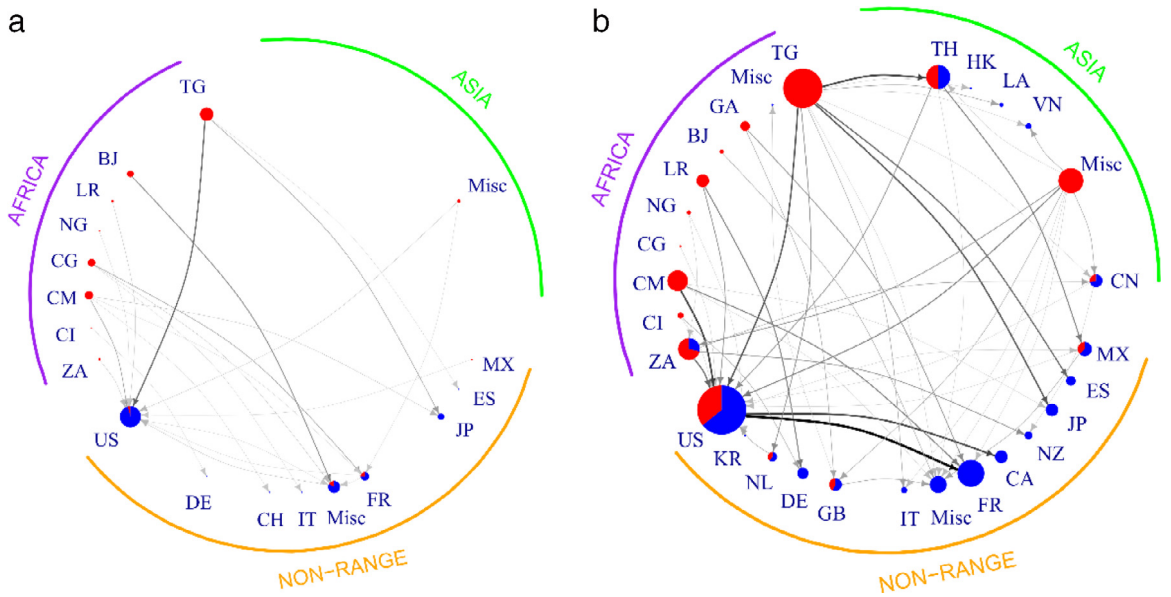

Fig. 3. African species incidents (a) prior to 2001, and (b) post 2000. Countries are classified by whether (or not) they are African, Asian, or non-range countries. Refer to Table S1 for corresponding country names associated with each country code. Miscellaneous ('Misc') includes countries that were involved in less than 5 incidents (Asian and African countries), or less than 10 incidents (non-range countries). The size of the nodes (and the coloured pies), and the directional trade arrows (Export [red pie] to Import [blue pie]), are natural-log transformed by the number of incidents represented. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

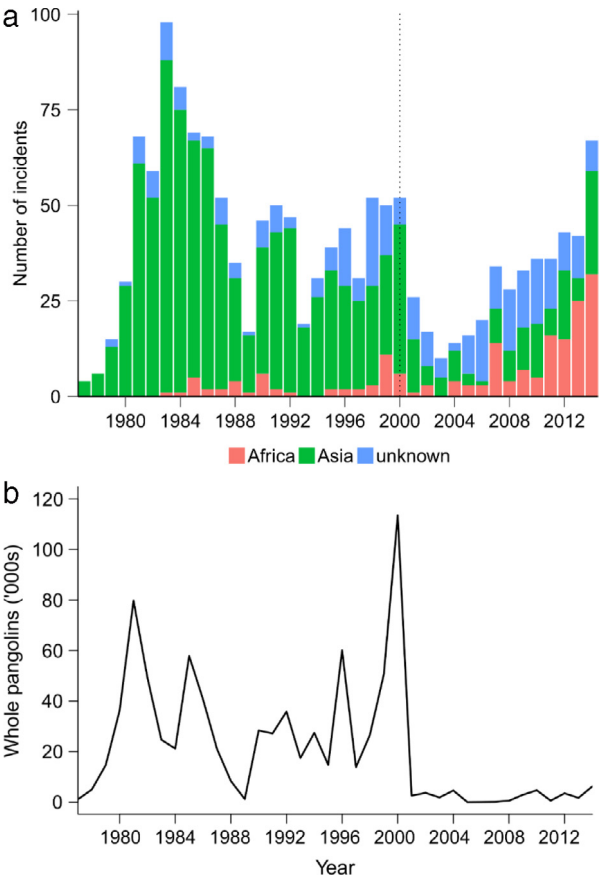

Fig. 4. (a) Total number of incidents for African, Asian and unknown pangolin species through time, and (b) the estimated number of (mean) whole pangolins for all eight species traded through time ($n = 82.3\%$ incidents; see main text for more details).

