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Going batty: US bat imports raise concerns for species conservation and human health

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ABSTRACT

The relationship between bats (order: Chiroptera) and humans is complex, highly contextualized across the globe, and dynamic. We assessed the United States (US) importation of live bats, as well as bat-derived products, from bat conservation and human health (zoonotic disease) perspectives. From 2015 to 2023, at least 284 bat species were imported into the US from at least 106 countries of origin, predominantly Indonesia. Scientific use was the most frequently declared import purpose. According to the IUCN Red List, thirty-seven of these bat species are extinction vulnerable. An investigation of US-based e-commerce platforms for live bats and bat-derived products located ads for 28 bat species for sale, including one for which trade is prohibited. Considering zoonotic spillover risk, we identified host-pathogen associations between 106 reported bat species imports and 45 zoonotic RNA viruses, representing 11 viral families. Twenty-five of the 45 viruses for which we found bat associations are listed as pathogens of concern by the World Health Organization or by US federal agencies. Rabies is the most hosted virus among bat species in our studies, followed by Dengue virus. We discuss the implications of our findings, as well as make recommendations for improving the science and policy necessary to mitigate trade-driven risks to bat and human populations. There is a need for ongoing assessments of bat population viability, as well as pathogen surveillance along the bat trade pathway. Greater attention by regulatory agencies is warranted to mitigate bat conservation and zoonotic pathogen risks apparent in e-commerce pathways. The Convention on the International Trade in Endangered Species of Fauna and Flora (CITES) and other multilateral environmental agreements could bring this issue to the forefront of member countries as part of the emerging global agenda at the conservation-zoonotic disease interface.

1. Introduction

The relationship between bats (order: Chiroptera) and humans is complex, highly contextualized across the globe, and dynamic. For some people, bats are a hallmark of horror movies and spooky decorations. For others, bats are an intricate aspect of personal and cultural survival. Bats may be a food source and traditional medicine. At local, national, and international scales, income may be generated through the commerce in live bats, bat-derived products (e.g., taxidermy and skeleton décor), and bat ecotourism. Increasingly, bats are recognized for their beneficial role as pollinators, seed dispersers, and agricultural pest controllers. Bats may be regarded as purveyors of disease, such as rabies, or protectors from mosquito-borne pathogens [1–3].

At least 1482 bat species have been scientifically described [4], making bats second only to Rodentia in terms of mammal diversity [5]. The International Union for Conservation of Nature's (IUCN) Red List of Threatened Species categorized conservation status for 1314 of these species [6]. Evidence of stable or increasing populations was found for only 20 % of assessed bat species. IUCN listed 23 (1.8 %) bat species as Critically Endangered, 60 (4.6 %) as Endangered, and 109 (8.3 %) as Vulnerable. For 18 % of the assessed species, data were insufficient to determine population status (i.e. Data Deficient). The primary drivers of bat population declines include habitat change (esp., agricultural expansion and deforestation), human disturbance (e.g., activity at roost

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sites), and harvesting for local uses and trade [7].

The trade in live and processed bats may facilitate human exposure to deadly viruses, some with pandemic potential [8]. More than 130 viruses have been detected in bat tissues, nearly half of which may be zoonotic [5]. As the COVID-19 pandemic has recently demonstrated, zoonotic disease outbreaks have broad, long-term ecological and societal consequences [9].

Our paper addresses bat harvesting dynamics and implications. We focus on bat conservation and human health (zoonotic disease) aspects of the United States (US) importation of live bats, as well as bat-derived products. To the best of our knowledge, the US is the only country that routinely and systematically collects trade information on all wildlife species entering the country [10]. This means that much of what is known about international wildlife trade patterns and trends beyond CITES-listed species is informed by US data. Most governments limit record keeping to the species listed under the Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendices, an inter-governmental agreement intended to ensure that international trade in wild animals and plants is legal and sustainable [11]. The bat import data held in the US Fish and Wildlife Services' (USFWS) Law Enforcement Information System (LEMIS) thus provides a unique opportunity for identifying bat trade patterns of conservation concern. Although this dataset is managed to support national regulatory programs [12], it can also inform zoonotic disease risk assessments [13].

