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Original Article

Wildlife hosts for OIE-Listed diseases: considerations regarding global wildlife trade and host–pathogen relationships

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Abstract

The expanding international wildlife trade, combined with a lack of surveillance for key animal diseases in most countries, represents a potential pathway for transboundary disease movement. While the international wildlife trade represents over US $300 billion per year industry involving exchange of billions of individual animals, animal products, and plants as traditional medicines, meat from wild animals, trophies, live exotic pets, commercial products and food, surveillance and reporting of OIE-Listed diseases in wildlife are often opportunistic. We reviewed peer-reviewed literature for reports of 73 OIE-Listed terrestrial animal diseases in wild animals and found 528 possible wild animal hosts using our methodology. Not all host–pathogen relationships indicate that a particular species serves an epidemiologically significant role in the transmission of disease, but improved reporting of infections in wild animals along with clinical and pathological findings would contribute to improved One Health risk assessments.

Keywords: trade, disease, host, reportable, wildlife.

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Introduction

Given the increasing trend in global wild animal trade, the lack of strong surveillance and control of a number of diseases in wild species in many countries represents a missing link and a potentially concerning pathway for disease exchange between nations. The international wildlife trade represents over US $300 billion per year industry involving exchange of billions of individual animals, animal products, and plants as traditional medicines, meat from wild animals, trophies, live exotic pets, commercial products and food (Ahlenius *et al.* 2008; Smith *et al.* 2009). Unlike the case with domestic animal trade, minimal health monitoring systems exist surrounding the trade of some wild animals, while it appears adequate in others for certain diseases (e.g. cloven hoofed animals for foot and mouth disease). Further, there is an estimated US $5–20 billion per year illegal global trade of wild animals and their products that do not undergo any type of inspection. Thus, movement and intermixing of wild animals along global trade chains presents potentially significant risk of disease emergence and transmission to humans, livestock and native wildlife within both the exporting and importing countries if adequate procedures are not followed to mitigate such risk.

Background

Since the founding of the Office International des Epizooties (OIE) in 1924 (called the World Organisation for Animal Health since May, 2003), Member Countries (from 28 founding countries to 180 presently) have been working together to eradicate and/or control the spread of diseases detrimental to food animal production and/or public health, and create an environment of transparent international communication regarding infection, and the sharing of information on epizootic diseases, their control

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and prevention. The first list of diseases agreed upon by Members for mandatory reporting was composed of rinderpest, rabies, foot-and-mouth disease (FMD), glanders, contagious pleuropneumonia, dourine, anthrax, swine fevers, sheep pox and goat pox as well as the relevant species for which disease notification to OIE should occur. The notification system has evolved over the years to include additional diseases and data relevant to the epizootics reported. Resolutions passed by the OIE International Committee and recommendations issued by the OIE Regional Commissions resulted in the establishment of a single OIE list of notifiable terrestrial and aquatic animal diseases (also referred to as OIE-Listed diseases) to replace the former priority-based Lists A and B. The aim in drawing up a single list was to be in line with the terminology of the Sanitary and Phytosanitary (SPS) Agreement of the World Trade Organization, by classifying diseases as specific hazards and giving all listed diseases the same degree of importance in international trade. The OIE International standards are recognized as the reference for international sanitation for animal diseases including zoonotic diseases, by the World Trade Organization under its Agreement on SPS measures, making them internationally enforceable (Domenech *et al.* 2006; Thiermann 2005.)

Disease control measures

Some OIE Member Countries have an official status pertaining to specific diseases, recognized by the OIE following an official classification procedure for disease occurrence in that country. While 'disease/infection-free' status of a country is often the goal, due to the endemic nature of certain diseases, complete eradication may be impractical, not possible or too expensive. In such cases, a distinct geographical zone or compartmentalized subpopulation may be established under the regionalization clause of the SPS Agreement to facilitate international trade. Establishment of such zones and subpopulations must follow strict surveillance, monitoring and biosecurity measures (Thiermann 2005; Brückner 2009). This may be an important option for countries with notifiable diseases present in free-ranging wildlife populations (e.g. H5 or H7 avian influenzas and classical swine fever; Thiermann 2005).

