Check for updates

Received: 30 September 2020 | Revised: 15 March 2021 | Accepted: 25 March 2021

DOI: 10.1111/csp2.430

CONTRIBUTED PAPER

Conservation Science and Practice
A journal of the Society for Conservation Biology
Open Access

WILEY

Live wild animal exports to supply the exotic pet trade: A case study from Togo using publicly available social media data

Lauren A. Harrington[1] | **Mark Auliya**[2,3] | **Harry Eckman**[4] | **Alix P. Harrington**[1] | **David W. Macdonald**[1] | **Neil D'Cruze**[1,4]

[1]Wildlife Conservation Research Unit, Department of Zoology, University of Oxford, Recanati-Kaplan Centre, Abingdon, UK

[2]Department of Conservation Biology, Helmholtz Centre for Environmental Research GmbH – UFZ, Leipzig, Germany

[3]Zoological Research Museum Alexander Koenig, Bonn, Germany

[4]World Animal Protection, London, UK

Correspondence
Lauren A. Harrington, Wildlife Conservation Research Unit, Department of Zoology, University of Oxford, Recanati-Kaplan Centre, Tubney House, Abingdon Road, Tubney, Abingdon, OX13 5QL, UK.
Email: lauren.harrington@zoo.ox.ac.uk

Funding information
World Animal Protection

Abstract

Exotic pet supply is a key, predominantly legal, component of global wildlife trade, but few studies have quantified its diversity or global reach. Here, using information extracted from the public (open) Facebook accounts of two wildlife exporters in Togo, West Africa, we identified at least 200 species, predominantly reptiles, but also mammals, birds, amphibians and invertebrates, advertised as available for sale and export, between the years 2016 and 2020. Of the animals identified, several hundred, possibly several thousand, individuals were shipped, at least monthly, to North America, Europe, Asia, and elsewhere in Africa, via a number of major airlines. Among the vertebrates observed, approximately one-third had not yet been evaluated on the IUCN Red list, and three quarters were not CITES-listed (i.e., their trade was not regulated under this international treaty). The apparent lack of adequate monitoring of population status, disease, biological invasion, and animal welfare risks associated with this trade, as well as neglected taxa (e.g., invertebrates), has potential implications for environmental, public, and animal health. The findings of this case study suggest that a systematic review of social media activity could efficiently reveal significant insights into the otherwise undocumented global supply of exotic pets, directing legislators to aspects and areas where regulation is insufficient, and informing international and national policy change.

KEYWORDS

animal welfare, CITES, conservation status, Facebook, invasive species, local livelihoods, public health, sustainability, wildlife trade

1 | INTRODUCTION

Large quantities of live wild animals, many sourced directly from the wild (e.g., Auliya, 2003; Harrington, 2015; Krishnasamy & Zavagli, 2020; Sinovas, Price, King, Hinsley, & Pavitt, 2017), are transported around the world to supply the international exotic pet market, an industry considered to be a key component of the global wildlife trade

This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.
© 2021 The Authors. Conservation Science and Practice published by Wiley Periodicals LLC. on behalf of Society for Conservation Biology

(UNODC, 2016). The CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) Trade Database (https://trade.cites.org) contains records of c. 2.2 million individual live (wild-sourced to captive-bred) wild animals belonging to 1,316 species, exported every year, to 189 different countries (Can, D'Cruze, & Macdonald, 2019). Many more species collected for the pet trade (including some threatened species) are not listed on CITES appendices (see https://cites.org/eng/app/index.php for details of protection afforded under each of the three appendices)—for these species, some aspects of their trade may be regulated (e.g., the International Air Transport Association regulates the conditions under which animals are transported on airlines) but there is no international monitoring or regulation of the species and numbers involved (e.g., UNEP-WCMC, 2009; Auliya et al., 2016; Frank & Wilcove, 2019.

The exotic pet trade can provide conservation benefits to local wildlife (by giving wildlife economic value, Helm, 2015) and may provide an important source of income for local communities (Cooney et al., 2015; Phelps, Biggs, & Webb, 2016; Robinson et al., 2018; Roe, 2008; Roe et al., 2002). Sinovas et al. (2017), for example, attribute population recovery of the yellow-spotted Amazon river turtle *Podocnemis unifilis* in Peru to productive conservation efforts, as part of a system that also has significant positive social impacts. However, a number of case studies suggest that even for CITES-regulated species, the evidence required to assess sustainability is often lacking, and it is therefore often not possible to robustly ensure that a particular trade is sustainable (e.g., D'Cruze et al., 2020; Di Minin et al., 2019; Harris et al., 2017; Schlaepfer, Hoover, & Dodd, 2005; Smith et al., 2011). In addition, there are numerous cases of species traded as pets becoming invasive in destination countries (e.g., García-Díaz, Ross, Woolnough, & Cassey, 2017; Hulme, 2009; Liu et al., 2020; Lockwood et al., 2019; Stringham & Lockwood, 2018). There are also public health issues associated with the role of national and international animal movements in the spread and release of zoonotic disease (e.g., Borsky, Hennighausen, Leiter, & Williges, 2020; Brown, 2008; Can et al., 2019; Karesh, Cook, Bennett, & Newcomb, 2005; Kuiken et al., 2005; Smith et al., 2017; Travis, Watson, & Tauer, 2011; Warwick, Arena, Steedman, & Jessop, 2012), and animal welfare issues and mortalities associated with capture, confinement, and local, national, and international transport (e.g., Steinmetz, Pütsch, & Bisschopinck, 1998; reviewed in Baker et al., 2013).

Despite the potential risks associated with the legal international trade and transport of live wild animal species, the practice has received relatively little attention in the scientific literature compared with the illegal wildlife trade more generally (Vinke & Vinke, 2012; Milner-Gulland, 2018 and references therein; see also 't Sas-Rolfes, Challender, Hinsley, Veríssimo, & Milner-Gulland, 2019). As such few studies (but see Bush, Baker, & Macdonald, 2014) have attempted to quantify the full extent and nature of the trade in live wild animals, in terms of taxonomic diversity or global reach—both of which are needed to enable appropriate management, and prediction and avoidance of various risk factors (e.g., Scheffers, Oliveira, Lamb, & Edwards, 2019).

National and international sales of live wild animals (and other wildlife products), both legal and illegal, are facilitated by the internet and the availability of various e-commerce sites and social media platforms (e.g., IFAW, 2014, 2017; Krishnasamy & Stoner, 2016; Lavorgna, 2014; Liu et al., 2020; Marshall, Strine, & Hughes, 2020; Morcatty, Feddema, Nekaris, & Nijman, 2020; Sharma et al., 2019; Siriwat, Nekaris, & Nijman, 2019; Siriwat & Nijman, 2018, 2020; Sung & Fong, 2018; Sy, 2018; Ye et al., 2020). In the case of exotic pets, even when transactions take place elsewhere (e.g., via encrypted messaging applications, or offline), advertisements are often placed on open (public) social media sites. This means that social media also provides a wealth of data on the legal (and illegal) wildlife trade that, for species whose trade is not regulated or monitored under CITES, would not otherwise be readily available (see, e.g., Martin, Senni, & D'Cruze, 2018).

In this case study, we review supply-side wildlife trade activity, by two (anonymized) wildlife exporters in Togo, West Africa, using social media posts from two different Facebook accounts made between 2016 and April 2020. Togo, together with neighboring Ghana and Benin, is a major source and exporter of reptiles (e.g., Jensen et al., 2018; Luiselli, Starita, Carpaneto, Segniagbeto, & Amori, 2016), with a number of well-established wildlife "farms" and export companies in place (Ineich, 2006). The role of Togo in the production and export of ball pythons *Python regius* under CITES has been documented elsewhere (D'Cruze et al., 2020; de Buffrénil, 1995; UNEP-WCMC, 2014). However, recent observations at reptile farms in Togo also revealed significant trade in non-CITES listed species (D'Cruze, Bates, Assou, Ronfot, et al., 2020; Jensen et al., 2018). The two wildlife exporters in this study were identified on the basis of a brief online search for exporters operating in Togo via social media.

To obtain a comprehensive insight into wildlife trade in this region, using information obtained from Facebook posts, and posted images and videos, we asked: (a) to what extent were traders focused on non-CITES listed species, (b) what were the potential conservation impacts of these exports, (c) what were the welfare conditions provided to wild animals prior to (and during) shipment, and (d) what were the prominent international trade routes involved. Our aim was to assess the diversity and

global extent of wildlife exports from this well-known trade-hub, in part as a demonstration of the utility of social media data in providing insights into wildlife trade in supply-side countries. We discuss briefly the broader nature of the supply of live animals for the international exotic pet market (considering not only conservation, but also animal welfare, and public health) and highlight where information and/or regulation appears to be lacking, with a view to informing future research, policy and planning.

2 | METHODS

Between April 21 and May 29, 2020, all unique posts (dated 2016–2020) belonging to both Facebook accounts were viewed, and data collated per post based on the text, images or videos posted, and any comments left by viewers. For each post, we manually recorded the date posted, the type of information shown (images of animals held in containers or cages, animals packaged for shipping, labeled shipping crates, or text only), taxonomic class (and order) of any animal shown, the number of individuals shown (where possible), whether contact information was provided, and any additional information such as the names of species offered for sale provided by traders, and comments from viewers suggesting interest in a potential purchase. The number of posts containing comments, and the number of comments, beyond a simple enquiry about price or delivery, was too few to allow any type of content analysis or more detailed assessment of viewer response. For posts showing animals packaged for shipping, we estimated, where possible, the number of individuals per crate, and for those showing only the shipping crates, we recorded taxonomic class as marked on the shipping label, and the number of crates that could be seen. Where shipping labels could be seen in images, we recorded any visible information on airlines, or destination; and where Airway Bill (AWB) numbers could be seen these were recorded and tracked via online air cargo tracking systems (https://www.track-trace.com/aircargo, accessed May–August 2020) to obtain details of the route taken. A small number of cases of identical images posted on both Facebook accounts suggested that the two accounts were not entirely independent (although both operated under different names and the nature of any operational or business link between them was unknown); therefore, posts and images from both accounts were combined for analysis (duplicate images were removed).