We investigated which bat species have been imported into the US, from which countries, and for what purposes over the 2015 to 2023 period. To better ascertain how bats are marketed through US domestic commerce pathways, we complemented the import assessment with an investigation of bats and bat-derived products advertised on US-based e-commerce platforms. We cross referenced bat species from both assessments with the zoonotic viruses they are known to host and identified risk-relevant patterns. We considered our findings from scientific and policy perspectives, recommending a) a scientific research agenda to fill knowledge gaps in technical information and b) policy advancement at national and multi-national scales to mitigate identified risks to bat conservation and/or human health. Our findings are US-specific and thus represent a subset of the live bats, bat parts, and bat products in international trade. On the global scale, they need to be considered alongside other recent studies of bats in trade [e.g., 8,14,15].

2. Methods

2.1. Trade data analysis

US wildlife imports must be declared to the USFWS. With limited exceptions, the associated import records are captured as LEMIS data [16]. Through a data sharing agreement with the USFWS, we obtained LEMIS data for all US wildlife imports from 2015 to 2023, from which we extracted bat species shipments. In addition to the species in trade, shipment data gleaned for this project included purpose (e.g., commercial or scientific), country of origin and country of export to the US. Although we recognize the importance of trade volume as a metric when considering wildlife conservation and human health risks, LEMIS data are insufficient for confidently determining import volumes. To the highest degree feasible, we harmonized all recorded species names using Global Biodiversity Information Facility (GBIF) services [17] and identifier keys of the National Center for Biotechnology Information (NCBI) [18] and Integrated Taxonomic Information System (ITIS) databases [19]. We completed dataframe manipulation and API calls using Python (version 3.10).

2.2. E-commerce platforms assessment & species verification

We identified e-commerce sites advertising bat products/parts by inputting individual search phrases (bat, bats, bat curio, curio bat, bat shadow box, shadow box bat, bat taxidermy, taxidermy bat, bat skeleton, skeleton bat, bat skull, skull bat, bat craft, craft bat, bat souvenir, and souvenir bat) into Google. We located 25 relevant US-based websites. From each site, for each product listing, we gleaned stated specimen type (e.g., live, skeleton), genus/species, common name, price (USD), and country of origin. We then cataloged natural history information and population status according to the IUCN Red List [6], CITES [11], and the US Endangered Species Act [20]. To enable the species verification process, we took screenshots of each listing, numbered each image sequentially in the order collected, and cross-referenced each screenshot to the corresponding items' URL.

We attempted morphological taxon identification of product images following a standard protocol and reference collection employed at the US National Fish and Wildlife Forensics Laboratory (NFWFL) [21] as well as published literature [22–25]. In cases where identification from product screenshots was not possible, we evaluated the consistency of morphological features with the vendor-stated scientific or common name.

2.3. Viral association evaluation

We downloaded virus-host associations cataloged in the VIRION database [26]. VIRION is a comprehensive, auto-populated database that draws data from scientific literature and other online databases to consolidate virus-host association at the species level [27]. We used R (version 4.3.3) to limit the VIRION output to a list of zoonotic viruses we compiled from pathogen lists found in Taylor et al. [28], Jones et al. [29], and the Merck Veterinary Manual [30]. Although VIRION harmonizes most host and virus names to the National Center for Biotechnology Information (NCBI) [31], we identified discrepancies in the database. To control for duplicate and incorrect taxonomic nomenclature in the LEMIS data, we harmonized host taxonomy to the Global Biodiversity Information Facility (GBIF) [32]. GBIF was selected because it is generally robust and the GBIF ID can be easily cross-referenced with other checklists through the Checklist Bank repository [33]. We harmonized virus names with the International Committee on Taxonomy of Viruses (ICTV) [34]. We then used the filtered zoonotic pathogen output to identify bat species–zoonotic pathogen associations for bat species recorded in LEMIS and the e-commerce analyses.