Species diversity decreased prior to 1995 (estimated break-point(s) = 1995, SE = 1.9; slope ± SE = −0.024 ± 0.011, t-value = −2.13), and has increased thereafter (slope ± SE = 0.086 ± 0.014, t-value = 5.83); reaching a maximum in 2014; the first year in which all eight pangolin species were recorded in the trade (Fig. 5(a)). Prior to 1995, the average number of pangolin species recorded (year^{-1}) in trade was 3.2 (SE = 0.2). More than 93% of incidents over this period consisted of just two Asian species: *M. javanica* (63.5%) and *M. pentadactyla* (30.2%) (Figure S1). The relative contributions of these species to the overall trade declined substantially post-2000 (*M. javanica* slope = −0.03, 95% CI = −0.05, −0.02; *M. pentadactyla* slope = −0.01, 95% CI = −0.02, −0.01). Since 2001, the number (Fig. 5(b); slope ± SE = 0.25 ± 0.03, t-value = 8.74) and proportion (Fig. 5(c); slope ± SE = 0.19 ± 0.03, t-value = 5.69) of African species incidents have significantly increased. Since 2001, approximately two-thirds (67%) of the incidents involving whole animals (alive and dead), has been African species.

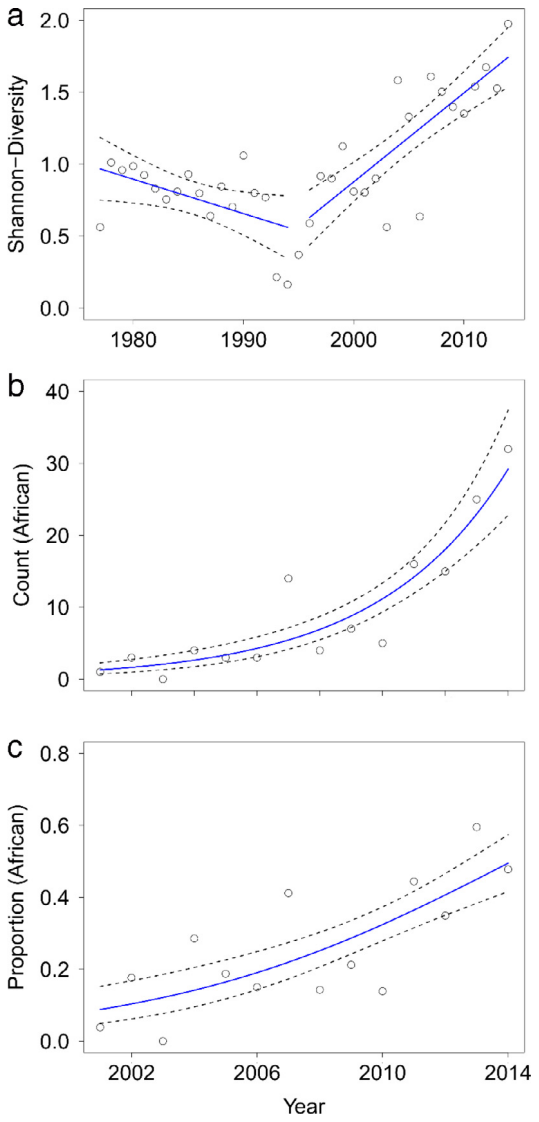

Fig. 5. (a) Shannon (H) species diversity index (Spellerberg, 1991) for the relative proportional trade in eight pangolin species through time; including segmented fitted regression lines (breakpoint = 1995). (b) The sum (Poisson regression with log link-function), and (c) proportion (binomial regression with logit link-function) of CITES trade incidents involving African pangolin species since 2001. Dashed lines (in all three panels) are 95% Confidence Intervals.

