CONVENTION ON INTERNATIONAL TRADE IN ENDANGERED SPECIES
OF WILD FAUNA AND FLORA

Sixty-ninth meeting of the Standing Committee
Geneva (Switzerland), 27 November – 1 December 2017

OVERVIEW OF HEALTH THREATS ASSOCIATED WITH INTERNATIONAL COMMERCIAL TRADE IN CITES-LISTED SPECIES

This information document has been submitted by the United States of America, and prepared by the Wildlife Conservation Society.*

The document does not reflect the official position of the United States. However, the document presents views that may help inform the discussion.

Background

1. The focus of CITES is the protection of species from over-exploitation in international trade. The CITES Vision, as per the CITES Strategic Vision (Resolution Conf. 16.3 (Rev. CoP17), is to "Conserve biodiversity and contribute to its sustainable use by ensuring that no species of wild fauna or flora becomes or remains subject to unsustainable exploitation through international trade, thereby contributing to the significant reduction of the rate of biodiversity loss and making a significant contribution towards achieving the relevant *Aichi Biodiversity Targets*." Notably, CITES regulates and documents the legal and illegal movement of wildlife but not the potential pathogens they may carry.

2. The international movement of wildlife and the pathogens they carry has resulted in health threats to native species, domestic animals, and humans[1]. To date, scientists have provided descriptive assessments of health threats associated with the global trade along with more quantitative national and regional assessments[2–16]. A recent global characterization of the live animal trade using CITES data concludes agencies should consider stricter surveillance on importation of these high-risk reservoir hosts and on imports from high-risk trade routes[17]. Although the text of the CITES treaty, and CITES regulations, deal only with the potential harm to the conservation status of the species being traded, it is important for governments authorizing exports or imports to take into consideration any potential threats to other wildlife species, livestock/domestic animals, or people. This document provides the first global overview of trade-associated health threats for consideration by the CITES Parties, and makes recommendations for further discussion and action. This document discusses trade-associated disease threats (to people, wildlife, and livestock) from commercial trade in live animals, as well as disease threats from commercial trade in parts and products, including meat, trophies, other parts, etc.

3. CITES has dealt with invasive alien species, but not the disease issue itself. The Parties adopted Resolution Conf. 13.10 (Rev. CoP14), which recommends that Parties consider the problems of invasive species when developing national legislation and regulations that deal with the trade in live animals or plants, and consult with the CITES Management Authority of a proposed country of import, when possible and when applicable, when considering exports of potentially invasive species, to determine whether there are domestic measures regulating such imports. We recommend that the Standing

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* *The geographical designations employed in this document do not imply the expression of any opinion whatsoever on the part of the CITES Secretariat (or the United Nations Environment Programme) concerning the legal status of any country, territory, or area, or concerning the delimitation of its frontiers or boundaries. The responsibility for the contents of the document rests exclusively with its author.*

Committee and Parties review the broader issue of trade-associated health threats to humans, livestock, and wildlife, and take action accordingly (see “Recommendations” section).

4. This paper gives examples both from the legal and illegal trade in wild animals and their parts and products. While we assume that there are greater threats from illegal trade, due to lack of regulatory oversight, quarantine, and other controls, we believe that more research is needed to assess this issue, particularly as relates to international trade for primarily commercial purposes.

Wildlife Health Threats

5. There are tangible examples of trade-associated health threats impacting wildlife in destination and re-exporting countries. In 2014, genetic analyses revealed that avian prey-breeding facilities in the United Arab Emirates likely acquired a highly pathogenic avian influenza H5N1 virus from falcons (*Falco spp.*) and houbara bustards (*Chlamydotis undulata macqueenii*) that traveled through Central Asia[18]. While the outbreak spread to domestic poultry sectors, the cultural practice of housing falcons in private homes created a significant human health threat[19]. In another example, a fungal pathogen commonly referred to as Bsal (*Batrachochytrium salamandrivorans*) has likely caused a 96% population decline of *Salamandra* in the Netherlands and caused outbreaks across Europe[2]. Bsal likely originated in East Asia and entered Europe via the pet trade[2]. Often native species (wild or domestic) lack any immunity to a newly introduced pathogen, resulting in significant population loss as well as economic or conservation concerns.