All images and videos included in the posts of both accounts were downloaded, and all vertebrates shown identified to genus (and where possible to species) level on the basis of visible distinguishing features (e.g., color, morphology), where photo quality permitted it. For each unique species identified, we collated information on conservation status, population trend, geographical distribution, and habitat preference (based on the IUCN Red List of Threatened Species, hereafter the IUCN Red List, categories, and species information), whether or not the species was listed on CITES appendices (https://speciesplus.net/), and estimated the number of individuals seen per image or video. Species distribution was categorized as in D'Cruze, Harrington, Assou, Green, et al. (2020) as "restricted" (i.e., those species with regional distributions, RE), "widespread" (W), or "exotic" (not found on the African continent, EX). For species with either restricted or widespread distributions, we also recorded whether a species was native to Togo specifically, and/or whether the species (or its habitat) are considered to be scarce in Togo, and therefore where it was likely that the species had been supplied by another country or range state (further details in Table S1a). Habitat preference was categorized as forest, wetland, savannah, the semi-arid Sahelo-Saharan region, or "other" (where "other" included agroecosystems and villages). Note that while the numbers of individual animals observed in a single image provided some indication of whether a particular species was harvested en masse or captured as individuals, it was not possible to estimate total numbers harvested because we could not determine whether the images represented the entire stock or a proportion of it, or what proportion of the stock the images represented.

For all posts showing vertebrates pictured in holding cages/containers prior to shipment (i.e., those where animals were not packaged for shipping) where the whole cage/container could be seen, welfare conditions were assessed based on provision of space, shelter, water, and substrate, and the level of hygiene (details of the scoring system in Table S2a). We did not attempt to assess formally images showing animals packaged for shipping for compliance with International Air Transport Association (IATA) animal welfare guidelines due to uncertainty regarding the actual conditions that animals would travel under (i.e., images of open crates might not show insulation or further protective packaging added prior to sealing the crates).

In accordance with ethical research practices (e.g., Zook et al., 2017), to protect the identity of individual exporters, the name and URL (web address) of the Facebook accounts were not recorded, and are not reported here, and no other identifiable data (e.g., AWB numbers) are presented. In addition, as recommended by Kosinski, Matz, Gosling, Popov, and Stillwell (2015), we only collected data for which it was reasonable to assume

that they were knowingly made public by exporters (i.e., as posts were clearly made to solicit trade among a wide audience it was assumed that exporters intended their posts, and the information included within them, to be publicly available), and we did not interact or communicate with either the exporters or their potential customers. In all cases, data were collated manually without the use of automatic web scrapers.

Chi-squared tests were used to compare the distribution of taxa shown in pre-shipment posts with that shown in shipping posts. Major clusters (groupings) of species characteristics were identified using k-modes (Huang, 1998) in the klaR package (Weihs, Ligges, Luebke, & Raabe, 2005) for each taxonomic order, with 1 million iterations used to generate three clusters; figures were plotted using ggplot2 (Wickham, 2016) and gridExtra (Auguie, 2017). All statistical analyses were carried out in R (version 4.0.2, R Core Team, 2020).

3 | RESULTS

3.1 | Description of posts

During the observation period, the two Facebook accounts contained 911 posts, with a total of 3,781 images

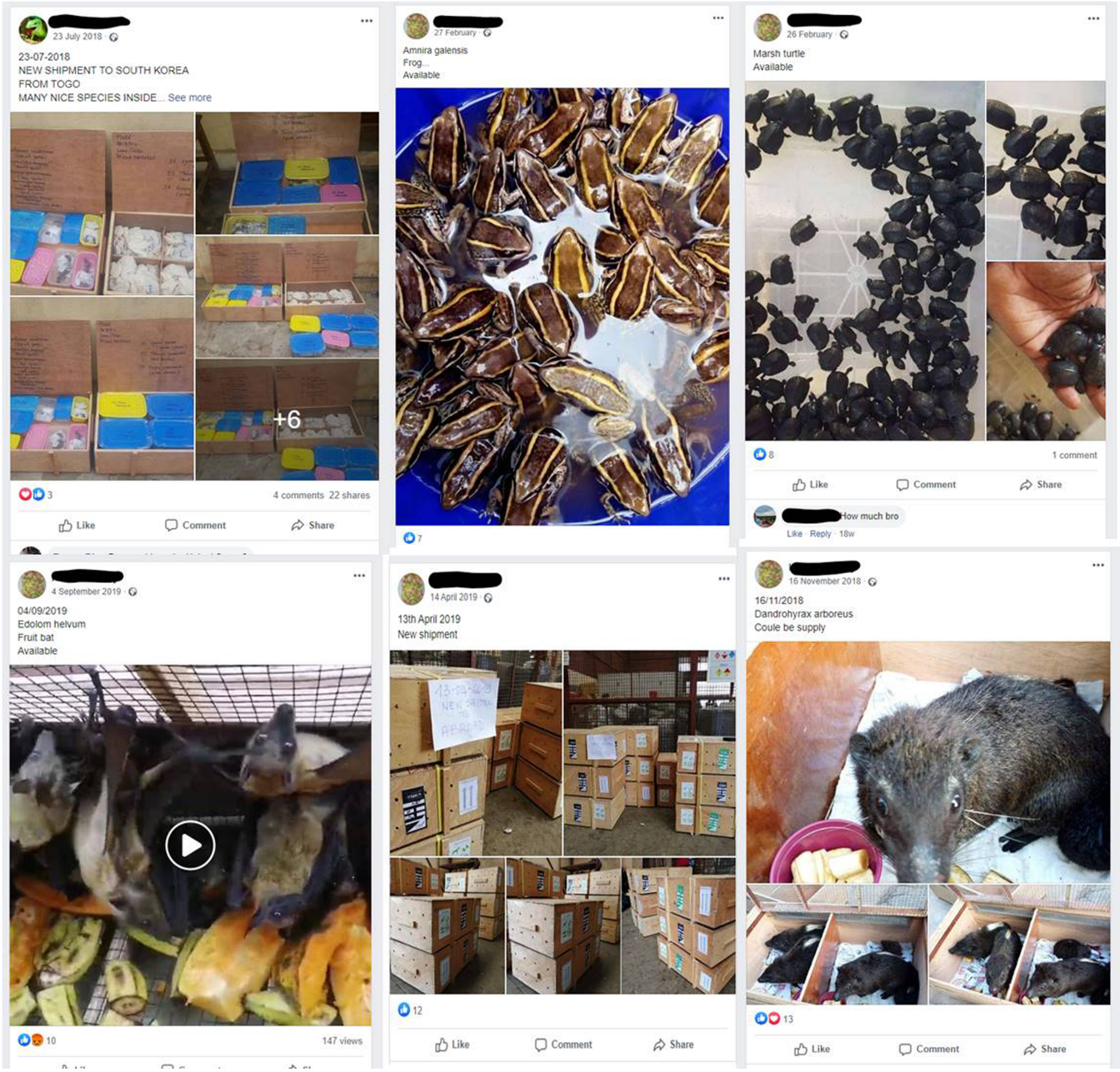


FIGURE 1 Screenshots from the Facebook accounts of two wildlife exporters in Togo, West Africa

(Figure 1). Most ($n = 660$, 72.4%) posts showed images of animals pre-shipment, 221 (24.4%) showed "shipping" images (crates or animals packed in crates; 179 of the latter also either showed the animals being shipped [$n = 38$] or the taxonomic class marked on the shipping label [$n = 141$]). Approximately a quarter (28.9%, $n = 263$) of posts provided contact details for the exporters, 10% ($n = 91$) elicited viewer comments enquiring about purchase or delivery. None of the posts contained prices for the animals shown.

Most pre-shipment posts ($n = 471$, 71.4%) showed reptiles (79.2% [$n = 373$] of those were Sauria and Serpentes [lizards and snakes], 17.6% [$n = 83$] Testudines spp. [freshwater turtles and tortoises]). Invertebrates and mammals were shown in c. 10% of pre-shipment posts (invertebrates $n = 76$, mammals $n = 61$), and amphibians and birds in 3–4% (amphibians $n = 26$, birds $n = 20$). The number of individual animals, counted in images or advertised in the post text as available, ranged between 1 and 20–30; exceptionally, several hundred (e.g., 300 fire skinks, *Mochlus [Riopa] fernandi*, or 300 tarantula spiders [Family Theraphosidae]) or several thousand (e.g., 5,000 savannah monitor lizards, *Varanus exanthematicus*).

Most shipping posts where taxonomic class could be identified ($n = 163$, 91.1%) showed reptiles; only eight (4.5%) showed mammals, seven (3.9%) showed invertebrates, and one (0.6%) amphibian, none showed birds. Two posts showed crates labeled as "venomous" or "poisonous" snake. Compared with pre-shipment posts, shipping posts were significantly more likely to comprise reptiles ($\chi^2 = 26.99$, $df = 1$, $p < .001$, with Yate's continuity correction for the proportion of posts showing reptiles vs. those showing all other taxa). Crates were labeled as containing 50–450 reptiles, and images showed a range in individual numbers, from two sub-adult tortoises to c. 50 (up to 200) juveniles, per shipping crate (Figure 2a). Mammals identified or named in shipping posts included genets (*Genetta* spp.), African civets (*Civettictis civetta*), Egyptian mongooses (*Herpestes ichneumon*), and the southern tree hyrax (*Dendrohyrax arboreus*), sometimes packed in the same crate (Figure 2b). One post showed crates labeled as containing 410 centipedes. Two hundred