Prior to 2001, the vast majority of the trade (year^{-1}) was for commercial purposes (72.5% year^{-1}, SE = 3.05%), although the purpose of much of the remaining trade was unknown. The average proportion of trade for commercial purposes declined through time (pre 2000: slope = −0.01, 95% CI = −0.02, −0.00; post 2000: slope = −0.03, 95% CI = −0.04, −0.01), whilst trade for personal purposes (slope = 0.02, 95% CI = −0.01, 0.05) and scientific purposes (slope = 0.02, 95% CI = −0.01, 0.04) increased post 2000. The average trend in leather products traded significantly declined through time

(pre 2000: slope = −0.02, 95% CI = −0.03, −0.01; post 2000: slope = −0.02, 95% CI = −0.04, −0.01). Approximately, two-thirds of all reported trade in pangolins has been leather/skins (922 out of 1485 incidents) and over 90% of this trade occurred prior to 2001 (Figure S2). This trade has included 625,211 skins, and 31,396 kilograms (kg) plus 4103 metres (m) of leather. In the last half-decade (since 2010), the majority of the trade (85.7%) has been in African species (Figure S3; 979 skins). Approximately 5% (71 out of 1485) of the total number of incidents were related to the export/import of pangolin scales (average incident^{-1} ± SE = 505.4 ± 159.43kg). Prior to 2010 there were only two incidents of African pangolin scales recorded in trade. Post 2010, over 4500 kg of African scales have been reported, 79% of the total trade recorded for that period (5744 kg).

Compared with other (Asian and unknown) species, African species were significantly more likely to be traded as whole animals and for commercial purposes, and significantly less likely to be miscellaneous items, and traded for personal purposes (Fig. 6). Alternately, compared with other (African and unknown) species, Asian species were significantly more likely to be traded as specimens/medicine for scientific purposes, and significantly less likely to be traded as whole animals (Fig. 6). Unknown species, compared with African and Asian (identified) species, were significantly more likely to be miscellaneous items, traded for personal purposes, and significantly less likely to be specimens/medicine, traded for scientific or commercial purposes (Fig. 6).

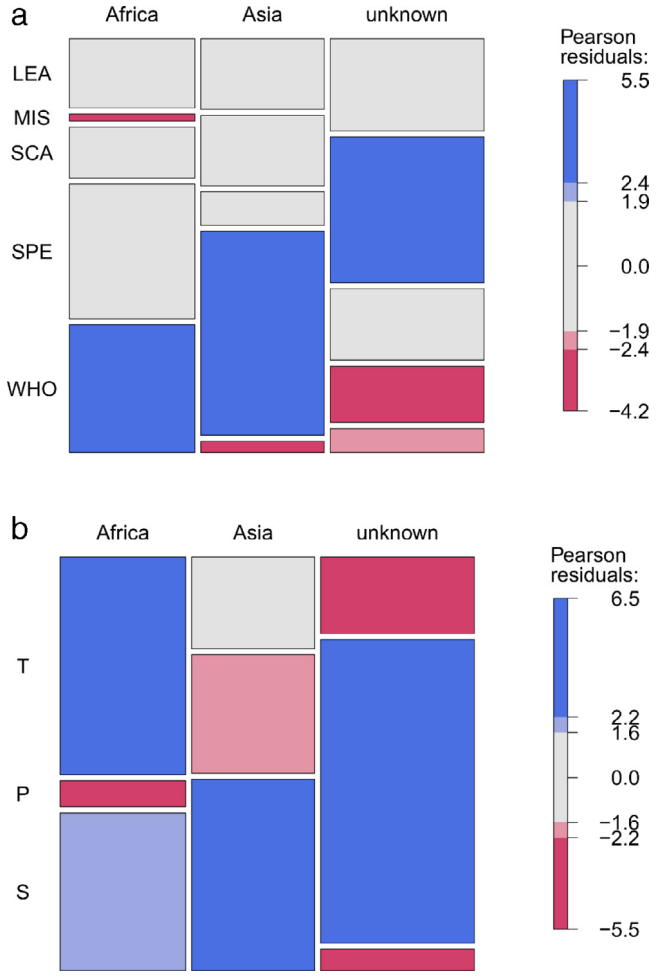

Fig. 6. Mosaic plots of the deviation in conditional independence between pangolin species (African, Asian, unknown) and CITES trade categories: (a) term (LEA = leather/skins, MIS = miscellaneous, SCA = scales, SPE = specimens/medicine, WHO = whole animals); and (b) purpose (T = commercial, P = personal, S = scientific) for all CITES trade incidents since 2001 (n = 422). The plot is constructed so that the size of each cell (rectangle) is proportional to the observed cell frequency for each trait. The residual-based shading follows Zeileis et al. (2007), and reflects the cell contribution to the Chi-square statistic: shades of blue, when the observed frequency is substantially greater than the expected frequency under independence; shades of red, when the observed frequency is substantially less, as shown in the legend. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