Disease surveillance in animals and subsequent reporting by countries are cornerstones of the OIE programmes. As a condition of OIE membership, Member Countries are required to conduct surveillance and submit immediate notification on newly detected or reoccurring OIE-Listed diseases, as well as weekly reports subsequent to a notification to provide further information on the evolution of the event which justified the notification (follow-up reports), and the control measures put in place to control the event. There are biannual reports on OIE-Listed disease situations in Member Countries. This information is stored in the OIE's World Animal Health Information System (WAHIS) which is accessible to the public (http://www.oie.int/wahid).

OIE-Listed diseases and wildlife

Member Countries are obliged to report all detected occurrences of OIE-Listed diseases regardless of the animals affected (whether domestic, wild, captive wild or feral). According to the OIE Terrestrial Animal Health Code (2015), 'wildlife' refers to wild animals, captive wild animals and feral animals. The differentiations are based on whether the animal or group of animals is primarily dependent on care by humans and whether the animal's phenotype has been selected by humans. These classifications can help to delineate approaches to disease prevention and control and identify potential epidemiological roles of each type of animals in disease epidemiology and dynamics.

Surveillance and reporting of OIE-Listed diseases in wildlife are often opportunistic in many countries. Systematic and comprehensive wildlife pathogen surveillance is challenging for several reasons including large geographical host ranges and challenges with access to wildlife, wide diversity of species present in regions, limited resources (especially as many developing countries host the most biodiversity) and lack of infrastructure for wild animal pathogen surveillance (e.g. professional training, best practices, diagnostic facilities, etc.). While many countries may conduct livestock disease surveillance through the

Ministry of Agriculture or other governmental Veterinary Services, which work closely with the OIE through a delegate generally from the Ministry of Agriculture or Livestock, wild animal health often falls separately under a Ministry of Environment or Forestry, which may or may not have the capacity for running adequate disease surveillance programmes. The OIE has put in place the concept of wildlife focal points that could be from other national ministries to improve coordination and information sharing on wild animal diseases. The paucity of validated diagnostic tests available for use in most wild animals presents an additional challenge to determining current or previous pathogen infection and significance (Cousins & Florisson 2005).

While the OIE has traditionally focused on livestock, the growing intersection of wild and domestic animals and increasing global wildlife trade warrant a closer look at wildlife pathogen susceptibility. The OIE has demonstrated a strong commitment to integrating wildlife considerations into its disease reporting, prevention and animal health capacity-building efforts. To further this goal, EcoHealth Alliance collaborated with the OIE World Animal Health Information and Analysis Department to generate a database of host wildlife families with species proven to be susceptible to OIE-Listed diseases. The intention of the database was to provide information to better assist OIE Member Countries in their consideration of wildlife surveillance and trade activities, and to provide the OIE with a reference list of potential wildlife hosts based on peer-reviewed scientific literature to be considered for inclusion in the WAHIS reporting system. In general, the database serves to identify a broad scope of known families with host species of OIE-Listed diseases.

Materials and Methods

An analysis of the peer-reviewed literature published in the English language between 1900 and 2014 was carried out for each of the 73 OIE-Listed terrestrial animal diseases (categorized according to Table 1) between May 2012 and July 2014. The disease name, causal pathogen(s) and any historical scientific names for the pathogens were used as keywords in separate searches in Web of Knowledge. Reported confirmed animal host–pathogen relationships (with the exception of avian hosts) for OIE-Listed diseases were recorded in our database. For this study, a 'host' was defined as a species for which at least one individual was documented to have been infected with a particular pathogen through diagnostic testing. Host–pathogen relationships reported in review articles were verified via the original peer-reviewed source. Host–pathogen relationships established through experimental research (i.e. laboratory-induced infections) and originating from laboratory or zoological collections were excluded.

For each host–pathogen relationship identified from the literature, the host species, pathogen, pathogen detection method (i.e. laboratory test applied) and scientific reference were recorded. The pathogen detection method was compared against the 'Prescribed and alternative diagnostic test for OIE-Listed diseases' in the OIE *Manual of Laboratory Diagnostic Tests and Vaccines (*OIE Manual*)*. If the detection method fell within the OIE criteria or was considered more reliable (i.e. possessed a higher sensitivity and specificity), the host–pathogen relationship was considered confirmed and included in our database. Host–pathogen associations were excluded if the detection method was deemed inadequate according to the OIE Manual or not stated. Hosts for which evidence was based on serology alone were only included if the serological test used was the OIE prescribed test, and it was noted whether the serological test included antibody identification vs. antigen detection. Once one valid reference was found for each host–pathogen relationship, further references for that relationship were not pursued. Although wild animals were the focus of the database, domestic animal host and human host records from the literature were separately noted to highlight the potential for cross-exposure.