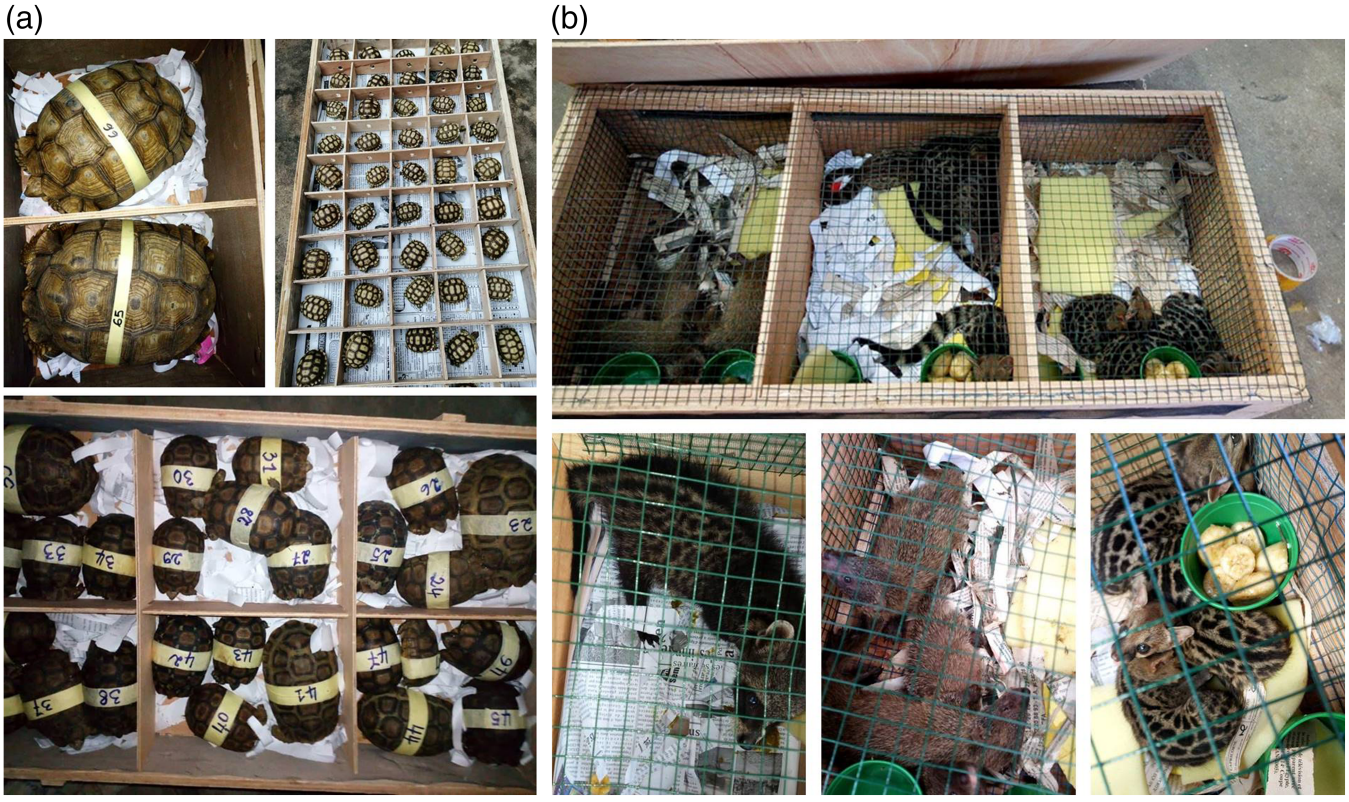


FIGURE 2 Images of animals packed for shipping, posted on the Facebook account of a wildlife exporter in Togo, West Africa, showing (a) subadult (top, left) and juvenile (top, right) African spurred tortoise, *Centrochelys sulcate*, and subadult Western hinge-back tortoise *Kinixys nogueyi* (bottom), and (b) packing crate (top) containing Eygptian mongooses, *Herpestes ichneumon* (left compartment) and genets, Genetta spp. (centre and right compartments), and close ups of African civet (bottom, left), *Civettictis civetta*, Eygptian mongoose (centre), and pardine genet (right), *Genetta pardina*

images showed between one and 22 labeled shipping crates stacked, apparently ready for shipping.

3.2 | Species identified

One hundred and sixty-seven unique vertebrate species were differentiated visually from images and videos included in the posts, an additional 20 were named in the text of the post by the traders, giving a total of 187 vertebrate species exported or advertised as available for export between 2016 and 2020. All differentiated species were identified to genus or family level; 154 were assigned to species (Table S1a). The vast majority of species were reptiles, but within each class there was considerable taxonomic diversity (particularly among birds and mammals that were represented by seven and 10 different orders, respectively; Table 1). In addition, c. 13 invertebrate species were named in the posts—including Arachnida (here: spiders and scorpions), Myriapoda (here: millipedes and centipedes), Crustacea (here: crabs), Hexapoda (insects [here: beetles and praying mantises]), and Mollusca (here: snails) (Table S1b).

Across vertebrate taxa, half ($n = 84$, 54.5%) of the traded species observed (of those identified to species level) are classified on the IUCN Red List as Least Concern, but over one-third ($n = 53$, 34.4%) are not evaluated on the IUCN Red List, and at least 7% are classified as threatened (see below); nearly half ($n = 75$; 48.7%) have restricted ranges, and less than a quarter ($n = 34$; 22.0%) are listed on CITES appendices. Reptiles differed from other taxa in that the largest grouping of traded reptiles (identified through clustering) comprised species that are not evaluated on the IUCN Red List, not listed on CITES appendices, and are either widespread or have restricted ranges. In contrast the largest grouping of traded mammals and birds comprised species that are classified as Least Concern, not listed on CITES appendices, and are widespread, as were amphibians except that amphibians tended to be restricted range species (Figure 3). Most traded species ($n = 126$; 81.8%) could be described as habitat generalists using a mix of forest, savannah and/or other habitat types; four primate species were considered forest species, as were 12 reptile species (Table 2(a), Table S1a).

Of those species classified on the IUCN Red List as Least Concern, almost half ($n = 11$; 44.0%) of mammals and over three-quarters ($n = 15$; 75.0%) of amphibians, respectively, were reported to have either unknown or declining population trends (Table S1a). Of the 21 identified reptile species that were classified as Least Concern, 80.0% ($n = 16$) had unknown population trends. There were also images, and mentions in posts, of 10 threatened species (Figure 3), including one Critically Endangered species (the hooded vulture, *Necrosyrtes monachus*), one Endangered species (the Timneh parrot, *Psittacus timneh*), and eight Vulnerable species (including two that were non-native to Togo and one that might be extinct in Togo, Table 2(b)). In addition, some images may have shown the Critically Endangered Nubian flapshell turtle *Cyclanorbis elegans* but the poor quality of the images meant that the identification could not be confirmed. All but one of the threatened species are listed on CITES appendices (Table 2(b)). CITES documents were shown in at least one post, but it was not possible to verify from the information available whether all CITES-listed species were accompanied by the required CITES permits.

Among both restricted-range and widespread species, there were a small proportion of African species that were likely to have been imported into Togo either because they are not native to Togo ($n = 9$) or because they (or their habitat) are considered to be scarce (or extinct) in Togo ($n = 9$) (Table S1a). In addition, three of the traded species observed (all reptiles) were exotic to Africa: the king cobra *Ophiophagus hannah*, and red-headed krait *Bungarus flaviceps* native to South East Asia, and the red-eared slider *Trachemys scripta elegans*, a well-known invasive species native to the United States (cf. below).

TABLE 1 Taxonomic composition of vertebrate species shown in posts, identified on the basis of visual inspection of images and videos, and species names provided in post text (details in Appendix S1)

Class	No. orders	No. families	No. species
Amphibians	1	8	24
Reptiles	3	23	102
Birds	10	12	25
Mammals	7	15	36
Total	**21**	**58**	**187**

3.3 | Welfare assessments

Of 207 posts that included images showing animals in their holding (non-shipping) cage or container, where the complete cage or container could be seen, none showed any provision of enrichment. Welfare scores were poor for all factors (Figure S2), but particularly so for shelter and water: none of the cages/containers shown provided any shelter, and 85% (176 of 207) provided no water. Although cages/containers appeared (from photos) to be intermediately hygienic, those occupied by multiple animals ($n = 194$) lacked appropriate space for individuals.

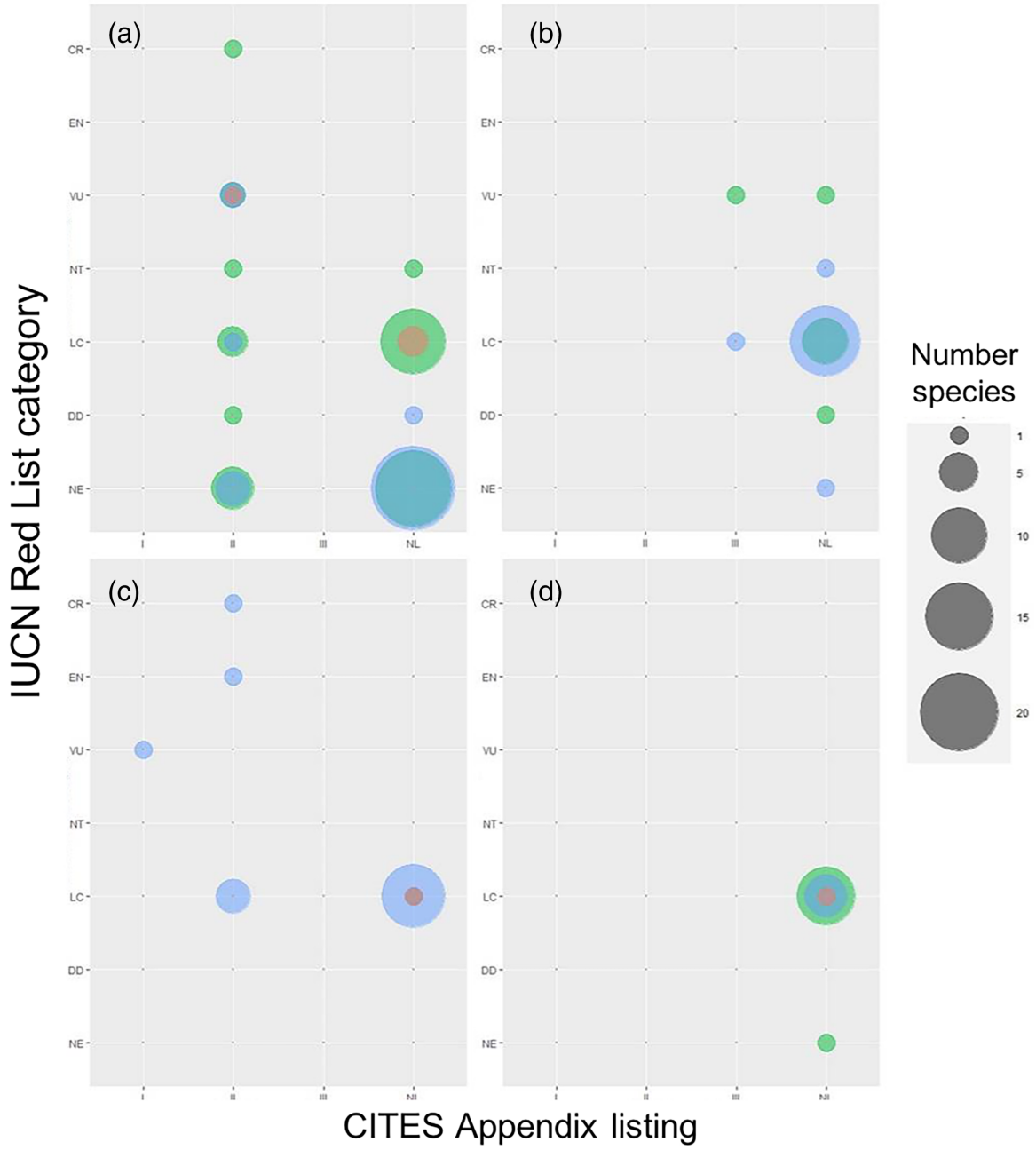


FIGURE 3 Conservation status (based on IUCN Red List of Threatened Species categories), CITES listing, and geographical distribution of exotic pet species identified ($n = 154$) on the Facebook posts of two wildlife exporters in Togo, West Africa: (a) reptiles ($n = 84$), (b) mammals ($n = 29$), (c) amphibians ($n = 19$), (d) birds ($n = 22$) (invertebrates listed in Appendix S1). Geographical distribution depicted by color, where RE (green) = restricted or regional range species, W (blue) = widespread species, and EX (pink) = species that are exotic to Africa (further details in Appendix S1). "Bubbles" are proportional in size to the number of species belonging in each set of categories (see Key). IUCN Red list categories: CR, Critically Endangered; EN, Endangered; VU, Vulnerable; NT, Near Threatened; LC, Least Concern; DD, Data Deficient; NE, Not Evaluated (IUCN Species Survival Commission, 2012). CITES listing categorized according to Appendix listings (Appendices I, II or III); NL, not listed on CITES Appendices