The proportion of incidents from African range-state countries, which were identified to species level, has not changed significantly through time (Fig. 7(a); slope ± SE = 0.01 ± 0.02, t-value = 0.39). However, the proportion of incidents, for which species were identified, from both Asian (Fig. 7(b)) and non-range countries (Fig. 7(c)), have significantly declined through time (Asian: slope ± SE = −0.08 ± 0.00, t-value = −8.05; non-range: slope ± SE = −0.07 ± 0.01 t-value, = −6.87).

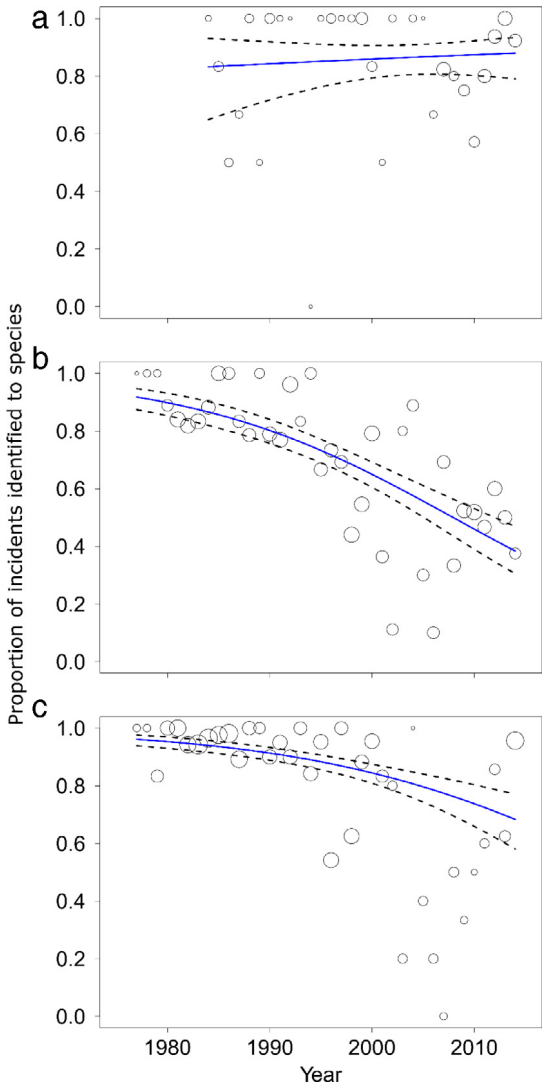

Fig. 7. Proportion of incidents identified to species level from export countries that are either: (a) African range countries. (b) Asian range countries, or (c) non-range countries. Fitted binomial regression lines, and 95% Confidence Intervals, are also shown.

4. Discussion

CITES trade data revealed a significant shift in pangolin trade from Asian to African species, pre- and post-2000, despite Asian species still being traded in large numbers; from 2001 to 2014 more than c. 17,500 whole Asian pangolins were traded. Trends in the global trade in pangolin species revealed that whilst the trade in Asian species has decreased, the trade in African species has increased significantly since 2001. Prior to 2000, Asian pangolins constituted the majority of trade, and there was almost no trade in any of the African species (Figure S1). It is possible, that African specimens may have been misidentified during this period (e.g., see Bräutigam et al. (1994)), yet, since 1995 *M. tricuspis* has become increasingly common in the trade. Since 2000, *M. tricuspis* and *M. gigantea* were the most frequently encountered of the African species, and in 2014 all eight pangolin species were recorded in the trade for the first time. Non-implementation of CITES provisions for Appendix III species may also have accounted for trade in African species not being consistently reported to CITES prior to 1995 (Bräutigam et al., 1994).