Domestic animal health threats

6. Domestic animal health has been impacted by trade-associated health threats with implications for food security and the global economy. Examples include both domestic and international animal movements to exemplify the type of risks to consider. In 1977, rabies-infected raccoons (*Procyon lotor*) were brought to West Virginia to repopulate hunting grounds and this triggered a unprecedented rabies spread across the US,[20,21] which by 2014 had infected dogs, cats, cattle, horses, mules, sheep, goats, and a llama[22]. In 1987, African Horse Sickness virus spread to Spain, Portugal and Morocco and caused over 1000 equine deaths due to the importation of sub-clinically infected zebras from Namibia to a safari park in Spain[23]. In 2000, a shipment of leopard tortoises (*Geochelone pardalis*) imported to Florida from Zambia were found to have *Amblyomma sparsum* ticks carrying *Ehrlichia ruminantium*, a bacteria responsible for heartwater disease in ruminants[24]. In Africa, where heartwater is endemic, 60-80% mortality rates in cattle and sheep are common[25]. In 2007, an avian-origin influenza virus (H3N8) was transmitted in its entirety to dogs, which then spread from dog-to-dog in South Korea[26]. The index canine case was a dog that was housed at a live-animal market in Kyunggi province that sold birds (some from international trade), rabbits, cats, and dogs[26].

Human health threats

7. Wildlife trade has also facilitated the movement of pathogens affecting human health. Three-quarters of human emerging pathogen species originated from animals[27]. The majority (72%) of emerging zoonotic infectious diseases originated in wildlife, and the role of wildlife in disease emergence has been increasing with time[28]. Wildlife trade has inarguably played a major role[29,30].

8. Some examples to illustrate the risk, including both within country and through international animal or animal product contact or movements, include the following: In 2003, 72 human cases of monkeypox occurred in the USA after pet prairie dogs (*Cynomys* spp.) were infected after being co-housed in an exotic animal distribution center with imported Gambian pouched rats (*Cricetomys gambianus*) [31–34]. Studies have estimated pet primates and non-human primate bushmeat in Africa to have between 5 and 40% seroprevalence with *Simian immunodeficiency virus* and Simian T- lymphotropic viruses (STLV), close relatives of the virus that causes AIDS [35–37]. Furthermore, bushmeat hunters are found to be infected with known and new human T-lymphotropic viruses and STLVs[38,39] indicating these viruses can jump to humans with unknown consequences, and the illegal trade in bushmeat results in potential global risks from this source. Further, epidemiological investigations of Ebola outbreaks show they are often associated with bushmeat contact with chimpanzees, gorillas, duikers, monkeys, and fruit bats[40]. Scientists have studied Severe Acute Respiratory Syndrome (SARS), which emerged in 2003 in China infecting over 8,000 people and causing 774 human deaths in 37 different countries[41]. The trade in horseshoe bats (*Rhinolophus* spp.) is likely to have brought virus-shedding animals into contact with the Himalayan masked palm civet (*Paguma larvata*), another wildlife reservoir, and eventually humans [42–44]. A unique study of the religious bird trade in Phnom Penh, Cambodia found influenza A virus (10%

prevalence) as well as two species of bacteria known to cause human pneumonia (1-4% prevalence) in a market that deals in more than half a million birds each year[45]. Another study found ten human pathogens in aquaria containing common goldfish (*Carassius auratus*) and Chinese algae eaters (*Gyrinocheilus aymonieri*) from seven pet stores in the US state of Rhode Island[46]. Studies have also detected multi-drug resistant bacteria in confiscated birds in Brazil that are typically sent to wildlife rehabilitation facilities, posing direct threats to humans and native wildlife[47].

Beyond trade in live animals

9. The issue reaches beyond the discussion of the live animal trade described above and carries with it large negative economic consequences. Beyond trade in live animals, there are considerable health risks associated with trade in wildlife products. Illegal importation of meat also poses significant risks[3,4]; bushmeat smuggled into international airports was found to carry viable zoonotic bacteria and viruses and smoked fish were carrying known carcinogens[5,6]. On the economic side wildlife trade-associated disease outbreaks have cost hundreds of billions of dollars (USD) globally[48]. Analysts estimated SARS alone cost China's economy US$25 billion and cost US$54 billion to the global economy[49,50]. Further work to internalize market externalities of health costs of wildlife trade would greatly benefit stakeholders and decision-makers to take into account wider costs of trading[51].