Results

Among the 73 OIE-Listed terrestrial animal diseases reviewed, 528 wild animal host species were documented from the literature using our methodology. The number of wild animal hosts (by species) for

Table 1. Number of host species of OIE-Listed diseases and their corresponding families.

OIE-Listed disease	Wildlife host families			Number wildlife host species
African horse sickness	Canidae	Felidae	Rhinocerotidae	11
	Elephantidae	Hyaenidae	Viverridae	
	Equidae			
Audjeszky's disease	Cricetidae	Leporidae	Procyonidae	6
	Felidae	Muridae		
African swine fever	Suidae			2
Anthrax	Bovidae	Giraffidae	Mustelidae	58
	Canidae	Hippopotamidae	Myocastoridae	
	Elephantidae	Hominidae	Rhinocerotidae	
	Equidae	Hyaenidae	Suidae	
	Eupleridae	Lorisidae	Viverridae	
	Felidae			
Bluetongue	Antilocapridae	Elephantidae	Muridae	57
	Bovidae	Felidae	Rhinocerotidae	
	Canidae	Giraffidae	Ursidae	
	Cervidae	Hyaenidae	Viverridae	
Bovine anaplasmosis	Antilocapridae	Equidae	Rhinocerotidae	39
	Bovidae	Giraffidae	Sciuridae	
	Cervidae	Nesomyidae		
Bovine babesiosis	Bovidae	Cervidae		8
Bovine genital campylobacteriosis				0
Bovine spongiform encephalopathy				0
Bovine viral diarrhea	Antilocapridae	Camelidae	Rhinocerotidae	39
	Bovidae	Cervidae	Tragulidae	
Brucella abortus	Bovidae	Didelphidae	Leporidae	30
	Camelidae	Equidae	Muridae	
	Canidae	Giraffidae	Procyonidae	
	Cervidae	Heteromyidae	Suidae	
	Cricetidae	Hippopotamidae	Ursidae	
Brucella melitensis	Bovidae	Cervidae	Suidae	6
	Camelidae	Equidae		
Brucella ovis	Cervidae			2
Brucella suis	Bovidae	Equidae	Suidae	6
	Canidae	Leporidae	Ursidae	
Camelpox				0
Caprine arthritis/encephalitis				0
Chlamydophila abortus	Bovidae	Ranidae		6
	Phocidae			
Classical swine fever				0
Contagious agalactia	Bovidae			1
Contageous bovine pleuropneumonia				0
Contagious caprine pleuropneumonia	Bovidae			3
Contagious equine metritis				0
Crimian congo hemorrhagic fever	Bovidae	Hystricidae	Pedetidae	35
	Elephantidae	Leporidae	Rhinocerotidae	
	Equidae	Muridae	Sciuridae	
	Erinaceidae	Nesomyidae	Suidae	
	Giraffidae			
Dourine				0
Echinococcus granulosus	Bovidae	Equidae	Hippopotamidae	14
	Canidae	Felidae	Suidae	
	Cervidae	Giraffidae		