3. Results & discussion

3.1. Trade data analysis

LEMIS records indicate that at least 284 bat species were reported as imported into the US from 2015 to 2023 across 1340 shipments (Supplementary [S] 1). Some bats and bat-derived products were only recorded with higher order taxa designations: 78 genera and one family-level description. Of the bats and bat-derived products only declared as higher order taxa, seven genera were not otherwise represented among the species-level declaration records. This leads us to conclude that additional, undeterminable, species were imported. Table 1 summarizes the import purposes and metrics for the shipments we assessed. Scientific use accounted for the greatest cumulative number of species imported (260; 92 %), as well as comprised the highest quantity of imported bat material by total number of items. The greatest proportion of shipments (58.7 %) was imported for commercial purposes. It's likely that some scientific shipments represent byproduct samples collected from bats overseas, (e.g., blood or fecal samples) but LEMIS record-keeping does not enable this determination. To an indiscernible degree, these byproducts could inflate perception of the number of bats and bat species that entered the US during the study period.

LEMIS records document the countries of origin and countries of export of imported bats as separate variables [S1]. Country of origin denotes either where animals were born or where they were removed from the wild. The country of export denotes the country from which the

Table 1
Summary of Imported Bats, Bat-derived Products and Reported Purposes.

Purpose	No. of Species	No. of Items	Kilograms	No. of Shipments
Scientific	260	174,110	10.55	812
Commercial	48	159,826	0.27	401
Biomedical	32	5701	1.67	15
Personal	31	1876	2.76	101
Educational	15	1898	0	8
Circus/ Exhibition	2	7	0	2
Zoological	1	15	0	1

These data reflect all imported shipments, except for 20 shipments that cumulatively contained 8232 ml of bat material for scientific purposes. Note that the quantity columns ("No. of Items" and "Kilograms") are mutually exclusive shipment quantities are reported either in number of items or in kilograms.

wildlife was shipped to the US. These variables differ for the same commodity imported whenever animals are collected or bred in one country and then transported through intermediary countries prior to US arrival. According to LEMIS records, bats were imported from at least 106 countries of origin, predominantly Indonesia. In comparison, 91 countries of export were documented. Of these, three countries (Denmark, Iraq, and Netherlands) were documented as countries of export but not origin, indicating that bats solely transited through them. Fig. 1 depicts countries of origin for the bat species recorded in LEMIS, the majority of which are native to Asia and Latin America [S1].

The conservation status of bat species recorded in LEMIS is cataloged in S1. Of the 284 species reported as imported, the majority are listed by the IUCN Red List as Least Concern (239). Of the remaining species, 23 are threatened with extinction (Critically Endangered: 1, Endangered: 8 Vulnerable: 14), 15 are Near Threatened, and seven are Data Deficient. One species supposedly imported is listed as Extinct and likely an error in the import records [S1].

3.2. *E-commerce platforms assessment & species verification*

Using key search phrases over a five-week period (57 total hours), we conducted a systematic search of online US marketplaces selling live bats, bat parts, and/or bat products. We located 230 individual ads (listings) of bats or bat products online, offering an estimated minimum of 463 bats for sale for various purposes. Biomedical supply websites (9) provided specimens to researchers and educators. General merchandise (6) and decor (8) websites provided decorative specimens. In certain cases, specimens appeared too damaged to serve for aesthetic purposes and were potentially intended for medicinal use. Lastly, websites selling live exotics (2) were primarily marketing bats as pets.

According to the species names listed by the advertisers, we cataloged 28 bat species for sale, representing 22 genera and 90 families [S1 Column J listed as "Both" or "E-commerce"]. A live giant golden flying fox (*Acerodon jubatus*) was the only species advertised by e-commerce vendors that was not also represented in the LEMIS import dataset [S1 J1]. The Pteropodidae was the most commonly observed family in online listings, accounting for 55.1 % of listed bats (125 bats out of 227 with taxonomic family information), followed by the Vespertilionidae (27.8 % of bats for sale). Bats with nasal ornamentation, including leaf-nosed bats and horseshoe bats, accounted for 12.3 % of listed bats (Families: Hipposideridae, Rhinolophidae, Phyllostomidae, and Megadermatidae). Twenty-five listings indicated the country of origin for the bat product. Fourteen of these listings (56.0 %) indicated Indonesia as the bats' origin country, followed by China with ten listings (40.0 %). The bat species observed in our e-commerce survey naturally occur across 170 countries. The conservation status of bat species reported by vendors is cataloged in S1. Note that one vendor reported a species (*Acerodon jubatus*) listed on CITES Appendix 1 for which commercial trade is generally prohibited.