Risk assessment efforts

10. Work has begun to help characterize the wildlife trade-associated health risks. Globally, live mammals, particularly artiodactyls, primates, bats, and rodents in the trade could be hosts for 77% of known wildlife pathogens[17]. In an analysis of US imports, canines and felines, rodents, equines, primates and hares were hosts capable of harboring the most zoonotic pathogens[7]. Experimental studies are underway to make more robust estimates of the total number of known and unknown pathogens that mammalian hosts harbor[52,53] and to determine which traded animals will pose greatest risks for host switching of pathogens[54]. Studies are also beginning to look at the most likely geographical points of entry in models of bat-borne viruses[8].

11. More general wildlife trade characterizations are also being done. Over a fourteen year period (2000-2013) the US imported 11 billion individual wild animals, and US imports were predominantly for commercial purposes (e.g. pet and aquatic trade), sourced from the wild, originating in Southeast Asia, and consisting of fish and coral[9,10]. US rodent imports have been also found to be increasing in size over time, but imports are mainly sourced from European large-scale captive breeding facilities since the monkeypox outbreak[11]. However, half of (illegal) bushmeat imports into the US were derived from rodents arriving from Africa[12]. Furthermore, there may be a tendency to decrease the risk associated with importation of captive bred animals; however, a study found at least 80% of the green pythons (*Morelia viridis*) exported from Indonesia annually are illegally wild-caught[55].

12. It is clear that we have only begun the process of mixing and spreading once-localized pathogens around the globe. We have not reached a saturation point yet for the rate of alien species invasions, a model for pathogen spread by the wildlife trade[56]. There are an estimated 320,000 mammalian viruses, at least, awaiting discovery, and the cost to discover these would be approximately $6.3 billion[52]. Socioeconomic variables such as the nearest distance to airports, seaports and human population density were found to be important predictors of global invasive alien species[57]. Furthermore, human population within a species range was associated with the number of zoonotic species in that species[53]. With the rate of current and future projections of globalization, it is clear that there is an urgent need to limit further global mixing and spread of pathogens.

Considerations for action

13. An integrated, comprehensive One Health approach, with the inclusion of all public, domestic, and wildlife health sectors as stakeholders will be needed if countries are serious about protecting human, capital, and environmental resources[58].

14. More effective management strategies (such as the quarantine, disease screening, morbidity and mortality investigations conducted by zoos and aquariums) may help address some of these trade-associated health risks in the movement of live animals. Similarly, wildlife samples imported for scientific or conservation purposes are handled with strict biosecurity protocols to minimize disease risk, and these biosecurity protocols are not conducted for other legal or illegally trafficked wildlife product

commercial imports. At the source, proof of provenance (e.g., examination of reptilian eggs[55]) is needed to verify the source and ensure animals are not being laundered illegally. Local educational outreach at the sources may also be of benefit; a study on risk-perception for bushmeat hunters found only 24-55% were aware of zoonotic disease transmission risks, and only 26% took protective measures[13,60]. The transport sector was found to be one of the weakest links in combatting the trafficking of wildlife[61]; improvements in customs data reporting and detailed infection control and management procedures have been suggested as a way to raise awareness of the transport industry of these issues[54,61]. Stress reduction of animals during shipment and in quarantine would be beneficial in decreasing the likelihood of emergence of latent infections[59].

15. Improvements to CITES records would also be of great benefit. CITES coverage of traded animals and countries is not all-inclusive and improvements to the World Customs Organization reporting system codes have been suggested[61]. For species on the CITES Appendices, records are still incomplete; for example, no data are provided on live seizures by 70% of CITES Parties[62]. Furthermore, expanding CITES reporting in certain areas, such as including details on the disposal of confiscated live animals, would be helpful[62]. Even with great improvements in CITES reporting, there is much we still do not know. The illegal trade is very challenging to study and monitor. Therefore, multifaceted methods of tracking the illegal wildlife are also needed to stay abreast of changes. Tools such as the HealthMap wildlife trade database, which uses unofficial online data sources to collect information on international wildlife trade, need to be used to augment traditional approaches[63].

16. Major trade network hubs and markets provide efficient control opportunities to decrease the risks for disease[48,64]. However, management strategies are in need of further geographical and taxonomic refinement of commodity chain analysis to know what to look for; a recent analysis of African straw-colored fruit bat (*Eidolon helvum*) bushmeat trade was found to have substantial differences to the non-human primate bushmeat trade in Ghana in terms of its scale and the marketplaces used to reach the consumers of the product[65]. Airport surveillance would also benefit from better strategies on when and how to conduct inspections; for example, an “enhanced” airport surveillance plan was found to detect four times as much smuggled bushmeat as routine efforts[12]. One study found that the effectiveness of inspections was limited by the organizational structures of multi-agency inspectors (i.e., customs, veterinary services) and that better integration would be useful[66].