Table 1. Continued

OIE-Listed disease	Wildlife host families			Number wildlife host species
Echinococcus multilocularis	Cervidae	Felidae		14
	Cricetidae	Muridae		
EEEV	Cercopithecidae	Emballonuridae	Phyllostomidae	23
	Cricetidae	Molossidae	Sciuridae	
	Dasypodidae	Muridae	Vespertilionidaae	
Enzootic bovine leukosis	Caviidae			1
Epizootic hemorrhagic disease	Antilocapridae	Cervidae		12
	Bovidae			
Equine arteritis	Equidae			1
Equine piroplasmosis	Equidae			1
Equine herpesvirus-1	Equidae	Rhinolophidae	Ursidae	6
Equine infectious anemia				0
Foot and Mouth disease	Bovidae	Erinaceidae	Tapiridae	60
	Camelidae	Giraffidae	Tayassuidae	
	Cervidae	Macropodidae	Ursidae	
	Elephantidae	Suidae		
Glanders	Felidae	Leporidae		2
Goat pox and sheep pox				0
H3N8 and H7N7				0
Heartwater	Bovidae	Cervidae		8
Hemorrhagic septicemia	Bovidae	Felidae	Phocidae	15
	Cebidae	Hominidae		
	Cervidae	Leporidae		
Infectious bovine rhinotracheitis	Bovidae	Cervidae		16
Japanese encephalitis	Cercopithecidae	Hominidae	Rhinolophidae	25
	Emballonuridae	Pteropodidae	Vespertilionidae	
	Hipposideridae			
Leishmania	Bradypodidae	Didelphidae	Myrmecophagidae	48
	Canidae	Echimyidae	Phocidae	
	Cebidae	Felidae	Phyllostomidae	
	Cricetidae	Herpestidae	Pitheciidae	
	Ctenodactylidae	Hystricidae	Procaviidae	
	Cuniculidae	Megalonychidae	Procyonidae	
	Dasypodidae	Muridae	Rodentia	
	Dasyproctidae	Mustelidae	Viverridae	
Lumpy skin disease	Bovidae	Giraffidae		10
Maedi-visna				0
Mycobacterium bovis	Bovidae	Herpestidae	Phalangeridae	45
	Canidae	Hyaenidae	Procyonidae	
	Cercopithecidae	Lemuridae	Rhinocerotidae	
	Cervidae	Leporidae	Suidae	
	Elephantidae	Muridae	Talpidae	
	Erinaceidae	Mustelidae	Ursidae	
	Felidae	Otariidae		
Myxoma virus	Leporidae			5
New world screw worm	Atelidae	Cervidae	Mustelidae	10
	Bovidae	Didelphidae Leporidae	Pitheciidae	
	Canidae			
Nairobi sheep disease	Antilocapridae	Muridae		3
	Cercopithecidae	Nesomyidae		

Table 1. Continued

OIE-Listed disease	Wildlife host families			Number wildlife host species
Nipah virus	Hipposideridae	Pteropodidae	Vespertilionidae	21
	Muridae	Rhinolophidae		
Old world screw worm	Aepycerotinae	Felidae	Rhinocerotidae	8
	Bovidae	Giraffidae	Ursidae	
	Elephantidae			
Paratuberculosis	Bovidae	Corvidae	Muridae	15
	Canidae	Leporidae	Mustelidae	
	Cervidae			
Peste des petits ruminants	Bovidae			5
Porcine cystocircosis	Hylobatidae	Ursidae		3
	Otariidae			
Porcine reproductive and respiratory syndrome				0
Q fever	Canidae	Muridae	Sciuridae	15
	Cricetidae	Otariidae	Suidae	
	Cricetidae	Phocidae	Ursidae	
	Didelphidae	Phocoenidae		
	Leporidae	Procyonidae		
Rabbit haemorrhagic disease	Leporidae	Muridae		3
Rabies	Bovidae	Felidae	Myocastoridae	137
	Canidae	Herpestidae	Phyllostomidae	
	Caviidae	Hyaenidae	Procyonidae	
	Cervidae	Mephitidae	Pteropodidae	
	Cricetidae	Molossidae	Rhinolophidae	
	Elephantidae	Mormoopidae	Sciuridae	
	Emballonuridae	Muridae	Vespertilionidae	
	Erethizontidae	Mustelidae	Viverridae	
Rift Valley fever	Bovidae	Muridae	Rhinocerotidae	18
	Hipposideridae	Pteropodidae	Vespertilionidae	
Rinderpest	Bovidae	Giraffidae	Suidae	25
	Cervidae	Hippotamidae	Tayassuidae	
Salmonellosis	Bovidae			1
Scrapie				0
Surra	Caviidae	Cricetidae	Phyllostomidae	9
	Cervidae	Echimyidae	Tayassuidae	
Swine vesicular disease				0
Theileriosis	Bovidae	Cervidae		2
Transmissable gastroenteritis				0
Trichinella	Canidae	Felidae	Mustelidae	59
	Castoridae	Herpestidae	Nandiniidae	
	Cricetidae	Hyaenidae	Odobenidae	
	Crocodylidae	Mephitidae	Procyonidae	
	Dasypodidae	Monodontidae	Sciuridae	
	Dasyuridae	Muridae	Ursidae	
	Didelphidae			
Tritrichomonas foetus	Leporidae	Muridae		2
Trypanosomosis	Bovidae	Felidae	Rhinocerotidae	25
	Camelidae	Hippopotamidae	Suidae	
	Cercopithecidae	Lorisidae		