3.4 | International trade routes identified

From 116 posts that included images containing information pertinent to intended trade routes (AWB numbers, airlines or destinations), we were able to retrieve 40 unique trackable AWB numbers (Table S3a), from which we identified 13 unique trade routes leading to 13 final destinations in Europe, Asia, and Africa, via Ethiopian Airlines (departing from Lomé, Togo and flying via

TABLE 2 (a) Forest species (excluding one species that is exotic to Africa) and (b) threatened species, identified in images and videos posted on the Facebook accounts of two wildlife exporters in Togo, West Africa

Species name	Common name	IUCN red list category	IUCN red list population trend	CITES status (quotas)	Distribution
a.					
Holaspis guentheri	Sawtail lizard	NE		NL	W 1
Lygodactylus conraui	Cameroon dwarf gecko	NE		NL	W 1
Mochlus fernandi ssp.[a]	Red-flanked skink	NE		NL	W 1
Varanus ornatus	Ornate (Nile) monitor	NE		II	RE 1,2
Atheris chlorechis	Western bush viper	NE		NL	RE 1
Bitis gabonica	Gaboon viper	NE		NL	W 3
Bitis nasicornis	Rhinoceros viper	NE		NL	RE 1
Bothrophthalmus lineatus	Red-black striped snake	NE		NL	W 1
Mehelya poensis	Western forest file snake	NE		NL	W 1,2
Polemon acanthias	Rheinhardt's snake-eater	LC	Unknown	NL	RE 1
Thrasops occidentalis	Western black tree snake	LC	Unknown	NL	RE 1
Perodicticus potto potto	West African potto	LC[b]	Stable/decreasing	NL	RE 1
Galagoides demidoff	Demidoff's dwarf galago	LC	Stable	NL	W 1
Cercopithecus mona	Mona monkey	LC[b]	Unknown/decreasing	NL	RE 1
Cercopithecus erythrogaster	*See (b)*				
b.					
Cyclanorbis elegans[c]	Nubian flapshell turtle	CR	Decreasing	II[d]	RE 1,2
Necrosyrtes monachus	Hooded vulture	CR	Decreasing	II	W1
Psittacus timneh	Timneh parrot	EN	Decreasing	I[e]	W
Ophiophagus hannah	King cobra	VU	Decreasing	II	EX
Cercopithecus erythrogaster	White-throated guenon	VU[f]	Decreasing	NL	RE 1
Cyclanorbis senegalensis	Senegal flapshell turtle	VU	Decreasing	II[d] (500R, 100 W)	RE 1,2
Kinixys homeana	Home's hinge-back tortoise	VU	Decreasing	II (0R, 0 W)	RE 1,2
Gazella dorcas	Dorcas gazelle	VU	Decreasing	III (Algeria, Tunisia)	RE 2
Trionyx triunguis	African softshell turtle	VU	Decreasing	II[d] (200R, 50 W)	W 1
Centrochelys (Geochelone) sulcate	African spurred tortoise	VU	Unspecified	II	W 2
Balearica pavonina	Black-crowned crane	VU	Decreasing	I[g]	W1

Note: IUCN Red list categories: CR, Critically Endangered; EN, Endangered; VU, Vulnerable; NT, Near Threatened; LC, Least Concern; DD, Data Deficient; NE, Not Evaluated (IUCN Species Survival Commission, 2012). Note that there are no population trends for species that are not evaluated on the IUCN Red List. CITES listing categorized according to Appendix listings (Appendices I, II or III, https://cites.org/eng/app/index.php); NL, not listed on CITES Appendices. Export quotas communicated with CITES are shown for 2020 for context but note that quotas may not have been communicated, or may have been higher, at the time the species was advertised for sale. Distribution: RE 1–3 = West African restricted range species (1 = native to Togo, 2 = species that extends beyond the region into neighboring countries, 3 = species [or its habitat] that does not occur, or is scarce, in Togo), RE 4 = African restricted range species that occurs outside West Africa, W=Widespread African species (1 = native to Togo, 2 = not found in Togo, 3 = species [or its habitat] that does not occur, or is scarce, in Togo, 4 = also found outside the African continent), EX, Exotic to the African continent.

[a]According to Wagner, Böhme, Pauwels, and Schmitz (2009), two populations occur in western Africa, that is, *fernandi* and *harlani*; however, the authors could not provide records for Togo and Benin.

[b]Upgraded to Near Threatened in 2019/2020.

[c]Identification unconfirmed.

[d]Listed in 2017.

[e]Listed under *Psittacus erithacus*, January 2017, listed on the IUCN Red List (updated 2018) as extinct in Togo.

[f]Upgraded to Endangered in August 2020.

[g]Uplisted to Appendix I in November 2019 (date of post: June 10, 2017).

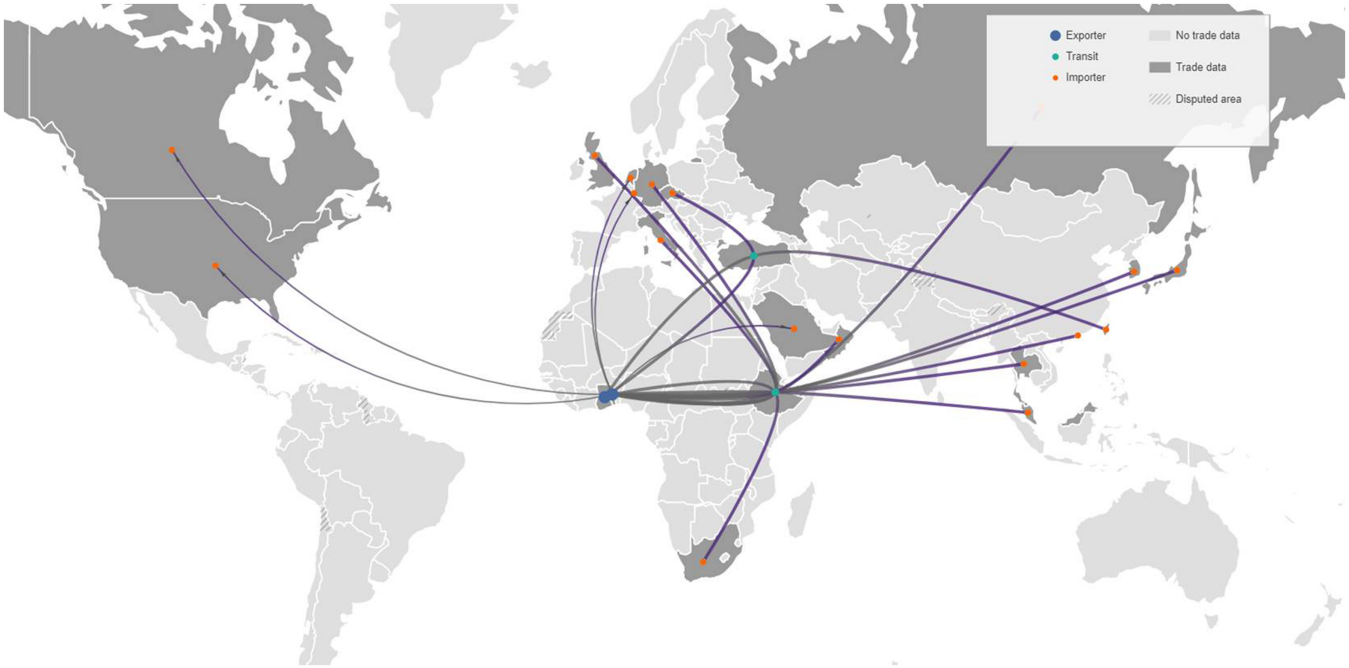


FIGURE 4 Trade routes and international destinations for exotic pets exported by two wildlife exporters from Togo, West Africa, identified on the basis of Airway Bill (AWB) number tracking (from AWB numbers seen in images of shipping crates, $n = 40$; shown as thick lines), and destinations named on shipping crates (also in shipping crate images, $n = 85$; shown as thin lines). Note that AWB tracking provides route details (i.e., flights via Egypt and Turkey shown in the figure), whereas destinations based only on place names are via unknown routes, indicated as direct routes on the map. Map drawn using TradeMapper (TRAFFIC, 2018)

Ethiopia) or Turkish Cargo (departing from Accra Airport, Ghana and flying via Turkey, predominantly to Taiwan) (Figure 4). Labeling on crates revealed involvement of three additional airlines (Royal Air Maroc [Moroccan airline], Delta Airlines, and Lufthansa cargo) and five additional country destinations (Table S3b). In total, there was evidence of shipments going to 18 different countries (Figure 4).

4 | DISCUSSION

4.1 | Diversity and extent of live wildlife trade from two exporters in Togo

Our study reveals a hugely diverse exotic pet trade sourced in Togo and surrounding countries and provides the most detailed insight as yet available into wildlife trade activity from a recognized trade hub and major exporter in West Africa. More broadly, our study also demonstrates how similar social media-based surveys could be used to, effectively and efficiently, characterize and monitor legal and illegal aspects of the global exotic pet trade in supply-side countries. Data retrieved from just two social media accounts allowed us to identify at least 200 species advertised as available for sale or export, comprising a range of taxa (vertebrate and invertebrate), from millipedes, to parrots, and primates (Table S1a, b). The mammals and birds presented were highly diverse (Table 1; including, e.g., among the mammals, bats, rodents, lagomorphs, small carnivores, and primates). Yet, reptiles were most often depicted in Facebook posts and comprised the most species compared with all other vertebrate classes (Table 1), including several species subject to regular international demand (such as the fat-tail gecko, *Hemitheconyx caudicinctus*, Togo fire skink, and the rough-scaled plated lizard, *Broadleysaurus major*) and a number of charismatic species restricted to west African forest habitats (e.g., the sawtail lizard, *Holaspis guentheri*, Conrau's dwarf gecko, *Lygodactylus conraui*, the rhinoceros viper, *Bitis nasicornis* and the West African gaboon viper, *B. rhinoceros*; cf. Auliya, 2003).