17. Rapid information systems linking existing health stakeholders need to be established[67–70]. These include agriculture, livestock development, and environmental ministries, quarantine facilities, veterinary laboratories, Armed Forces Health Surveillance Center zoonotic disease surveillance programs, and the U.S. Agency for International Development’s Emerging Pandemic Threats Program (PREDICT, PREVENT, IDENTIFY, and RESPOND)[67–70]. This is especially true in parts of Africa, Asia, and South America where there is the greatest shortfall between proactive response capacity (i.e., border controls, early-warning systems, research and collaboration) and the threat of emerging invasive species, a proxy for pathogen invasions[71].

18. More simulations and modelling work combining trade and pathogen-specific data to provide predictions of the risk of entry of particular pathogens to particular areas within a region are also needed and useful[8,14]. This can be combined with network methods to determine the best placement of resources[64]. However, to do so in a robust fashion, there is a great need for more detailed pathogen (e.g., likelihood of pathogen release, geographical distribution, ability to maintain infections that could persist in the population or be transmitted to other species), wildlife reservoir host (e.g., host ecology, geographical distribution, phylogenetic host relatedness) and wildlife trade pathway data[8,30,72,73]. Models will also need to incorporate the likelihood of transmission to native wildlife, domestic animals, and humans, the severity of the disease (consequences)[15,74], and climate, land use, habitat characteristics, and socioeconomic activities for further refinement of risks[57].

19. Policies will need to be amended quickly to address health threats. For example, in the US recently, 201 live salamander species importations were suspended due to the threat of the Bsal fungus[16]. Enhancements in risk prioritization, building upon the global surveillance work, will hopefully lead to more sophisticated response capacity and quicker policy recommendations[15,70].

Recommendations

20. It is recommended that the Standing Committee (possibly at SC70) and/or the Conference of the Parties (possibly at CoP18) discuss this issue in detail and consider specific recommendations to the Parties, including elements of the “Considerations for Action”, above. An intersessional working group could help progress the issue, in advance of CoP18.

21. Many of the issues discussed herein are of relevance at the national level, and Parties may wish to consider the disease transmission risks and take relevant actions when issuing permits for exports, re-exports, or imports, including consulting broadly with their health ministries, veterinarians, and other experts, to minimize the risk of disease transmission through international trade in CITES-listed species.