Table 1. Continued

OIE-Listed disease	Wildlife host families			Number wildlife host species
Tularemia	Cambaridae	Felidae	Muridae	65
	Canidae	Gadidae	Mustelidae	
	Castoridae	Haemulidae	Procyonidae	
	Cervidae	Haliotidae	Salmonidae	
	Cichlidae	Heteromyidae	Sciuridae	
	Cricetidae	Leporidae	Soricidae	
	Equidae	Mephitidae	Talpidae	
	Erinaceidae	Moronidae	Ursidae	
	Falconidae			
Venezuelan equine encephalomyelitis	Cricetidae	Echimyidae	Phyllostomidae	33
	Cuniculidae	Heteromyidae	Sciuridae	
	Didelphidae	Muridae	Vespertilionidae	
Vesicular stomatitis	Antilocapridae	Cricetidae	Leporidae	58
	Aotidae	Dasypodidae	Megalonychidae	
	Atelidae	Dasyproctidae	Mephitidae	
	Bovidae	Didelphidae	Muridae	
	Bradypodidae	Echimyidae	Myocastoridae	
	Camelidae	Echimyidae	Myrmecophagidae	
	Canidae	Equidae	Phyllostomidae	
	Cebidae	Erethizontidae	Procyonidae	
	Cervidae	Heteromyidae	Sciuridae	
West Nile virus	Cercopithecidae	Molossidae	Pteropodidae	23
	Cervidae	Muridae	Sciuridae	
	Cricetidae	Procyonidae	Vespertilionidae	
	Didelphidae			
Western equine encephalomyelitis	Colubridae	Leporidae	Procyonidae	16
	Cricetidae	Mephitidae	Ranidae	
	Didelphidae	Phyllostomidae	Sciuridae	
Total wildlife host-pathogen relationships				1146

each disease ranged from 0 to 137, with a mean of 16 wild animal hosts per disease. Of these 73 diseases, 56 (76.7%) were documented to infect at least one wild animal host. The disease affecting the most wild animal hosts was rabies (137) followed by tularemia (65) and FMD (60). Table 1 provides the 73 OIE-Listed diseases evaluated and numbers of hosts. The 17 diseases for which no documented wild animal hosts were found were bovine genital campylobacteriosis, bovine spongiform encephalopathy, camelpox, caprine arthritis/encephalitis, classical swine fever, contagious bovine pleuropneumonia, contagious equine metritis, dourine, equine infectious anaemia, equine influenza, Maedi-visna, porcine respiratory and reproductive syndrome, sheep pox and goat pox, swine vesicular disease, scrapie and transmissible gastroenteritis. Most of these diseases are species specific in nature, however, the possibility also exists that adequate surveillance has never been conducted in wildlife.

Discussion

The goal of this research was to provide regulatory authorities, animal importers and exporters and the scientific community with a comprehensive wild animal host–pathogen list for OIE-Listed diseases causing natural infections in wild animal hosts and detected via proven diagnostic methodologies, thus providing authorities with additional science-based evidence to consider when assessing 'One Health' risk in the management, movement, or trade in these

species. This study was limited to OIE-Listed terrestrial diseases given our initial focus on threats to agriculture and the sufficient scientific literature documenting wild animal hosts for these diseases. There is a larger paucity of data for full range of wild animal hosts for some avian, aquatic, amphibian and bee diseases; however, the authors hope to summarize the existing knowledge and gaps in future assessments.