Prior to 2000, the CITES trade consisted almost exclusively of two species (*M. javanica* and *M. pentadactyla*), both of which were traded in enormous numbers, and are currently listed as Critically Endangered by the IUCN Red List (Challender et al., 2014b,c). In addition, very large shipments of trafficked pangolins have undoubtedly further contributed to their endangerment and IUCN listing (Challender, 2011; TRAFFIC, 2014; Challender et al., 2015; Andersen, 2016). Nevertheless, Asian pangolins were still 'legally' traded in substantial numbers, after 2000, despite the zero export quota. It is particularly noteworthy that the largest number of whole pangolins traded was in the year 2000, which aligns with the establishment of the zero export quota for Asian species. It has been previously found that trade in a species can increase (i.e., is 'stimulated') when legislation is changed to make it more difficult to trade a particular specimen in the future (Rivalan et al., 2007).

Prior to 2000 the dominant trade partnerships were between the US and Mexico, and the US and Japan, but also between the US and Asian range states, including Lao PDR, Thailand, Taiwan and Singapore. Notably, China does not contribute to the top 10 partnerships, with regards to frequency in CITES trade, prior to 2000 (Table S2). However, after 2000 China became a major exporter of pangolins to the US (Table S2). The US remained the key trader, mostly importing pangolins from the same trading partners as before, with the addition of African range countries, particularly Togo (Fig. 3). The US most frequently traded pangolins throughout the entire period (pre and post 2000) and was the greatest importer of pangolins and their products, measured both in volumes as well as in frequency. Since 2001, almost half of the CITES trade in pangolins (46.0%) has been reported as 'seized' (SE per *year* = 4.4%) and the majority of this trade has been seized by the US (82.5%). Although it remains unclear why so many pangolins and their parts are imported to the US, it is striking that globally many of the major contributors to the trade are actually non-range countries, both prior to and after 2000. A potential bias of the data is that non-range states may appear to be very prominent in the trade, because they largely rely on imports from source countries, whereas native range states can rely on exploiting their native pangolin populations, while they are still extant. Clearly this depends on the population status and availability of the native pangolin species within their range state and we could not account for this in the present analysis.

It is our belief that no captive bred pangolins exist in the wildlife trade. Instead, all supposedly 'captive bred' pangolins are suspected to be derived from the wild (Shepherd, 2008). To date, only Uganda, China, India, Singapore and Vietnam have reported breeding activities, though not in commercial quantities (CITES, 2015; Challender, Pers. Comm., 2016), and captive breeding programmes, or even captive care for pangolins, have so far been highly unsuccessful (Yang et al., 2007). Surprisingly, we found that a number of incidents were declared as captive bred (18 incidents), or ranched (four incidents). Captive bred specimens were reportedly sourced from Vietnam, Lao PDR, the Philippines, Hong Kong, Thailand, China and India (as origin states) and from the US, Taiwan, Lao PDR, South Africa, Thailand, Malaysia and Mexico (as exporter states). Togo and Lao PDR were the only countries that reported ranched pangolins in the trade (both as an exporter and origin country). There are no known reported breeding facilities in the Philippines, Hong Kong, Thailand, nor Lao PDR; therefore, the shipments with captive sourced pangolins reported to CITES, are highly questionable. China reported that they are at the stage of a population breeding development, but no sale has yet occurred (Yu et al., 2015; Challender, Pers. Comm., 2016). In India, pangolins are only allowed to be bred by recognised zoos for conservation purposes. Vietnam has a rescue centre for pangolins seized from trafficking incidents, and sometimes pangolins give birth in these rescue centres (*M. javanica* was bred in Vietnam at least once). In some zoos (e.g., in the Singapore and Taipei Zoo) pangolins give birth in captivity, though at great expense and effort, and in very small numbers and not for commercial sale. This does not explain the high numbers of pangolins traded, sometimes for commercial purposes. For example, the US reported the import of 198 skins of captive bred *M. javanica* in 1990 and 1991, being exported from Taiwan and with an origin in Vietnam. It is highly unlikely that these animals where bred in rescue centres or other breeding facilities, and it is unknown (yet very unlikely) that the reported rescue centres for pangolins even existed at that time. Furthermore, it is known that keeping pangolins in captivity is extremely difficult (Heath and Vanderlip, 1988; Wilson, 1994; Yang et al., 2007; Mohapatra and Panda, 2014; Hua et al., 2015) and few institutions have had success at keeping pangolins, let alone breeding them. It can only be concluded that the reports of captive bred specimens in the trade are misleading.