Some of the reptiles identified are reported to be "ranched" for export in Togo (e.g., ball pythons, *Python regius*, Calabar boas, *Calabaria reinhardtii*, Savannah monitor lizards, hinge-back tortoises, *Kinixys* spp., chameleons, *Chameleo* spp., and the African softshell turtle, *Trionyx triunguis*)—a process that involves the collection of eggs and gravid females (of which a pre-determined percentage are returned to the wild after they have laid their eggs; see D'Cruze, Harrington, Assou, Ronfot, et al., 2020) and is intended as a strategy to avoid

unsustainable wild off-take (but see discussion in D'Cruze, Bates, Assou, Ronfot, et al., 2020). African spurred tortoises (a species that does not occur or was extirpated in Togo, cf. Petrozzi et al., 2020) are captive-bred in Togo (but there are questions regarding the acquisition of breeding stock and dependence on wild-sourced animals, CITES SC71 Doc.13). Statements in the post text, however, together with the diversity of species (across taxa), and age classes shown, indicate that several of the species identified were also taken directly from the wild. Six percent ($n = 10$) of vertebrate species identified are threatened; notably, the flapshell turtles (*Cyclanorbis* spp.), which may have included the Critically Endangered Nubian flapshell turtle, a species considered to have largely disappeared from across its west and central African range (Baker, Luiselli, & Diagne, 2016). Almost one-third of vertebrate species identified were not evaluated on the IUCN Red list, and three-quarters of all identified vertebrate species were not listed in the appendices of CITES.

Images posted on social media showing animals apparently packaged for shipping, together with labeled shipping crates, suggested that shipments were made at a minimum once per month (up to nine times per month), containing potentially several hundred (and possibly several thousand) individuals, supplying at least 18 countries (in total) in North America, Europe, Asia, and elsewhere in Africa, via a number of major airlines.

4.2 | Conservation risks

Among the threatened species advertised, there was no mention of rarity suggesting that other factors (such as diversity, popularity, and regular demand) that might appeal to commercial buyers (as well as availability) were the intention, rather than rarity, which is often desired by specialist collectors (Angulo & Courchamp, 2009) and is associated with a high extinction risk (Courchamp et al., 2006). However, this strategy is not without conservation risk. Of the threatened species native to Togo, all were reported to have decreasing populations (Table 2 (b)), so any off take (even at low levels) could be potentially damaging to local populations in the absence of careful monitoring of population size and additional threats.

Among the advertised species that have established export quotas in Togo under CITES regulations, it is noteworthy that during the period of this study, zero quotas for both ranched and wild-sourced Home's hinge-back tortoise (*Kinixys homeana*) were published (https://www.speciesplus.net, Table 2(b)). This species, together with other *Kinixys* spp. (see Table S1a), is internationally sought-after as an exotic pet (e.g., Luiselli et al., 2016, 2018; Segniagbeto, 2016; Segniagbeto, Afiademagno, Akani, Petrozzi, & Luiselli, 2015; UNEP-WCMC, 2010), but like all turtles, and particularly tortoises, is vulnerable to over-exploitation due to their unfavorable life history traits (i.e., late maturity, and low reproductive output, see Bonin, Devaux, & Dupré, 2006; Vitt & Caldwell, 2009). The harvest of adult specimens is particularly detrimental. For all three *Kinixys* spp. identified during this study (including *K. homeana*), at least 30 individuals could be counted in a single image, and images of mature individuals (of both sexes) packaged for shipping were seen in addition to those of juveniles. The two threatened bird species observed have more recently been uplisted to CITES Appendix I (Table 2(b)), prohibiting further commercial trade.

Forest-limited species in Togo may be particularly vulnerable to off take and trade given the degradation and fragmentation of their habitat (closed-canopy forest and tree-savanna) due to agricultural expansion, bush fires, and timber extraction (Atsri, Konko, Cuni-Sanchez, Abotsi, & Kokou, 2018; Dangbo et al., 2020). While none of the three West African "forest" primate species that have been evaluated on the IUCN Red List (Table 2(a)) are currently considered to be threatened by the pet trade (and they appeared only occasionally among the images of animals available), all are thought to be severely impacted by hunting for bushmeat and habitat loss (Matsuda Goodwin et al., 2020; Svensson, Oates, Pimley, & Gonedelé Bi, 2020), and in recent IUCN Red List assessments have been upgraded to a higher threat level. This includes the white-throated guenon *Cercopithecus erythrogaster*, a species found only in the rainforests in Nigeria and Togo, and recently classified on the IUCN Red List as Endangered (Matsuda Goodwin, Segniagbeto, Nobimè, & Imong, 2020). The two large viper species (the Gaboon viper, *Bitis gabonica*, and the rhinoceros viper) are also hunted for bushmeat across western Africa (e.g., Akani, Luiselli, Angelici, & Politano, 1998; Brugiere & Magassouba, 2009; Soaga, Shotuyo, Oduntan, & Fatoki, 2015). For these already vulnerable species, local populations may not be able to withstand any additional (even occasional) pressure.

Only one of these forest species (the ornate monitor, *Varanus ornatus*, morphologically but not genetically distinct from the Nile monitor, *V. niloticus*, Dowell et al., 2016), that we here consider an ecomorph, is CITES-listed. Conrau's dwarf gecko together with other congeners elsewhere appears to be a substitute for the now Critically Endangered turquoise dwarf (or "electric blue") gecko *Lygodactylus williamsi* from Tanzania, which was listed on CITES Appendix I in 2017 (cf. Altherr, Freyer, & Lameter, 2020).

For the non-threatened species, the high proportion reported to have unknown or declining populations, or that are not yet evaluated on the IUCN Red List, highlights uncertainty in terms of sustainable off take for many of the species currently traded. And, beyond individual species-specific issues, the diversity of species collected from across a range of habitat types suggests the potential for broad scale impacts on native biodiversity (Dirzo et al., 2014 and references therein). Invertebrates, in particular, generally attract little attention in the wildlife trade (Fukushima, Mammola, & Cardoso, 2020), despite the key ecological roles they play globally (e.g., Cardoso et al., 2020). Elsewhere, there is considerable global demand for some invertebrate species (e.g., stag beetles in Japan, New, 2005; see also Simičević, 2017; Esmail et al., 2020) and, in this study, although we did not attempt to identify the species involved, we observed invertebrates in Facebook posts at similar frequency to mammals in pre-shipment and shipment settings (albeit usually in higher numbers).

Beyond Togo, transport of any of the species identified in this study outside their native range also represents a potential invasive risk (Lockwood et al., 2019 and references therein; Nelufule et al., 2020). Most notable among the species observed was the red-eared slider, a North American species, not known to occur in Togo but established in wetlands throughout the world (Liu et al., 2020; Pearson, Avery, & Spotila, 2015) and considered one of the worlds' "100 most invasive species" (Global Invasive Species Database, 2020; Lowe, Browne, & Boudjelas, 2000).

4.3 | Broader implications: Animal welfare and public health

Animal welfare standards on farms appeared to be poor, with most images showing animals in barren containers, lacking shelter or water, and often in overcrowded conditions. While some of the images may not have been representative of long-term care (e.g., animals photographed in buckets may show animals as they are collected from the wild, and before they are properly housed), there was little evidence of "good" welfare conditions in any of the images observed (FIgure S2). In addition, although further on the ground research would be required to establish the degree of compliance with IATA Live Animal Regulations (https://www.iata.org/en/programs/cargo/live-animals/), preliminary observations of images showing animals being packaged for shipping revealed at least some cases where (in terms of space criteria alone) tortoises packed in restricted spaces were highly unlikely to be able to fully extend their head and neck during the journey (Figure 2a). Airlines found to be in violation of the regulations may be subject to legal penalties (www.iata.org). Animal welfare in captive settings (including during transport) is relevant not only to the welfare of the animals themselves but also to public health, where poor conditions such as over-crowding and proximity to other species (particularly where it is hot and humid) can create an environment for zoonotic disease emergence and spread (Greger, 2007; Tu et al., 2004 and references therein).

Trade routes identified (Figure 4) show how far and wide a potential zoonotic disease (or invasive species) could be spread (at a minimum since there may be additional flight paths and destinations not mentioned in posts or shown in images). A number of species observed in the images viewed highlight the potential zoonotic disease risks. For example, both genets and civets (Family Viverridae) can act as hosts for several pathogens including 11 viruses that have potential significance for human and animal health (Wicker, Canfield, & Higgins, 2017). Genets (*Genetta* spp.) were the most frequently posted type of mammal, and images of animals in shipping crates (Figure 2b) provided evidence that pardine genets (*G. pardina*, and possibly also common genets, *G. genetta*), African civets, and Egyptian mongooses, were exported (with shipments identified to Italy and Japan). Various internet sources (e.g., https://www.thesprucepets.com/pet-genets-1239556, https://pethelpful.com/exotic-pets/genetcare) suggest that genets are increasingly popular as exotic pets, as are African civets (https://www.youtube.com/watch?v=h_wTxJKxIjE; despite the association of the Chinese masked palm civet *Paguma larvata* with the 2003–2004 outbreak of SARS-CoV; (Tu et al., 2004). Venomous snakes sourced from the wild can pose potential risks to snake catchers, traders, and eventual owners (Hierink et al., 2020) and more generally reptiles can carry a number of chronic "unseen" zoonotics, such as reptile-bourne *Salmonella* (Pasmans et al., 2017). A full review of disease risk is beyond the scope of this study but see Karesh et al. (2005), Boseret, Losson, Mainil, Thiry, and Saegerman (2013), Smith et al. (2017), and Can et al. (2019).

4.4 | Compliance and regulation

Trade route details revealed that a number of shipments left West Africa from Accra in Ghana (Table S3a; approximately 20 km from Lomé, Togo), which may have been advantageous for exporters because Accra is internationally better connected than Lomé (www.flightconnections.com). It is also possible that, for some species, exporters

were using Ghana to circumvent limited trade quotas in Togo (e.g., a zero export quota was established for wild-sourced Home's hinge-back tortoises from Togo at the request of the CITES Standing Committee [SC67 SR] in 2016, while Ghana maintained a quota of several hundred, https://speciesplus.net; see also Luiselli et al., 2016). Similarly, evidence of species that are not found (or are scarce) in Togo and presumably originally sourced from other west African countries (e.g., Geyr's spiny-tailed lizard, *Uromastyx geyri*, found in neighboring Niger [Wilms, Wagner, & Niagate, 2018], and subject to a zero export quota between 2008 and 2017, https://speciesplus.net), suggests that some species are transported across national borders (possibly illegally, or in excess of agreed quotas) before being shipped to other continents. Whether or not these intra-continental movements were in compliance with CITES regulations (i.e., with required permits, in accordance with established export quotas, and correctly reported as re-exports from Togo) warrants further investigation.