Fig. 2 depicts the number of ads for bats by bat family and commerce type. Ads for deceased bats substantially surpassed the number of ads for live bats in the online marketplaces. Most ads were for taxidermy bats,

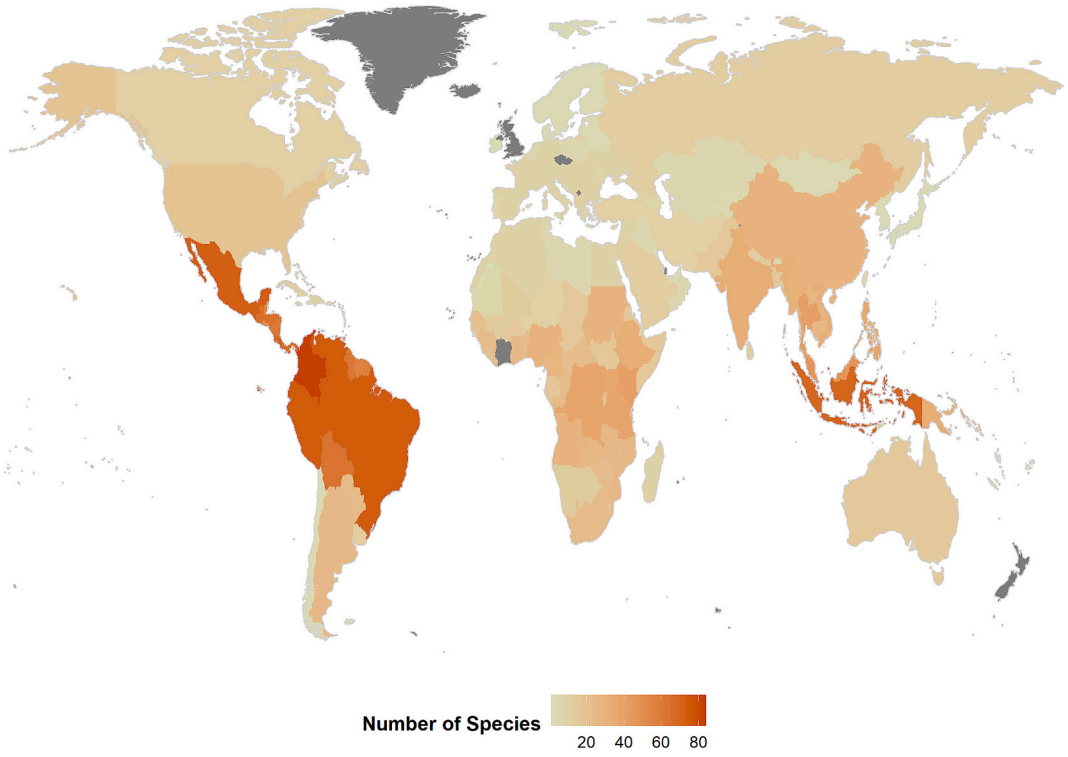

Fig. 1. Native range map of bat species identified in US wildlife trade.
Geographical data was sourced from The IUCN Red List of Threatened Species. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