The increasing numbers of ranched specimens in the trade in recent years, most of them coming from Togo, are particularly concerning. In contrast to captive bred specimens, ranched animals, by CITES definition (CITES, 2010), can be taken from the wild as a juvenile and need not necessarily be born in captivity. To date, 10 skins of *M. gigantea*, supposedly ranched in Togo (where they do not even occur), have been reported in 2011 (and were possibly re-exported in 2013 from Thailand). A further 500 live pangolins of ranched *M. tricuspis* were imported to Italy from Togo in 2008. Lao PDR reported the export of 1000 skins of ranched *M. pentadactyla* in 2010. Given the difficulties in keeping pangolins alive in captivity for a prolonged length of time (Heath and Vanderlip, 1988; Wilson, 1994; Yang et al., 2007; Mohapatra and Panda, 2014; Hua et al., 2015), it is highly unlikely that ranching occurs and these claims are probably misleading. It is critical that further research is conducted to identify if this clause is providing traders with a harvest and conservation loophole.

African species have mostly been traded as whole animals, for commercial purposes, which might further indicate their increasing supplementary role for Asian species. Asian species prior to 2000 were mostly traded for the commercial trade in leather and skins (see also Challender, 2011; Challender et al., 2015). The commercial trade decreased after 2000, which could be due to the fact that Parties were not required to report re-exports of manufactured goods since January 1994 for species in Appendix II and III (see Notification to the Parties No. 788: CITES, 1994). The commodities most frequently traded were leather and skins, and this is also in contrast to the commodities most frequently encountered in pangolin trafficking, which are scales, whole animals (dead and alive), and meat (Challender, 2011; TRAFFIC, 2014; Challender et al., 2015; Zhang et al., 2015). In the CITES trade, scales only constituted 4.8% of the whole trade, and the trade in meat, bodies and live animals only

constituted 0.6%, 5.4%, and 6.6% of total incidents, respectively. We recognise, therefore, that there are clear differences in the drivers between legal trade and trafficking, and these differences deserve urgent research attention in order to understand future pressures, particularly from trafficking.

It is interesting to observe that the proportion of incidents identified to species level, for shipments coming from both Asian and non-range countries, have significantly declined through time. We propose that it is highly likely that unidentified species coming from Asian range countries are also Asian species, which leads to the question, why are they being declared as 'unknown'? One possible explanation could be that, following the establishment of stricter international trade regulation for Asian species, more specimens are being disingenuously categorised as 'unknown', presumably to circumvent the zero export quota. This possible illegal activity requires immediate attention, and further investigation.

Although legal trade in wild sourced Asian species (traded for primarily commercial purposes) decreased, as predicted, after the zero export quota in 2000, there were still questionable exceptions. We found 15 recorded incidents, all involving wild caught Asian species (all but one were *M. javanica*) being traded for commercial purposes in the period 2001–2012. Notably, all but one of these incidents originated in Malaysia. In sum, the trade included 3300 kg scales, 17 small leather products, 1 large leather product, and 7909 skins. Even if these incidents were re-exported, from shipments before the zero export quota, (for example, there were exports from Malaysia to Singapore including 11,430 kg of scales prior to 2000, and 3300 kg originating from Malaysia and being exported from Singapore to China after 2000), it remains unclear to us why a permit for the trade in these specimens was allowed to be issued.

A number of limitations have been previously reported with CITES trade data. Parties regularly fail to reliably report wildlife to species level (Gerson et al., 2008; Phelps et al., 2010), and Blundell and Mascia (2005) found significant discrepancies in CITES and Customs reporting in the US. The reported units and quantities are also often missing in the CITES database (Foster et al., 2016), and Parties sometimes report by permits that have been issued rather than permits that have been used (CITES, 2013c). Not all countries, including some pangolin range states, have been a Party to CITES since its' inception, and trade from years before they became members will be under reported. Vietnam for example, a range state for the Chinese and the Sunda pangolin, and believed to be a major consumer country for pangolin products, only became a Party to CITES in April 1994. In addition, Angola, a range state of all four African pangolin species, only became a Party to the Convention in December 2013. Furthermore, 17 pangolin range states do not appear at all in the reported CITES data, 14 of which are in Africa, further indicating a possible lack of reporting.