References cited

1. Daszak, P., Cunningham, A. A. & Hyatt, A. D. Emerging Infectious Diseases of Wildlife-- Threats to Biodiversity and Human Health. *Science* **287,** 443–449 (2000).
2. UNEP-WCMC. Review of the Risk Posed by Importing Asiatic Species of Caudata Amphibians (Salamanders and Newts) into the EU. (2016).
3. Wooldridge, M., Hartnett, E., Cox, A. & Seaman, M. Quantitative risk assessment case study: smuggled meats as disease vectors. *Rev. Sci. Tech. Int. Off. Epizoot.* **25,** 105–117 (2006).
4. Beutlich, J. *et al.* Characterization of illegal food items and identification of foodborne pathogens brought into the European Union via two major German airports. *Int. J. Food Microbiol.* **209,** 13–19 (2015).
5. Chaber, A.-L. & Cunningham, A. Public Health Risks from Illegally Imported African Bushmeat and Smoked Fish : Public Health Risks from African Bushmeat and Smoked Fish. *EcoHealth* **13,** 135–138 (2016).
6. Smith, K. M. *et al.* Zoonotic Viruses Associated with Illegally Imported Wildlife Products. *PLOS ONE* **7,** e29505 (2012).
7. Pavlin, B. I., Schloegel, L. M. & Daszak, P. Risk of importing zoonotic diseases through wildlife trade, United States. *Emerg. Infect. Dis.* **15,** 1721–1726 (2009).
8. Simons, R. R. L. *et al.* A Generic Quantitative Risk Assessment Framework for the Entry of Bat-Borne Zoonotic Viruses into the European Union. *PLOS ONE* **11,** e0165383 (2016).
9. Smith, K. F. *et al.* Ecology. Reducing the risks of the wildlife trade. *Science* **324,** 594–595 (2009).
10. Smith, K. M. *et al.* Summarizing US Wildlife Trade with an Eye Toward Assessing the Risk of Infectious Disease Introduction. *EcoHealth* **14,** 29–39 (2017).
11. Lankau, E. W., Sinclair, J. R., Schroeder, B. A., Galland, G. G. & Marano, N. Public Health Implications of Changing Rodent Importation Patterns - United States, 1999-2013. *Transbound. Emerg. Dis.* **64,** 528–537 (2017).
12. Bair-Brake, H. *et al.* Is that a rodent in your luggage? A mixed method approach to describe bushmeat importation into the United States. *Zoonoses Public Health* **61,** 97–104 (2014).
13. Subramanian, M. Zoonotic disease risk and the bushmeat trade: assessing awareness among hunters and traders in Sierra Leone. *EcoHealth* **9,** 471–482 (2012).
14. Daut, E. F., Jr, G. L., Peterson, M. J. & Ivanek, R. Interacting Effects of Newcastle Disease Transmission and Illegal Trade on a Wild Population of White-Winged Parakeets in Peru: A Modeling Approach. *PLOS ONE* **11,** e0147517 (2016).
15. Bueno, I. *et al.* Risk Prioritization Tool to Identify the Public Health Risks of Wildlife Trade: The Case of Rodents from Latin America. *Zoonoses Public Health* **63,** 281–293 (2016).
16. Injurious Wildlife Species; Listing Salamanders Due to Risk of Salamander Chytrid Fungus. *Federal Register* (2016). Available at: https://www.federalregister.gov/documents/2016/01/13/2016-00452/injurious-wildlife-species-listing-salamanders-due-to-risk-of-salamander-chytrid-fungus. (Accessed: 18th June 2017)
17. Patel, N. G., Olson, S., Lieberman, S. & Osofsky, S. Disease risks associated with the wildlife trade. *Prep.*
18. Naguib, M. M. *et al.* Outbreaks of highly pathogenic avian influenza H5N1 clade 2.3.2.1c in hunting falcons and kept wild birds in Dubai implicate intercontinental virus spread. *J. Gen. Virol.* **96,** 3212–3222 (2015).
19. Monne, I. *et al.* Co-circulation of two sublineages of HPAI H5N1 virus in the Kingdom of Saudi Arabia with unique molecular signatures suggesting separate introductions into the commercial poultry and falconry sectors. *J. Gen. Virol.* **89,** 2691–2697 (2008).
20. Nettles, V. F., Shaddock, J. H., Sikes, R. K. & Reyes, C. R. Rabies in translocated raccoons. *Am. J. Public Health* **69,** 601–602 (1979).
21. Slate, D. *et al.* Status of oral rabies vaccination in wild carnivores in the United States. *Virus Res.* **111,** 68–76 (2005).
22. Monroe, B. P. *et al.* Rabies surveillance in the United States during 2014. *J. Am. Vet. Med. Assoc.* **248,** 777–788 (2016).
23. Rodriguez, M., Hooghuis, H. & Castaño, M. African horse sickness in Spain. *Vet. Microbiol.* **33,** 129–142 (1992).
24. Burridge, M. J., Simmons, L. A., Simbi, B. H., Peter, T. F. & Mahan, S. M. Evidence of Cowdria ruminantium infection (heartwater) in Amblyomma sparsum ticks found on tortoises imported into Florida. *J. Parasitol.* **86,** 1135–1136 (2000).
25. OIE. HEARTWATER - COWDRIOSIS. (2009).
26. Song, D. *et al.* Transmission of Avian Influenza Virus (H3N2) to Dogs. *Emerg. Infect. Dis.* **14,** 741–746 (2008).