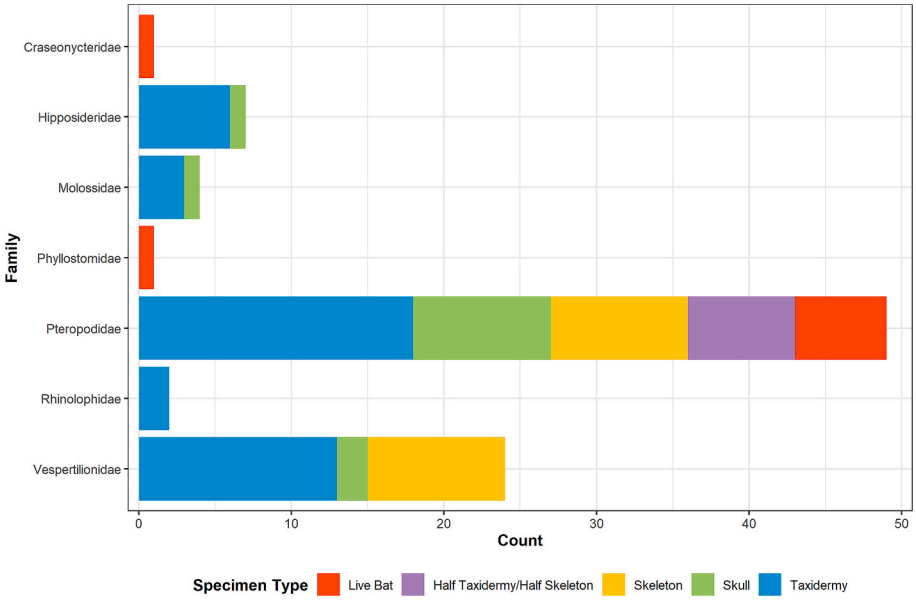

Fig. 2. Specimen types and taxonomic families observed in e-commerce platform assessments.
Product listings that did not include taxonomic classifications were excluded from this analysis.

followed by bat skulls. Ads for bat skeletons and bats prepared as half taxidermy and half skeleton were also observed.

We attempted to verify the identity of marketed bats. Morphological identification of bats is very challenging [23,35]. Most morphological identification guides rely on locality information, which is often unavailable or unreliable with online listings, and on data that can only be obtained from handling immobilized bats, such as measurements of the forearm or dental row [23,35] or from traits only visible on skeletonized remains [24]. Even then, reliable morphological identification to species may still be impossible [35].

With few exceptions, species identification based on the morphological features evident in online listings was not feasible. Listings averaged 3 photos of the item for sale, which made observing sufficient distinctive morphological features for species identification difficult. We were able to make some taxonomic assignment to family or better for 66.3 % of the bats listed for sale online, only 11.0 % of which were identifiable to species based solely on the morphology evident in the listing. The bats listed for sale appeared morphologically consistent with

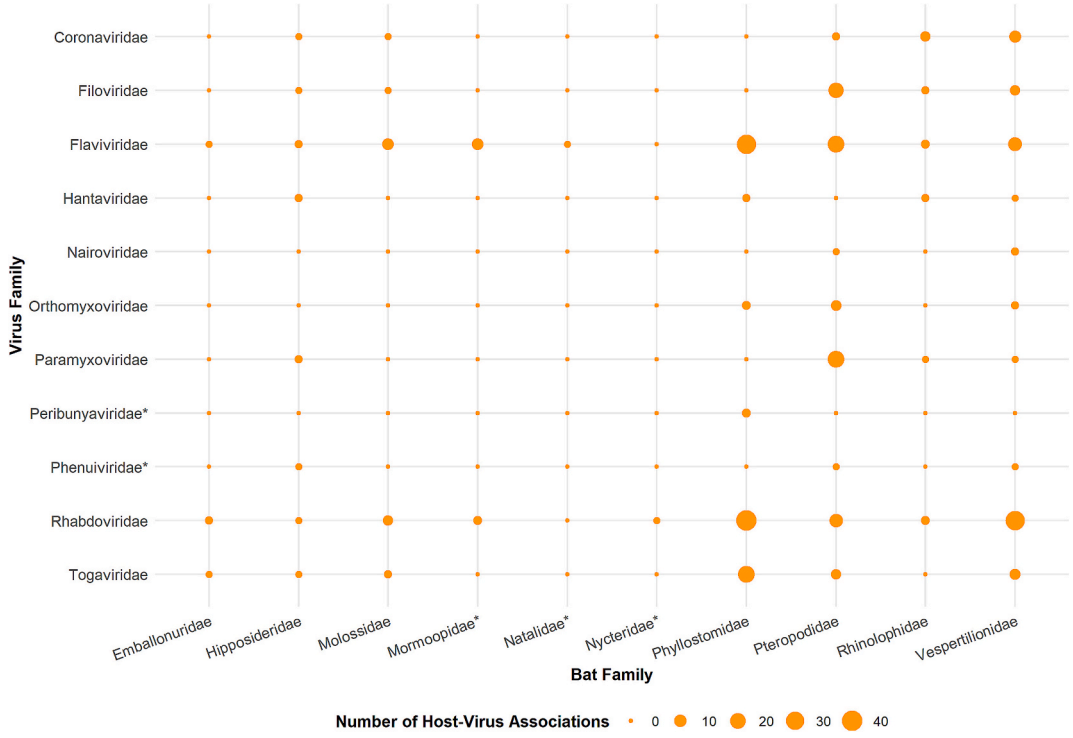

Fig. 3. Number of host–virus associations at the species level by bat and virus family.
Orange dot size corresponds to the number of associations. Asterisks highlight virus and bat families found in domestic wildlife trade but not in the e-commerce trade analyses addressed in this paper.