Currently, however, international trade in only a small proportion of the species we observed advertised is regulated under CITES. More broadly, there is no overarching body to regulate or address the potential impacts (positive or negative) of the global supply of exotic pets on biodiversity, animal welfare, and/or public health, and although there are a number of international entities and corporations that could play an influential role, it is not always immediately clear where responsibility lies. For example, at a national level, animal welfare is beyond the remit of CITES and so (in the absence of local animal welfare laws) even CITES-listed species are not protected in this regard until they reach an international border where CITES requires Parties to ensure "minimal delays" [in processing and transport] and "proper care" [of living specimens] (Res. Conf. 10.21 [Rev. CoP16]). IATA Live Animal Regulations only come into force when animals are actually loaded onto the airline.

There is also a recognized lack of biosecurity measures at farms in West Africa (D'Cruze, Harrington, Assou, Green, et al., 2020), but while safeguarding of human health falls under the remit of several international organizations including the World Health Organisation (WHO, www.who.int) and the World Organisation for Animal Health (OIE, www.oie.int), their role is primarily advisory. In practice, there is a lack of surveillance for key animal diseases in most countries and relatively limited implementation of health regulations in the wild animal trade compared with agricultural trade (Smith et al., 2017). Furthermore, Facebook and some other social media and e-commerce platforms prohibit commerce listings that promote buying or selling live animals (https://www.facebook.com/policies) to protect animal welfare. However, identifying listings that violate hosting platform policies is often dependent on reports by the public, and there are no regulatory bodies to provide oversight (Esmail et al., 2020). Similarly, while a number of major airlines have recently committed to tackling illegal trafficking of wildlife (e.g., the Buckingham Palace Declaration, https://unitedforwildlife.org), their remit (beyond animal welfare conditions during transport) is often limited where trade is legal.

4.5 | Knowledge gaps, limitations, and policy recommendations

This type of international commercial wildlife trade presumably provides a valuable source of income and profit, including for local communities (see, e.g., D'Cruze, Harrington, Assou, Ronfot, et al., 2020—albeit possibly limited to relatively few key actors), but a key question is whether the (potentially short term) economic benefits outweigh the (potentially long-term) costs (e.g., biodiversity loss due to over-exploitation) and risks (e.g., impacts on biodiversity elsewhere due to invasive species, and disease outbreak due to the spread of zoonoses, cf. Montgomery & Macdonald, 2020). Research is required on the economics of the trade (including information on local dependence on the trade, and who profits financially), sustainability, biosecurity, and whether there are alternatives that could benefit both people and wildlife.

Our data were limited by what the exporters chose to advertise in the public domain, and by the posts that were online during the period of observation (i.e., any previously deleted posts could not be seen, although we expect those to be few). Moreover, our study was based on just two Facebook accounts. As such we do not suggest that the data provided here represent a complete inventory of species traded from Togo or are necessarily representative of all other wildlife exporters in Togo. However, the data presented here are in keeping with observations made during visits to reptile farms in Togo as part of an earlier study (D'Cruze, Bates, Assou, Ronfot, et al., 2020), and a Facebook search for "wildlife exporter/s Togo" at the conclusion of this study revealed only one other social media account belonging to a wildlife exporter in Togo. This suggests that these two exporters were two of a limited number that operate via social media. It is also possible that not all species shown were actually sold and exported. The lack of engagement between exporters and prospective buyers in the post comments, for example, suggest that negotiations may have taken place via a different platform (e.g., encrypted private messenger applications, such as WhatsApp) given in their contact details. Similarly, we make no attempt to estimate the volume of trade carried out by the two

anonymized wildlife exporters that were the subject of the study, although we note that single images showed more than 20 crates packaged for shipping, each of which could contain several hundred individuals. We also do not suggest that these data are representative of trade elsewhere, rather they demonstrate, despite inherent limitations, the type and extent of information that can be obtained from systematic scrutiny of social media data, and the insights that can be gained (particularly on the supply-side of the trade chain—on species involved, age classes exported, frequency of exports, and trade routes used) that would otherwise be inaccessible.

In summary, our study reveals the magnitude of a trade that depends predominantly on native wildlife and (given the proportion of non-CITES listed species involved) appears to fall largely outside the current standard regulatory system afforded under CITES. Togo is a trade hub that is already under some scrutiny from CITES (cf. UNEP-WCMC, 2010) but research and policy action is required (see, e.g., D'Cruze, Harrington, Assou, Green, et al., 2020; Mallon et al., 2015; Segniagbeto, 2016). For Togo specifically, we recommend assessment of (a) the population status of, and major threats to, native wildlife (e.g., via a National Red List), (b) the health and welfare of wild animals involved in trade, and (c) the potential biosecurity risk associated with the live wild animal trade. More broadly, we urge policy makers and conservation scientists to consider how best to regulate this trade in a more holistic manner (cf. Macdonald, 2019; Marshall et al., 2020), to ensure that it is not only sustainable from a population perspective but also safe, and humane, while recognizing that for some species trade restrictions may represent the most appropriate management tool. Currently, assessment of the species subject to trade suggests that there are gaps in management and policy, concerning lack of monitoring of population status, disease, biological invasion, and welfare risks, as well as neglected taxa (e.g., invertebrates), all of which have potential implications for environmental, public, and animal health. The diversity of species involved and the global reach of just two exporters in a small West African country described here, beg the question: what is the situation (and its impact) in the rest of the world? Given the growing nature of global social media engagement (www.statista.com), a systematic review of social media activity such as demonstrated here but at a global scale could provide an efficient approach to help answer this question, to highlight where regulation may be needed, and to inform necessary international and national policy change.

ACKNOWLEDGMENTS

This study was funded by World Animal Protection. Mark-Oliver Rödel kindly assisted in the identification of some amphibian species and Philippe Gaubert in the identification of genets. The manuscript benefited from the comments of three anonymous reviewers.

CONFLICT OF INTEREST

The authors declare no conflicts of interest. The study was funded by an animal welfare organization but the funding source did not in any way influence our findings, which were based entirely on species identified in images, published species-specific information (e.g., CITES and IUCN Red List listings), and standard specified methods of welfare assessment.

AUTHOR CONTRIBUTIONS

N.D.C. conceived the study, N.D.C., M.A., and L.A.H. designed the study, H.E. and A.P.H. collated FaceBook data and contributed to interpretation, M.A. provided species expertise, L.A.H. analyzed the data. All authors wrote, reviewed, and edited the manuscript.

DATA AVAILABILITY STATEMENT

All data supporting this publication are included in the supplemental material.

ORCID

Lauren A. Harrington https://orcid.org/0000-0002-7212-2336

REFERENCES

Akani, G. C., Luiselli, L., Angelici, F. M., & Politano, E. (1998). Bushmen and herpetofauna: Notes on amphibians and reptiles traded in bushmeat markets of local people in The Niger Delta (Port Harcourt, Rivers state, Nigeria). *Anthropozoologica*, *27*, 21–26.

Altherr, S., Freyer, D., & Lameter, K. (2020). Strategien zur Reduktion der Nachfrage nach als Heimtiere gehaltenen Reptilien, Amphibien und kleinen Säugetieren. In *BfN-Skripten 545* (p. 465). Bundesamt für: Naturschutz, Bonn.

Angulo, E., & Courchamp, F. (2009). Rare species are valued big time. *PLoS One*, *4*, e5215.

Atsri, H. K., Konko, Y., Cuni-Sanchez, A., Abotsi, K. E., & Kokou, K. (2018). Changes in the west African forest-savanna mosaic, insights from Central Togo. *PLoS One*, *13*, e0203999.

Auguie, B. (2017). gridExtra: Miscellaneous Functions for "Grid" Graphics. R package version 2.3. https://CRAN.R-project.org/package=gridExtra

Auliya, M. (2003). *Hot trade in cool creatures: A review of the live reptile trade in the European Union in the 1990s with a focus on Germany*. Brussels, Belgium: TRAFFIC Europe.

Auliya, M., Altherr, S., Ariano-Sanchez, D., Baard, E. H., Brown, C., Brown, R. M., … Ziegler, T. (2016). Trade in live reptiles, its impact on wild populations, and the role of the European market. *Biological Conservation*, *204*, 103–119.

Baker, P.J., Luiselli, L. & Diagne, T. (2016). *Cyclanorbis elegans*. The IUCN Red List of Threatened Species 2016: e.T6004A3086539. Retrieved from https://doi.org/10.2305/IUCN.UK.2016-2.RLTS.T6004A3086539.en

Baker, S. E., Cain, R., van Kesteren, F., Zommers, Z. A., D'Cruze, N., & Macdonald, D. W. (2013). Rough trade: Animal welfare in the global wildlife trade. *Bioscience*, *63*, 928–938.

Bonin, F., Devaux, B., & Dupré, A. (2006). *Turtles of the world*. Baltimore, MD: Johns Hopkins.

Borsky, S., Hennighausen, H., Leiter, A., & Williges, K. (2020). CITES and the zoonotic disease content in international wildlife trade. *Environmental and Resource Economics*, *76*, 1001–1017.

Boseret, G., Losson, B., Mainil, J. G., Thiry, E., & Saegerman, C. (2013). Zoonoses in pet birds: Review and perspectives. *Veterinary Research*, *44*, 36.

Brown, C. M. (2008). Reaping the whirlwind? Human disease from exotic pets. *Bioscience*, *58*, 6–7.

Brugiere, D., & Magassouba, B. (2009). Pattern and sustainability of the bushmeat trade in the haut Niger National Park, Republic of Guinea. *African Journal of Ecology*, *47*, 630–639.

Bush, E. R., Baker, S. E., & Macdonald, D. W. (2014). Global trade in exotic pets 2006–2012. *Conservation Biology*, *28*, 663–676.

Can, Ö. E., D'Cruze, N., & Macdonald, D. W. (2019). Dealing in deadly pathogens: Taking stock of the legal trade in live wildlife and potential risks to human health. *Global Ecology and Conservation*, *17*, e00515.

Cardoso, P., Barton, P. S., Birkhofer, K., Chichorro, F., Deacon, C., Fartmann, T., … Samways, M. J. (2020). Scientists' warning to humanity on insect extinctions. *Biological Conservation*, *242*, 108426.

Cooney, R., Kasterine, A., Macdonald, D. W., Milledge, S., Nossal, K., Roe, D., & 't. Sas-Rolfes, M. (2015). *The trade in wildlife: A framework to improve biodiversity and livelihood outcomes*. Geneva, Switzerland: International Trade Centre.

Core Team, R. (2020). *R: A language and environment for statistical computing*. Vienna, Austria. Retrieved from: R Foundation for Statistical Computing. https://www.R-project.org/

Courchamp, F., Angulo, E., Rivalan, P., Hall, R. J., Signoret, L., Bull, L., & Meinard, Y. (2006). Rarity value and species extinction: The anthropogenic allee effect. *PLoS Biology*, *4*, e415.