27. Taylor, L. H., Latham, S. M. & Woolhouse, M. E. Risk factors for human disease emergence. *Philos. Trans. R. Soc. Lond. B. Biol. Sci.* **356,** 983–989 (2001).
28. Jones, K. E. *et al.* Global trends in emerging infectious diseases. *Nature* **451,** 990–993 (2008).
29. Karesh, W. B., Cook, R. A., Bennett, E. L. & Newcomb, J. Wildlife trade and global disease emergence. *Emerg. Infect. Dis.* **11,** 1000–1002 (2005).
30. Travis, D. A., Watson, R. P. & Tauer, A. The spread of pathogens through trade in wildlife. *Rev. Sci. Tech. Int. Off. Epizoot.* **30,** 219–239 (2011).
31. Di Giulio, D. B. & Eckburg, P. B. Human monkeypox: an emerging zoonosis. *Lancet Infect. Dis.* **4,** 15–25 (2004).
32. Guarner, J. *et al.* Monkeypox transmission and pathogenesis in prairie dogs. *Emerg. Infect. Dis.* **10,** 426–431 (2004).
33. Hutson, C. L. *et al.* Monkeypox zoonotic associations: insights from laboratory evaluation of animals associated with the multi-state US outbreak. *Am. J. Trop. Med. Hyg.* **76,** 757–768 (2007).
34. Reed, K. D. *et al.* The detection of monkeypox in humans in the Western Hemisphere. *N. Engl. J. Med.* **350,** 342–350 (2004).
35. Steve, A.-M. *et al.* High Prevalences and a Wide Genetic Diversity of Simian Retroviruses in Non-human Primate Bushmeat in Rural Areas of the Democratic Republic of Congo. *EcoHealth* **14,** 100–114 (2017).
36. Peeters, M. *et al.* Risk to Human Health from a Plethora of Simian Immunodeficiency Viruses in Primate Bushmeat. *Emerg. Infect. Dis.* **8,** 451–457 (2002).
37. Liégeois, F. *et al.* New STLV-3 strains and a divergent SIVmus strain identified in non-human primate bushmeat in Gabon. *Retrovirology* **9,** 28 (2012).
38. Wolfe, N. D. *et al.* Emergence of unique primate T-lymphotropic viruses among central African bushmeat hunters. *Proc. Natl. Acad. Sci. U. S. A.* **102,** 7994–7999 (2005).
39. Mossoun, A. *et al.* Bushmeat Hunting and Zoonotic Transmission of Simian T-Lymphotropic Virus 1 in Tropical West and Central Africa. *J. Virol.* **91,** (2017).
40. Judson, S. D., Fischer, R., Judson, A. & Munster, V. J. Ecological Contexts of Index Cases and Spillover Events of Different Ebolaviruses. *PLoS Pathog.* **12,** e1005780 (2016).
41. Smith, R. D. Responding to global infectious disease outbreaks: lessons from SARS on the role of risk perception, communication and management. *Soc. Sci. Med. 1982* **63,** 3113–3123 (2006).
42. Guan, Y. *et al.* Isolation and characterization of viruses related to the SARS coronavirus from animals in southern China. *Science* **302,** 276–278 (2003).
43. Lau, S. K. P. *et al.* Severe acute respiratory syndrome coronavirus-like virus in Chinese horseshoe bats. *Proc. Natl. Acad. Sci. U. S. A.* **102,** 14040–14045 (2005).
44. Li, W. *et al.* Bats are natural reservoirs of SARS-like coronaviruses. *Science* **310,** 676–679 (2005).
45. Gilbert, M., Sokha, C., Joyner, P. H., Thomson, R. L. & Poole, C. Characterizing the trade of wild birds for merit release in Phnom Penh, Cambodia and associated risks to health and ecology. *Biol. Conserv.* **153,** 10–16 (2012).
46. Smith, K. F., Schmidt, V., Rosen, G. E. & Amaral-Zettler, L. Microbial Diversity and Potential Pathogens in Ornamental Fish Aquarium Water. *PLOS ONE* **7,** e39971 (2012).
47. Matias, C. A. R., Pereira, I. A., Reis, E. M. F. dos, Rodrigues, D. dos P. & Siciliano, S. Frequency of zoonotic bacteria among illegally traded wild birds in Rio de Janeiro. *Braz. J. Microbiol.* **47,** 882–888 (2016).
48. Karesh, W. B., Cook, R. A., Gilbert, M. & Newcomb, J. Implications of wildlife trade on the movement of avian influenza and other infectious diseases. (2016).
49. Hai, W., Zhao, Z., Wang, J. & Hou, Z.-G. The Short-Term Impact of SARS on the Chinese Economy. *Asian Econ. Pap.* **3,** 57–61 (2004).
50. Lee, J.-W. & McKibbin, W. J. *ESTIMATING THE GLOBAL ECONOMIC COSTS OF SARS*. (National Academies Press (US), 2004).
51. Perrings, C. Options for managing the infectious animal and plant disease risks of international trade. *Food Secur.* **8,** 27–35 (2016).
52. Anthony, S. J. *et al.* A Strategy To Estimate Unknown Viral Diversity in Mammals. *mBio* **4,** (2013).
53. Olival, K. J. *et al.* Host and viral traits predict zoonotic spillover from mammals. *Nature* nature22975 (2017). doi:10.1038/nature22975
54. Picco, A. M., Karam, A. P. & Collins, J. P. Pathogen host switching in commercial trade with management recommendations. *EcoHealth* **7,** 252–256 (2010).
55. Lyons, J. A. & Natusch, D. J. D. Wildlife laundering through breeding farms: Illegal harvest, population declines and a means of regulating the trade of green pythons (Morelia viridis) from Indonesia. *Biol. Conserv.* **144,** 3073–3081 (2011).
56. Seebens, H. *et al.* No saturation in the accumulation of alien species worldwide. *Nat. Commun.* **8,** (2017).
57. Bellard, C., Leroy, B., Thuiller, W., Rysman, J.-F. & Courchamp, F. Major drivers of invasion risks throughout the world. *Ecosphere* **7,** n/a-n/a (2016).
58. Mwangi, W., Figueiredo, P. de & Criscitiello, M. F. One Health: Addressing Global Challenges at the Nexus of Human, Animal, and Environmental Health. *PLOS Pathog.* **12,** e1005731 (2016).