the taxonomic information provided by the listing, with only 9 bats (3.3 % of individuals) obviously incorrectly assigned to family. It is possible that some bats were attributed to the wrong genus and/or species. Ultimately, these analyses did not change our assessment of the number of species or families reported by vendors.

At least 24.7 % of ads, featuring 10.3 % of all advertised bats, included a disclaimer that the photos were representative and not of the actual product that would ship or that they featured photos of the same specimen across multiple listings. Several of the listings of live bats for sale included photos from other, unrelated websites (e.g., from National Geographic or stock images featuring watermarks), instead of the actual bats for sale. These practices, in addition to the difficulty identifying listed bats based on supplied images, mean that consumers cannot rely on e-commerce listings to accurately depict the bat specimen or species they might receive.

Further, 12 photos and one video featured people handling bats for sale. Of these, ten photos showed the bat products being held with bare hands and two showed them being held with forceps. Only two listings (0.8 %) provided safety information – both indicated that the specimens were "safe" and promised low formalin odor. Zero listings provided instructions on the safe handling of wildlife products. Online purchasers may be unaware of the zoonoses risks associated with bat commerce.

3.3. Viral association evaluation

Of the 284 bat species recorded in LEMIS, 106 were documented in VIRION as hosts of at least one zoonotic virus, for an average of 3.2 viruses per host (Fig. 3). Among these 106 species, we identified associations with 45 zoonotic pathogens, all of them RNA viruses, among 11 viral families [S1]. RNA viruses account for the largest proportion of human emerging pathogens [36]. The straw-colored fruit bat (*Eidolon helvum*) was associated with the largest number (14) of zoonotic viruses of any imported bat species, followed by great fruit-eating bat (*Artibeus lituratus*), Leschenault's rousette (*Rousettus leschenaultii*), and Jamaican fruit bat (*Artibeus jamaicensis*) (11 each). In total, there were 337 reported host-pathogen associations, of which >80 % were from the Phyllostomidae (109), Pteropodidae (91), and Vespertilionidae (77) families.

Fourteen of the bat species marketed on the e-commerce platforms are documented in VIRION as hosts of at least two zoonotic viruses, with an average of 6.7 viruses per species [S1]. Collectively, these bats are known to host 33 zoonotic viruses, for a total of 94 virus–host associations in this study. The most frequently associated viruses are Nipah virus (8 hosts), followed by rabies virus, Reston ebolavirus, Zaire ebolavirus, and Dengue virus (6 hosts). Of the 94 host–virus associations, over half of the hosts were from the Pteropodidae family (56; references provided in Supplemental Table 2).

Twenty-five of the 47 viruses for which we found bat associations are listed as pathogens of concern by the World Health Organization [37] or by US federal agencies [38–40]. Rabies is the most hosted virus among bat species in our studies, followed by dengue virus (Table 2). Research is warranted to evaluate the risk of pathogen transmission from live bats and bat-derived products along the trade pathway. The viruses identified in this study vary widely in human health consequences and transmission routes (e.g., the 20 vector borne viruses identified in this study. Work is ongoing to assess relative viral risks, as well as the risks associated with other microbial groups and parasites.

4. Recommendations & Conclusions

4.1. Science

This survey of the bat conservation and human health implications of US bat imports points to the need for the government to invest in routine bat population viability analyses for at least 38 bat species of conservation concern (S1 Column F), as well as a program of zoonotic pathogen

Table 2
Documented bat host-zoonotic pathogen associations.