Seventeen diseases did not have any documented wild animal hosts according to our methodology, thus demonstrating that the risk for (non-zoo) wildlife spreading these diseases is negligible until further evidence to the contrary is found. Many of the diseases affecting numerous wild animal hosts were predictable, including diseases well known to have a broad host range such as rabies (137) and anthrax (58). However, other diseases had a noteworthy number of proven wild animal hosts such as vesicular stomatitis (58), leishmaniasis (48) and Q fever (15). The host list of the latter included marine mammals and rodents, and more than doubled when wild birds and domestic animals were also considered. While the composition of wild animal hosts for many diseases were well recognized (e.g. FMD in a wide range of hoofstock species), there were other diseases represented in less well-recognized hosts (e.g. rodents, foxes, opossums and rabbits as carriers of *Brucella abortus* (30), and rodents and bats infected with Rift Valley fever (RVF) virus (18)).

In certain cases for which the wild species host range is widely acknowledged, such recognition may only be in terms of effective disease management in domestic animals rather than in consideration of risks surrounding wild animal importation. An example of this is bovine tuberculosis (*Mycobacterium bovis*) (45), for which certain wild animal hosts are an integral component of national eradication strategies (e.g. opossums in New Zealand and badgers in the United Kingdom) while other species' roles as potential hosts for *M. bovis* are less appreciated when it comes to international trade (e.g. including lagomorphs, mustelids, marine mammals and rodents). In other situations, certain taxonomic groups present in international trade such as wild ungulates may be well regulated and inspected for specific diseases such as FMD but not for other diseases they may harbour such as haemorrhagic septicemia. This becomes significant especially for pathogens that may infect and be shed by wild animal hosts but not cause clinical signs in those species and thus are more likely to go undetected even during quarantine if specific tests for such pathogens are not performed (Levinson *et al.* 2013).

The families with the highest host–pathogen relationships were *Bovidae* (427 host–pathogen relationships), *Cervidae* (111) and *Canidae* (91), illustrating that OIE-Listed diseases of concern to domestic animals are often capable of being transmitted by wild animal members of the same families of those domestic animals (e.g. FMD in *Bovidae*). Other common wild animal families hosting OIE-Listed diseases included *Muridae* (57), *Phyllostomidae* (58) and *Vespertilionidae* (61), emphasizing the role of rodents and bats as carriers of diseases of importance to human and livestock health. Of particular note, our host–pathogen count within *Muridae* was a gross underestimate, as in several cases, all or most species of the *Muridae* family were believed to be potential hosts yet were not individually documented in the literature and only reported at the family level.

Of the 1146 host–pathogen relationships recorded in this study, approximately one-quarter were confirmed via serology for antibodies (using OIE-approved methodology). Serology was considered less definitive given the inability to confirm active infection vs. exposure based on antibody presence alone. Furthermore, although these tests were OI-approved for the given disease, often they were not validated for the wild animal host in which they were applied. Thus, in some cases, this may have resulted in an overestimation of true host range due to cross-reactivity of related pathogens in a given host species.

To be conservative, we did not include host–pathogen relationships that were not confirmed via OIE-approved test methods, which significantly decreased the number of wild animal hosts documented. For example, while we recorded 60 wild animal hosts for FMD using our review methodology, natural or experimental FMD virus has been reported in over 100 wild, feral, laboratory or semi-domesticated animals (Weaver *et al.* 2013). Furthermore, we chose

not to include recorded host–pathogen relationships that were noted in zoological collections given that they are considered captive wild animals according to the OIE definition, and the density of biodiversity present in such captive conditions presents an enhanced opportunity for interspecies disease exchange that would not be epidemiologically important in free-ranging wild animals. Thus, while captive wild animals such as those held in zoos and rehabilitation centres are likely to be involved in international trade, it is noteworthy to mention that these host–pathogen relationship records were not included in our database.

Finally, our records of host–pathogen relationship did not reflect prevalence, and any given documented relationship may represent findings of the disease in one animal, or thousands. Thus, these confirmed relationships should not be directly translated into quantitative risk of any given population of that species as carrying the disease, rather only potential host susceptibility at a species level.

Our findings for several OIE-Listed diseases are notable in showing the range of wild animal species affected, and align with other recent findings. Miller *et al.* (2013) reported that, of the OIE-Listed diseases found within the United States, 79% have a wild animal component with a role in the pathogen's life cycle, transmission or maintenance; and wild animal hosts serve as reservoirs that inhibit eradication in domestic species for at least six OIE-Listed diseases in the United States, including rabies. The same apply to other countries and regions in the world where the presence of infectious diseases is known in wild animals and considered endemic. Thus, the need to monitor or make regular surveillance for these diseases, such as African swine fever in phacocheres (wart hogs) in sub-Saharan Africa, African horse sickness in zebra in certain regions of Africa or yellow fever in non-human primates in parts of Africa and South America, might be determined by other animal or public health priorities.