The CITES trade database should only contain legal trade data, reported via granted permits and certificates (as specified in Article VIII of the Convention, Paragraph 6 and 7), however, Parties are recently required to report pangolin seizures, as was requested through Decision 16.41 in 2013 (CITES, 2013b). Therefore another limitation of the data, which will cause confusion, is that not all Parties are consistently reporting their seizures. The US is one of the few countries reporting trafficking incidents, and it seems to be doing this by reporting the seized code 'I' in the source column. To our understanding, and as also indicated in the '*guide to using the CITES Trade Database*' (CITES, 2013c), and confirmed by CITES Authorities (P. Cassey, Pers. Comm., 2016), the source column in the CITES database is used to describe the actual origin of a specimen (e.g. wild caught, captive bred, etc.). This means that the Code 'I' in the source column should only be used if a specimen was seized at some point and is then legally distributed under a CITES permit. To find supporting evidence of suspected misuse of the source column we compared incidents from the CITES and the LEMIS database, of which the latter provides more reliable details of whether or not a shipment was for example cleared or actually seized. We were able to match CITES 'seized' incidents with the LEMIS database, and found that 98.16% of incidents were in fact seized by US authorities, therefore indicating incorrect use of the 'source' data reporting column in CITES. However, it remains unclear which, if any, other Parties are doing the same. This provides further evidence of the unreliability of CITES data and the obvious confusion about CITES reporting requirements by some Parties. It should be noted, that unreported trafficking of pangolins is taking place in a variety of countries, and those seizures are in most cases not reported to CITES. Most notably in Asian countries, huge seizures of pangolins have been reported in the media, as for example, the seizure of 11.5 tonnes of pangolins that were seized in China's Guangdong Province (Anon, 2015). China is implicated in many incidents reported in the media, as either a seizure or destination country (Challender et al., 2015; Pangolin Seizure Database, unpublished data, 2016), and is likely to be the most dominant player in the global pangolin trade, if accounting for both the illegal and CITES reported trade. Here however, we focussed on CITES reported trade only, and even when reported 'seized' shipments are omitted, the US still remains the dominant player (see https://taaprowse.shinyapps.io/pangolins/); acknowledging all of the aforementioned limitations around CITES data when interpreting our results.

The total number of CITES recorded pangolins traded between 1977 and 2014 is enormous, with an estimated 809,723 whole pangolins; which does not account for 18.72% of recorded incidents (including: 7239 cartons of derivatives and skin pieces; 68 flasks of specimens; 568.19 kg of derivatives, medicines, specimens, and unspecified shipments; and, 60,307 specimens, derivatives, garments, medicines, carvings and bone pieces with an undefined unit). While we acknowledge that the numbers of whole pangolins will overestimate the trade, because we did not account for potential re-exports, the conversion process worked with fairly conservative numbers, and as noted before, it does not include all incidents. In addition, the previously discussed limitations to CITES data indicate that the trade is more likely to be underestimated than overestimated. Finally, the illicit global trafficking contributes enormously to the decline in pangolin species, and the contributions and trade partnerships of this illegal network go largely unstudied, and unquantified.

5. Conclusions

No previous study, has analysed CITES trade data for both African and Asian pangolins (but see Challender et al. (2015) for Asian pangolin species). Here, we found a massive increase in trade of African species after 2000, while Asian species trade has decreased. Again, it should be emphasised that these results do not reflect trafficking in pangolins, but only trade reported to CITES. There has been a dramatic switch from Asian to African species, and as Asian populations have declined (Wu et al., 2004; Baillie et al., 2014; Challender et al., 2014b,c), we predict the same to happen in African populations. We therefore recommend that all trade, legal and illegal, should be monitored closely and enforcement efforts should be enhanced considerably. The establishment of the new mandatory annual illegal trade report, with the first report due in October 2017 (CITES, 2016b), is also a step in the right direction. It should be emphasised, however, that the reports on trafficking and seizures should be kept separate to the legal trade data to avoid confusion, and in order to unmistakably distinguish between them. Generally, improved CITES reporting is necessary, and we strongly encourage Parties to reliably report all of the trade in a standardised manner, especially with regards to future reporting of trafficking.

Further research into the demand, the drivers, and the impact of pangolin trade and trafficking in all range countries, but also in non-range countries (e.g., the US and certain European countries), should be conducted to better understand trade characteristics and underlying networks. These findings can then be used to guide the strengthening of law enforcement and conservation efforts, and to raise awareness, change consumer behaviour, and finally, reduce the demand for pangolins.

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Appendix A. Supplementary data

Supplementary material related to this article can be found online at http://dx.doi.org/10.1016/j.gecco.2016.09.007.

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