59. Woodford, M. H. & Rossiter, P. B. Disease risks associated with wildlife translocation projects. *Rev. Sci. Tech. Int. Off. Epizoot.* **12,** 115–135 (1993).
60. Friant, S., Paige, S. B. & Goldberg, T. L. Drivers of bushmeat hunting and perceptions of zoonoses in Nigerian hunting communities. *PLoS Negl. Trop. Dis.* **9,** e0003792 (2015).
61. Chan, H.-K., Zhang, H., Yang, F. & Fischer, G. Improve customs systems to monitor global wildlife trade. *Science* **348,** 291–292 (2015).
62. D'Cruze, N. & Macdonald, D. W. A review of global trends in CITES live wildlife confiscations. *Nat. Conserv.* **15,** 47–63 (2016).
63. Hansen, A. L. S., Li, A., Joly, D., Mekaru, S. & Brownstein, J. S. Digital Surveillance: A Novel Approach to Monitoring the Illegal Wildlife Trade. *PLOS ONE* **7,** e51156 (2012).
64. Patel, N. G. *et al.* Quantitative methods of identifying the key nodes in the illegal wildlife trade network. *Proc. Natl. Acad. Sci. U. S. A.* **112,** 7948–7953 (2015).
65. Kamins, A. O. *et al.* Uncovering the fruit bat bushmeat commodity chain and the true extent of fruit bat hunting in Ghana, West Africa. *Biol. Conserv.* **144,** 3000–3008 (2011).
66. Jansen, W. *et al.* The Quantity and Quality of Illegally Imported Products of Animal Origin in Personal Consignments into the European Union Seized at Two German Airports between 2010 And 2014. *PLOS ONE* **11,** e0150023 (2016).
67. Wernery, U. Zoonoses in the Arabian Peninsula. *Saudi Med. J.* **35,** 1455–1462 (2014).
68. Chomel, B. B., Belotto, A. & Meslin, F.-X. Wildlife, Exotic Pets, and Emerging Zoonoses. *Emerg. Infect. Dis.* **13,** 6–11 (2007).
69. Burke, R. L. *et al.* A review of zoonotic disease surveillance supported by the Armed Forces Health Surveillance Center. *Zoonoses Public Health* **59,** 164–175 (2012).
70. Morse, S. S. Public health surveillance and infectious disease detection. *Biosecurity Bioterrorism Biodefense Strategy Pract. Sci.* **10,** 6–16 (2012).
71. Early, R. *et al.* Global threats from invasive alien species in the twenty-first century and national response capacities. *Nat. Commun.* **7,** (2016).
72. Weaver, G. V., Domenech, J., Thiermann, A. R. & Karesh, W. B. Foot and mouth disease: a look from the wild side. *J. Wildl. Dis.* **49,** 759–785 (2013).
73. Peeler, E. J., Reese, R. A. & Thrush, M. A. Animal Disease Import Risk Analysis--a Review of Current Methods and Practice. *Transbound. Emerg. Dis.* **62,** 480–490 (2015).
74. Cooper, N. *et al.* Phylogenetic host specificity and understanding parasite sharing in primates. *Ecol. Lett.* **15,** 1370–1377 (2012).