D'Cruze, N., Bates, J., Assou, D., Ronfot, D., Coulthard, E., Segniagbeto, G. H., … Rowntree, J. (2020). A preliminary assessment of bacteria in "ranched" ball pythons (*Python regius*), Togo, West Africa. *Nature Conservation*, *39*, 73–86.

D'Cruze, N., Harrington, L. A., Assou, D., Green, J., Macdonald, D. W., Ronfot, D., … Auliya, M. (2020). Betting the farm: A review of ball python and other reptile trade from Togo, West Africa. *Nature Conservation*, *40*, 65–91.

D'Cruze, N., Harrington, L. A., Assou, D., Ronfot, D., Macdonald, D. W., Segniagbeto, G. H., & Auliya, M. (2020). Searching for snakes: Ball python hunting in southern Togo, West Africa. *Nature Conservation*, *38*, 13–36.

Dangbo, F. A., Gardi, O., Adjonou, K., Hlovor, A. K. D., Blaser, J., & Kokou, K. (2020). An analytical assessment of forest cover changes over the last 30 years in the semi-deciduous forest zone of Togo. *Journal of Horticulture*, *12*, 70–83.

de Buffrénil, V. (1995). Les élevages de reptiles du Bénin, du Togo et du Ghana. Rapport d'étude réalisée Pour le Secrétariat de la CITES. 23 pp.

Di Minin, E., Brooks, T. M., Toivonen, T., Butchart, S. H. M., Heikinheimo, V., Watson, J. E. M., … Moilanen, A. (2019). Identifying global centers of unsustainable commercial harvesting of species. *Science Advances*, *5*, 1–7.

Dirzo, R., Young, H. S., Galetti, M., Ceballos, G., Isaac, N. J. B., & Collen, B. (2014). Defaunation in the Anthropocene. *Science*, *345*, 401.

Dowell, S. A., Portik, D. M., de Buffrénil, V., Ineich, I., Greenbaum, E., Kolokotronis, S.-O., & Hekkala, E. R. (2016). Molecular data from contemporary and historical collections reveal a complex story of cryptic diversification in the Varanus (Polydaedalus) niloticus species group. *Molecular Phylogenetics and Evolution*, *94*, 591–604.

Esmail, N., Wintle, B. C., t Sas-Rolfes, M., Athanas, A., Beale, C. M., Bending, Z., … Milner-Gulland, E. J. (2020). Emerging illegal wildlife trade issues: A global horizon scan. *Conservation Letters*, *13*, e12715.

Frank, E. G., & Wilcove, D. S. (2019). Long delays in banning trade in threatened species. *Science*, *363*, 686–688.

Fukushima, C. S., Mammola, S., & Cardoso, P. (2020). Global wildlife trade permeates the tree of life. *Biological Conservation*, *247*, 108503.

García-Díaz, P., Ross, J. V., Woolnough, A. P., & Cassey, P. (2017). The illegal wildlife trade is a likely source of alien species. *Conservation Letters*, *10*, 690–698.

Global Invasive Species Database. (2020). Species profile: *Trachemys scripta elegans*. Retrieved from http://www.iucngisd.org/gisd/speciesname/Trachemys+scripta+elegans

Greger, M. (2007). The human/animal interface: Emergence and resurgence of zoonotic infectious diseases. *Critical Reviews in Microbiology*, *33*, 243–299.

Harrington, L. A. (2015). International commercial trade in live carnivores and primates 2006-2012: Response to Bush et al. 2014. *Conservation Biology*, *29*, 293–296.

Harris, J. B. C., Tingley, M. W., Hua, F., Yong, D. L., Adeney, J. M., Lee, T. M., … Wilcove, D. S. (2017). Measuring the impact of the pet trade on Indonesian birds. *Conservation Biology*, *31*, 394–405.

Helm, D. (2015). *Natural capital: valuing the planet*. London, England: Yale University Press.

Hierink, F., Bolon, I., Durso, A. M., Ruiz de Castañeda, R., Zambrana-Torrelio, C., Eskew, E. A., & Ray, N. (2020). Forty-four years of global trade in CITES-listed snakes: Trends and implications for conservation and public health. *Biological Conservation*, *248*, 108601.

Huang, Z. (1998). Extensions to the k-means algorithm for clustering large data sets with categorical values. *Data Mining and Knowledge Discovery*, *2*, 283–304.

Hulme, P. E. (2009). Trade, transport and trouble: Managing invasive species pathways in an era of globalization. *Journal of Applied Ecology*, *46*, 10–18.

IFAW. (2014). *Wanted – dead or alive: Exposing online wildlife trade*. London, England: IFAW.

IFAW. (2017). *Out of Africa: Byting down on wildlife cybercrime*. London, England: IFAW.

Ineich, I. (2006). Les élevages de reptiles et de scorpions au Bénin, Togo et Ghana, plus particulière-ment la gestion des quotas d'exportation et la définition des codes 'source' des spécimens ex-portés. Rapport d'étude réalisée pour le Secrétariat de la CITES. *Projet CITES*, *A-251*, 1–113.

IUCN Species Survival Commission. (2012). *IUCN red list categories and criteria, version 3.1* (2nd ed.). Gland and Cambridge, England: IUCN.

Jensen, T. J., Auliya, M., Burgess, N. D., Aust, P. W., Pertoldi, C., & Strand, J. (2018). Exploring the inter- national trade in African snakes not listed on CITES: Highlighting the role of the internet and social media. *Biodiversity and Conservation*, *28*, 1–19.

Karesh, W. B., Cook, R. A., Bennett, E. L., & Newcomb, J. (2005). Wildlife trade and global disease emergence. *Emerging Infectious Diseases*, *11*, 1000–1002.

Kosinski, M., Matz, S., Gosling, S., Popov, V., & Stillwell, D. (2015). Facebook as a research tool for the social sciences: Opportunities, challenges, ethical considerations, and practical guidelines. *American Psychologist*, *70*, 543–556.

Krishnasamy, K., & Stoner, S. (2016). *Trading faces: A rapid assessment on the use of Facebook to trade wildlife in peninsular Malaysia*. Petaling Jaya, Selangor, Malaysia: TRAFFIC.

Krishnasamy, K., & Zavagli, M. (2020). *Southeast Asia: At the heart of wildlife trade*. Petaling Jaya, Selangor, Malaysia: TRAFFIC, Southeast Asia Regional Office.

Kuiken, T., Leighton, F. A., Fouchier, R. A. M., LeDuc, J. W., Peiris, J. S. M., Schudel, A., & Osterhaus, A. D. M. E. (2005). Pathogen Surveillance in Animals. *Science*, *309*, 1680.

Lavorgna, A. (2014). Wildlife trafficking in the internet age. *Crime Science*, *3*, 5.

Liu, S., Newman, C., Buesching, C. D., Macdonald, D. W., Zhang, Y., Zhang, K.-J., ... Zhou, Z.-M. (2020). E-commerce promotes trade in invasive turtles in China. *Oryx*, 1–4. https://doi.org/10.1017/S0030605319001030

Lockwood, J. L., Welbourne, D. J., Romagosa, C. M., Cassey, P., Mandrak, N. E., Strecker, A., ... Keller, R. (2019). When pets become pests: The role of the exotic pet trade in producing invasive vertebrate animals. *Frontiers in Ecology and the Environment*, *17*, 323–330.

Lowe, S., Browne, M., & Boudjelas, S. (2000). *100 of the World's worst invasive alien species. A selection from the global invasive species database*. Auckland, New Zealand: IUCN/SSC Invasive Species Specialist Group (ISSG).

Luiselli, L., Dendi, D., Pacini, N., Amadi, N., Akani, G. C., Eniang, E. A., & Ségniagbeto, G. H. (2018). Interviews on the status of west African forest tortoises (genus Kinixys), including preliminary data on the effect of snail gatherers on their trade. *Herpetological Journal*, *28*, 171–177.

Luiselli, L., Starita, A., Carpaneto, G. M., Segniagbeto, G., & Amori, G. A. (2016). Short review of the international trade of wild tortoises and freshwater turtles across the world and throughout two decades. *Chelonian Conservation Biology*, *15*, 167–172.

Macdonald, D. W. (2019). Mammal conservation: Old problems, new perspectives, transdisciplinarity, and the coming of age of conservation geopolitics. *Annual Review of Environment and Resources*, *44*, 61–88.

Mallon, D. P., Hoffmann, M., Grainger, M. J., Hibert, F., van Vliet, N., & McGowan, P. J. K. (2015). *An IUCN situation analysis of terrestrial and freshwater fauna in West and Central Africa*. Occasional Paper of the IUCN Species Survival Commission No. 54 (p. 162). Gland, Switzerland and Cambridge, England: IUCN.

Marshall, B. M., Strine, C., & Hughes, A. C. (2020). Thousands of reptile species threatened by under-regulated global trade. *Nature Communications*, *11*, 4738.

Martin, R. O., Senni, C., & D'Cruze, N. C. (2018). Trade in wild-sourced African grey parrots: Insights via social media. *Global Ecology and Conservation*, *15*, e00429.

Matsuda Goodwin, R., Oates, J.F., Nobimè, G., Segniagbeto, G.H., Ikemeh, R. & Mittermeier, R.A. (2020). *Cercopithecus erythrogaster*. The IUCN Red List of Threatened Species 2020: e. T4217A17946182. Retrieved from https://doi.org/10.2305/IUCN.UK.2020-2.RLTS.T4217A17946182.en

Matsuda Goodwin, R., Segniagbeto, G., Nobimè, G. & Imong, I. (2020). *Cercopithecus mona*. The IUCN Red List of Threatened Species 2020: e.T4222A17946672. Retrieved from https://doi.org/10.2305/IUCN.UK.2020-2.RLTS.T4222A17946672.en

Milner-Gulland, E. (2018). Documenting and tackling the illegal wildlife trade: Change and continuity over 40 years. *Oryx*, *52*, 597–598.

Montgomery, R. A., & Macdonald, D. W. (2020). COVID-19, health, conservation, and shared wellbeing: Details matter. *Trends in Ecology and Evolution*, *35*, 748–750.

Morcatty, T. Q., Feddema, K., Nekaris, K. A. I., & Nijman, V. (2020). Online trade in wildlife and the lack of response to COVID-19. *Environmental Research*, *193*, 110439.

Nelufule, T., Robertson, M. P., Wilson, J. R., Faulkner, K. T., Sole, C., & Kumschick, S. (2020). The threats posed by the pet trade in alien terrestrial invertebrates in South Africa. *Journal for Nature Conservation*, *24*, 125831.