Virus Family	Virus	Listed	# bat host species
Coronaviridae	Middle East Respiratory Syndrome virus (*Betacoronavirus cameli*)	Z, W	8 (2)
	Severe Acute Respiratory Syndrome virus (*Betacoronavirus pandemicum*)	Z, W, S	10 (4)
Filoviridae	Bundibugyo ebolavirus (*Orthoebolavirus bundibugyoense*)	W, A, S	1 (1)
	Marburg virus (*Orthomarburgvirus marburgense*)	W, A, S	4 (2)
	Reston ebolavirus (*Orthoebolavirus restonense*)	W, A, S	10 (6)
	Sudan ebolavirus (*Orthoebolavirus sudanense*)	W, A, S	1 (1)
	Tai Forest ebolavirus (*Orthoebolavirus taiense*)	W, A, S	1 (1)
	Zaire ebolavirus (*Orthoebolavirus zairense*)	W, A, S	10 (6)
Flaviviridae	Dengue virus (*Orthoflavivirus dengue*)		22 (6)
	Ilheus virus (*Orthoflavivirus ilheusense*)		11 (2)
	Japanese encephalitis virus (*Orthoflavivirus japonicum*)		12 (4)
	Kyasanur Forest virus (*Orthoflavivirus kyasanurense*)	S	4 (3)
	Murray Valley encephalitis virus (*Orthoflavivirus murrayense*)		1
	St. Louis encephalitis virus (*Orthoflavivirus louisense*)		16 (3)
	Usutu virus (*Orthoflavivirus usutuense*)		2 (1)
	Wesselsbron virus (*Orthoflavivirus wesselsbronense*)		2 (1)
	West Nile virus (*Orthoflavivirus nilense*)	Z	12 (5)
	Yellow fever virus (*Orthoflavivirus flavi*)		10 (2)
	Zika virus (*Orthoflavivirus zikaense*)	W	3 (2)
Hantaviridae	Andes Virus (*Orthohantavirus andesense*)	C	5 (2)
	Hantaan Virus (*Orthohantavirus hantanense*)	C	2
	Puumala Virus (*Orthohantavirus puumalaense*)	C	1
Nairoviridae	Crimean-Congo hemorrhagic fever virus (*Orthonairovirus haemorrhagiae*)	W, S	1
	Issyk-kul orthonairovirus (*orthonairovirus issykkulense*)		1
	Kasokero virus (*Orthonairovirus kasokeroense*)		1 (1)
Orthomyxoviridae	Influenza A virus (*Alphainfluenzavirus influenzae*)	Z, S	11 (4)
Paramyxoviridae	Hendra virus (*Henipavirus hendraense*)	W, S	8 (1)
	Menangle virus (*Pararubulavirus menangleense*)		5 (1)
	Nipah virus (*Henipavirus nipahense*)	W, C, S	14 (8)
Peribunyaviridae	Guama orthobunyavirus (*Orthobunyavirus guamaense*)		3
Phenuiviridae	Rift Valley fever virus (*Phlebovirus riftense*)	W, S	3
	Australian bat lyssavirus (*Lyssavirus australis*)		13 (4)
	Cocal virus (*Cocal vesiculovirus*)		1
	Duvenhage virus (*Lyssavirus duvenhage*)		4
	European bat lyssavirus 1 (*Lyssavirus hamburg*)		9 (1)
	European bat lyssavirus 2 (*Lyssavirus helsinki*)		4
	Mokola virus (*Lyssavirus mokola*)		2 (2)
	Rabies virus (*Lyssavirus rabies*)	Z	51 (6)
	Indiana *vesiculovirus* (*Vesiculovirus indiana*)		10 (2)
Rhabdoviridae	New Jersey vesiculovirus (*Vesiculovirus newjersey*)		9 (2)

(*continued on next page*)

Table 2 (*continued*)

Virus Family	Virus	Listed	# bat host species
Togaviridae	Chikungunya virus (*Alphavirus chikungunya*)	B	5 (3)
	Eastern equine encephalitis virus (*Alphavirus eastern*)	B, S	14 (3)
	Ross River virus (*Alphavirus rossriver*)	B	2
	Venezuelan equine encephalitis virus (*Alphavirus Venezuelan*)	B, S	15 (2)
	Western equine encephalomyelitis virus (*Alphavirus western*)	B	3