The OIE and the Food and Agriculture Organization of the United Nations have formed a Global Steering Committee on Trans-Boundary Animal Disease (GF-TADs), identifying major disease priorities, including rabies, FMD, Peste des Petit Ruminants, RVF, avian influenza and rinderpest (officially declared eradicated worldwide in May 2011). Although these diseases present important international priorities for the animal disease community and human health community, for some of these, little is known about the role of, and impact on, wild animals. For example, RVF, a zoonotic disease with serious economic implications for sheep, goat and cattle health and production (http://www.oie.int/fileadmin/Home/eng/Health_standards/tahm/2.01.14_RVF.pdf) (losses to the Kenyan economy from the 2007 outbreak were estimated at US $32 million), has not been thoroughly investigated in wild animal species although the virus has been confirmed in hosts including rodents, bats, rhinoceros, waterbuck, impala and wildebeest (Rich & Wanyoike 2010; OIE Terrestrial Animal Health Code, 2015) and reported in non-native wild animals such as llamas in the Republic of South Africa. Livestock can be vaccinated for RVF; however, because RVF is primarily transmitted through mosquito vectors that can acquire the virus from feeding on RVF-infected animals, virus in any wild animal hosts that overlap with competent vectors may pose threats to unvaccinated livestock, especially newborn animals (http://www.who.int/mediacentre/factsheets/fs207/en/). The role of potential wild animal hosts in inter-epidemic maintenance of this disease and its spread is yet to be fully explored.

Although the economic impact of livestock losses from OIE-Listed diseases are monitored and justify ongoing disease prevention efforts, endemic wild animal population losses due to these diseases have not been effectively quantified as OIE reporting did not require species identification for wild animals before 2012 (rather wild animals were recorded as Fauna using code Fau). Furthermore, the economic impact of livestock losses secondary to listed disease occurrences for which wild animals have played a reservoir role remains unspecified and therefore potentially underappreciated.

Conclusion

This study shows that more formal incorporation of wild animal considerations into advisements on

international trade-related disease risk is possible and is warranted. The goal of this report is not to suggest trade policy restrictions on wild animal hosts (which may be driven by species conservation issues not highlighted here), rather the aim is to encourage understanding and documentation of wild animal host-OIE-Listed disease relationships so that they may be acknowledged in Member Country surveillance, risk assessments and risk management.

Free-ranging wild animals present a challenge when defining the nature of a 'host'. Because in many cases, the diagnostic test being used to conduct surveillance has not been validated or approved for the species being tested, differentiating exposure, infection and false results poses a challenge. Until better understanding of the relevance of OIE-Listed diseases in certain wild animal hosts is gained, some countries may be deterred from performing surveillance in these hosts for fear of positive results and their implications including on trade. To reduce this concern, OIE provides a number of mechanisms which exempt positive findings in wildlife from trade restriction, and chapters of the OIE Terrestrial Code are now reviewed and updated with the consideration of the evidence for epidemiological significance of different wild animal hosts to reduce unnecessary trade restrictions.

Wild animals should be considered as a significant component of disease considerations for the international trade of animals. Until the presence and/or prevalence of diseases of concern in wild animal populations and their relevance can be better understood where they are lacking, and given the relatively limited health regulations implemented in the wild animal trade vs. the agricultural trade sector, countries can take note of the potential risks of wild animal importation and translocation in specific cases. Synergistic efforts across animal health, ecology and risk assessment may provide a more comprehensive understanding of the relative risks of various types of wild animal trade and relevant transmission pathways from this trade, and in identifying risk mitigation strategies where actual surveillance is not practical or feasible. While we believe this study and associated database are a critical first step, not all host–pathogen relationships indicate that a particular species serves an epidemiologically significant role in the transmission of disease. Reporting of infections in wild animals along with clinical and pathological findings will contribute to improved risk assessments for both wild and domestic animal species in the future.

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Conflict of Interest

The authors declare that they have no conflicts of interest.

Contributions

The authors have no additional contributions to declare.

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