New, T. R. (2005). Inordinate fondness: A threat to beetles in South East Asia? *Journal of Insect Conservation*, *9*, 147–150.

Pasmans, F., Bogaerts, S., Braeckman, J., Cunningham, A. A., Hellebuyck, T., Griffiths, R. A., ... Martel, A. (2017). Future of keeping pet reptiles and amphibians: Towards integrating animal welfare, human health and environmental sustainability. *The Veterinary Record*, *181*, 450. https://doi.org/10.1136/vr.104296

Pearson, S. H., Avery, H. W., & Spotila, J. R. (2015). Juvenile invasive red-eared slider turtles negatively impact the growth of native turtles: Implications for global freshwater turtle populations. *Biological Conservation*, *186*, 115–121.

Petrozzi, F., Hema, E. M., Demaya, G. S., Benansio, J. S., Eniang, E. A., Diagne, T., ... Luiselli, L. (2020). Centrochelys sulcata (Miller 1779) – African Spurred Tortoise, Grooved Tortoise, Sahel Tortoise, Tortue Sillonnée. In A. G. J. Rhodin, J. B. Iverson, P. P. van Dijk, C. B. Stanford, E. V. Goode, K. A. Buhlmann, & R. A. Mittermeier (Eds.), *Conservation biology of freshwater turtles and tortoises: A compilation project of the IUCN/SSC tortoise and freshwater turtle specialist group*. Chelonian Research Monographs (Vol. 5(14), pp. 110.1–110.16). https://doi.org/10.3854/crm.5.110.sulcata.v1.2020; https://www.iucn-tftsg.org/cbftt/.

Phelps, J., Biggs, D., & Webb, E. L. (2016). Tools and terms for understanding illegal wildlife trade. *Frontiers in Ecology and the Environment*, *14*, 479–489.

Robinson, J. E., Griffiths, R. A., Fraser, I. M., Raharimalala, J., Roberts, D. L., & St. John, F. A. V. (2018). Supplying the wildlife trade as a livelihood strategy in a biodiversity hotspot. *Ecology and Society*, *23*, 13.

Roe, D. (2008). *Trading nature: A report, with case studies, on the contribution of wildlife trade management to sustainable livelihoods and the Millennium Development Goals*. Cambridge, England: TRAFFIC International.

Roe, D., Mulliken, T., Milledge, S., Mremi, J., Mosha, S., & Grieg-Gran, M. (2002). *Making a killing or making a living? Wildlife trade, trade controls and rural livelihoods*. Biodiversity and Livelihoods Issue No.6. London: IIED and TRAFFIC.

Scheffers, B. R., Oliveira, B. F., Lamb, I., & Edwards, D. P. (2019). Global wildlife trade across the tree of life. *Science*, *366*, 71.

Schlaepfer, M., Hoover, C., & Dodd, J. C. (2005). Challenges in evaluating the impact of the trade in amphibians and reptiles on wild populations. *Bioscience*, *55*, 256–264.

Segniagbeto, G. H. (2016). *Study on four species of fauna subject to international trade in Togo. Ministry of the Environment and forest resources* (p. 51). Lomé, Togo: Department of Zoology and Animal Biology, Faculty of Sciences, University of Lomé.

Segniagbeto, G. H., Afiademagno, K., Akani, G. C., Petrozzi, F., & Luiselli, L. (2015). Sex ratio, size structure and morphometrics of turtle populations from Togo, West Africa. *Herpetozoa*, *28*, 29–38.

Sharma, C. P., Kumar, A., Vipin, Sharma, V., Singh, B., Kumar, G. C., & Gupta, S. K. (2019). Online selling of wildlife part with spurious name: A serious challenge for wildlife crime enforcement. *International Journal of Legal Medicine*, *133*, 65–69.

Simičević, V. (2017). Poachers threaten Balkans underground biodiversity. *Science*, *358*, 1116–1117.

Sinovas, P., Price, B., King, E., Hinsley, A., & Pavitt, A. (2017). *Wildlife trade in the Amazon countries: An analysis of trade in CITES listed species*. Technical report prepared for the Amazon Regional Program (BMZ/DGIS/GIZ). Cambridge, England: UN Environment - World Conservation Monitoring Centre.

Siriwat, P., Nekaris, K. A. I., & Nijman, V. (2019). The role of the anthropogenic Allee effect in the exotic pet trade on Facebook in Thailand. *Journal for Nature Conservation*, *51*, 125726.

Siriwat, P., & Nijman, V. (2018). Illegal pet trade on social media as an emerging impediment to the conservation of Asian otters species. *Journal of Asia Pacific Biodiversity*, *11*, 469–475.

Siriwat, P., & Nijman, V. (2020). Wildlife trade shifts from brick-and-mortar markets to virtual marketplaces: A case study of birds of prey trade in Thailand. *Journal of Asia Pacific Biodiversity*, *13*, 454–461.

Smith, K. M., Machalaba, C. M., Jones, H., Cáceres, P., Popovic, M., Olival, K. J., ... Karesh, W. B. (2017). Wildlife hosts for OIE-listed diseases: Considerations regarding global wildlife trade and host-pathogen relationships. *Veterinary Medicine and Science*, *3*, 71–81.

Smith, M. J., Benítez-Díaz, H., Clemente-Muñoz, M. Á., Donaldson, J., Hutton, J. M., McGough, H. N., ... Morgan, D. H. (2011). Assessing the impacts of international trade on CITES-listed species: Current practices and opportunities for scientific research. *Biological Conservation*, *144*, 82–91.

Soaga, J. A., Shotuyo, A. L. A., Oduntan, O. O., & Fatoki, J. G. (2015). Economic analysis of bushmeat trade in Abeokuta, Ogun State. *Journal of Environmental and Agricultural Sciences*, *14*, 97–108.

Steinmetz, M., Pütsch, M., & Bisschopinck, T. (1998). *Transport mortality during the import of wild caught birds and reptiles to Germany: An investigation; including a study on pre-export-conditions in the United Republic of Tanzania*. Bonn, Germany: German Federal Agency for Nature Conservation.

Stringham, O. C., & Lockwood, J. L. (2018). Pet problems: Biological and economic factors that influence the release of alien reptiles and amphibians by pet owners. *Journal of Applied Ecology*, *55*, 2632–2640.

Sung, Y.-H., & Fong, J. J. (2018). Assessing consumer trends and illegal activity by monitoring the online wildlife trade. *Biological Conservation*, *227*, 219–225.

Svensson, M., Oates, J.F., Pimley, E. & Gonedelé Bi, S. (2020). *Perodicticus potto*. The IUCN Red List of Threatened Species 2020: e.T91995408A92248699. Retrieved from https://doi.org/10.2305/IUCN.UK.2020-2.RLTS.T91995408A92248699.en

Sy, E. Y. (2018). *Trading faces: Utilisation of Facebook to trade live reptiles in The Philippines*. Petaling Jaya, Selangor, Malaysia: TRAFFIC.

TRAFFIC (2018) TradeMapper – a tool for visualising trade data. Retrieved from www.trademapper.co.uk

Travis, D. A., Watson, R. P., & Tauer, A. (2011). The spread of pathogens through trade in wildlife. *Revue Scientifique et Technique*, *30*, 219–239.

't Sas-Rolfes, M., Challender, D. W. S., Hinsley, A., Veríssimo, D., & Milner-Gulland, E. J. (2019). Illegal wildlife trade: Scale, processes, and governance. *Annual Review of Environment and Resources*, *44*, 201–228.

Tu, C., Crameri, G., Kong, X., Chen, J., Sun, Y., Yu, M., ... Wang, L. F. (2004). Antibodies to SARS coronavirus in civets. *Emerging Infectious Diseases*, *10*, 2244–2248.

UNEP-WCMC. (2009). *Review of non-CITES reptiles that are known or likely to be in international trade*. A Report to the European Commission. Cambridge, England: UNEP- WCMC.

UNEP-WCMC. (2010). *Review of species/country combinations subject to long-standing import suspensions: Reptile species from Africa*. Cambridge, England: UNEP- WCMC.

UNEP-WCMC. (2014). *Review of Python regius from Togo (source R)*. Cambridge, England: UNEP-WCMC.

UNODC. (2016). *World wildlife crime report: Trafficking in protected species* (p. 97). Vienna, Austria: United Nations Office on Drugs and Crime.

Vinke, S., & Vinke, T. (2012). Legal wildlife trade. *Schildkröten Im Fokus Online*, *2*, 1–15.

Vitt, L. J., & Caldwell, J. P. (2009). *Herpetology* (3rd ed., p. 697). Burlington, VT: Academic Press publications.

Wagner, P., Böhme, W., Pauwels, O. S. G., & Schmitz, A. (2009). A review of the African red-flanked skinks of the *Lygosoma fernandi* (BURTON, 1836) species group (Squamata: Scincidae) and the role of climate change in their speciation. *Zootaxa*, *2050*, 1–30.

Warwick, C., Arena, P. C., Steedman, C., & Jessop, M. (2012). A review of captive exotic animal-linked zoonoses. *Journal of Environmental Health Research*, *12*, 9–24.

Weihs, C., Ligges, U., Luebke, K., & Raabe, N. (2005). klaR analyzing German business cycles. In D. Baier, R. Decker, & L. Schmidt-Thieme (Eds.), *Data analysis and decision support* (pp. 335–343). Berlin, Germany: Springer-Verlag.

Wicker, L. V., Canfield, P. J., & Higgins, D. P. (2017). Potential pathogens reported in species of the family Viverridae and their implications for human and animal health. *Zoonoses and Public Health*, *64*, 75–93.

Wickham, H. (2016). *ggplot2: Elegant graphics for data analysis*. New York, NY: Springer-Verlag.

Wilms, T., Wagner, P. & Niagate, B. (2018). *Uromastyx geyri*. The IUCN Red List of Threatened Species 2018: e. T198536A2531409.

Ye, Y.-C., Yu, W.-H., Newman, C., Buesching, C. D., Xu, Y.-l., Xiao, X., ... Zhou, Z.-M. (2020). Effects of regional economics on the online sale of protected parrots and turtles in China. *Conservative Science and Practice*, *2*, e161.

Zook, M., Barocas, S., Boyd, D., Crawford, K., Keller, E., Gangadharan, S. P., ... Pasquale, F. (2017). Ten simple rules for responsible big data research. *PLoS Computational Biology*, *13*, e1005399.

SUPPORTING INFORMATION

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

How to cite this article: Harrington LA, Auliya M, Eckman H, Harrington AP, Macdonald DW, D'Cruze N. Live wild animal exports to supply the exotic pet trade: A case study from Togo using publicly available social media data. *Conservation Science and Practice*. 2021;3: e430. https://doi.org/10.1111/csp2.430