Zoonotic viruses that have been identified in bat species imported into the US and number of bat hosts per virus. Bat species were documented in LEMIS as imported between 2015 and 2023. Listed indicates the virus was listed as a pathogen of concern as of June 2024: Z = Top Zoonotic Disease of National Concern for the United States etiologic agent, W = World Health Organization Priority Disease etiologic agent, A = Centers for Disease Control and Prevention (CDC) bioterrorism agent A, B = CDC bioterrorism agent B, C = CDC bioterrorism agent C, S = CDC or US Department of Agriculture select agent. Parentheses indicate number of bat host species identified through the e-commerce platforms assessment.

surveillance along the bat trade pathway. Even though most of the bat species reported across the entirety of the project are listed by IUCN as Least Concern (239), we encourage active monitoring of these traded species – far less scientific attention is given to "common" species, and there are apparent extraction pressures. It is not currently feasible to quantify the zoonoses risk from human exposure to the bats and bat-derived products imported into the US, but concern for human health is warranted. We anticipate that future research will identify additional bat host–zoonoses relationships [41]. Zoonoses risk assessment capacity can be improved through further study of ability of bat viruses to persist on surfaces and under environmental conditions typical of the trade pathway [42]. Most bats enter the US as derived products, many of them as poorly prepared taxidermy. The presence and viability of zoonotic pathogens also needs to be assessed for bat commodities. The USFWS could establish biosecurity protocols for researchers and make confiscated bat imports available for diagnostic testing by certified laboratories. In addition to the analysis of harvest pressures on bat in source countries, we encourage pre-export pathogen surveillance and assessments of zoonoses exposure risk for people participating in the pre-export trade pathway.

4.2. Policy

Accurate species identification is necessary for effective bat trade regulation. This study suggests that a USFWS investigation of vendor-reported species vs actual species identity is warranted. E-commerce platform policies could also be promulgated that require vendors to include species name, source of the animal, conservation status, and human health precautions for each item marketed. A review of the Centers for Disease Control and Prevention bat import permits, as well as any accompanying exporter veterinary or disinfection certificates, is needed to better clarify pre-export levels of zoonoses risk mitigation. Very few bat species (mostly fruit bats) are listed on the CITES Appendices. We demarcate those imported into the US in S1. The USFWS could encourage CITES to convene an experts consultation on bat trade from conservation and human health perspectives to: a) determine if additional bat species warrant CITES listing and b) to better inform the convention's post-Covid zoonoses agenda. The status of Asian bat species is of particular concern from conservation and human health perspectives [14], with concern recently raised about threats to the painted woolly bat *(Kerivoula picta)* in particular [15]. Bi-lateral trade agreements between the United States and Asian exporting countries could be employed to improve risk mitigation from conservation and human health perspectives. The Convention on Biological Diversity's recent adoption of a Biodiversity and Health Framework provides an opportunity to further mobilize Parties' efforts to achieve Kunming-Montreal Global Biodiversity Framework Target 5: "Ensure that the use, harvesting and trade of wild species is sustainable, safe and legal, preventing overexploitation, minimizing impacts on non-target species and ecosystems, and reducing the risk of pathogen spillover, applying the ecosystem approach, while respecting and protecting customary sustainable use by indigenous peoples and local communities." Bats could serve as practical starting point for taxa-specific collaboration across biodiversity and health sectors.

CRediT authorship contribution statement

Mayla Tarango: Writing – original draft, Visualization, Methodology, Formal analysis, Data curation, Conceptualization. **Jonathan E. Kolby:** Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Orion L.B. Goodman:** Writing – original draft, Visualization, Formal analysis, Data curation. **C. Jane Anderson:** Writing – original draft, Visualization, Methodology, Formal analysis, Data curation. **Jen Tinsman:** Writing – original draft, Methodology, Formal analysis. **Jason Kirkey:** Writing – review & editing, Resources, Methodology. **Amanda Liew:** Visualization, Formal analysis. **Marshall Jones:** Supervision, Methodology, Conceptualization. **Cadhla Firth:** Supervision, Methodology, Conceptualization. **Jamie K. Reaser:** Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Funding acquisition, Conceptualization.

Declaration of competing interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.onehlt.2025.100999.

Data availability

The data that has been used are a subset of a larger research initiative in progress under the American Rescue Plan Act. They will be made publicly available upon project completion. Raw data (uncleaned) on US bat imports can be obtained from the USFWS via a FOIA request.

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