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IMPLICATIONS OF WILDLIFE TRADE ON THE MOVEMENT OF AVIAN INFLUENZA AND OTHER INFECTIOUS DISEASES[1,2]

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ABSTRACT: The global trade in wildlife provides disease transmission mechanisms that not only result in human disease outbreaks, but also threaten livestock, international trade, rural livelihoods, native wildlife populations, and the health of ecosystems. Global movement of animals for the pet trade is estimated at some 350 million live animals, worth approximately US$20 billion per year. Approximately one-quarter of this trade is thought to be illegal, hence not inspected or tested. Disease outbreaks resulting from trade in wildlife have caused hundreds of billions of dollars of economic damage globally. Rather than attempting to eradicate pathogens or the wild species that may harbor them, a practical approach would include decreasing the contact rate among species, including humans, at the interface created by wildlife trade. Wild animals are captured, transported, and sold either live or dead and commingled throughout the process in a system of scale-free networks with major hubs rather than random or evenly distributed supply systems. As focal points for distribution and sales, the hubs provide control opportunities to maximize the effects of regulatory efforts as demonstrated with domestic animal trading systems (processing plants and wholesale and retail markets, for example). Focusing efforts at markets to regulate, reduce, or in some cases, eliminate the commercial trade in wildlife could provide a cost-effective approach to decrease the risks for disease in humans, domestic animals, wildlife, and ecosystems.

Key words: Avian influenza, Ebola, infectious disease, networks, SARS, wildlife trade.

Threats to the health of people, animals, and ecosystems, and the risk factors for emerging infectious diseases run the gamut from climate change to poverty to security issues. Few are as immediately manageable as the risk factor of global trade in wildlife. Trade in wildlife provides disease-transmission mechanisms at scales that not only cause human disease outbreaks but also threaten livestock, international trade, rural livelihoods, native wildlife populations, and the health of ecosystems. Each year, roughly 350 million live plants and wild animals are shipped globally (World Wildlife Fund, 2001). Unfortunately, a single global total is not available for wild animals alone and much of the trade is illegal or not closely monitored. Surveys of live wildlife in markets in Guangzhou, China included masked palm civets (*Paguma larvata*), ferret badgers (*Melogale* spp.), barking deer (*Muntiacus reevesi*), wild boar (*Sus scrofa*), bamboo rats (*Rhizomys sinensis*), endangered leopard cats (*Prionailurus bengalensis*), and various species of hedgehogs, foxes, squirrels, gerbils, and snakes, together with domestic dogs, cats, and rabbits (Asia Animals Foundation, 2005). Following the severe acute respiratory syndrome (SARS) outbreak in 2003, 838,500 wild animals reportedly were confiscated from the markets in Guangzhou (British Broadcasting Corporation, 2003). Daily, wild birds flow through trading centers where they are in contact with dozens of other species before being shipped to other markets, sold locally, and even freed back in the wild as part of religious customs such as merit release (Mather, 2005) or because they become unwanted pets. In a single market in North Sulawesi, Indonesia, up to 90,000 mammals are sold per year (Clayton and

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Milner-Gulland, 2000). In a survey conducted at one market in Thailand over 25 weekends, over 70,000 birds comprised of 276 species were sold (Round, 1990). In lieu of precise trade data, we conservatively estimate that in East and Southeast Asia alone, tens of millions of wild animals are shipped regionally and from around the world annually for food or use in traditional medicine. The estimate for trade and local and regional consumption of wild animal meat in Central Africa is over one billion kilograms per year (Wilkie and Carpenter, 1999) and estimates for consumption in the Amazon Basin range from 67 to 164 million kilograms annually (Robinson and Redford, 1991; Peres, 2000). In Central Africa, the majority of wild animals harvested are small mammals (including small antelope and primates), birds, and reptiles. Assuming an average body weight of 5 kg results in a conservative estimate of 200 million animals in Central Africa and 12–35 million in the Amazon basin. The increasingly global scope of this trade, coupled with rapid modern transportation and the reality that markets serve as network nodes rather than as product endpoints (Dezso and Barabasi, 2002), dramatically increases the movement and potential cross-species transmission of the infectious agents that every animal naturally hosts. As with the trade in domestic animals, the scale-free network nature of the trade in wildlife also provides opportunities for intervention and control, as has been demonstrated with foot and mouth disease, Newcastle's disease, and highly pathogenic avian influenza (HPAI).

Since 1980, over 35 new infectious diseases, or about 1 every 8 mo, emerged in humans (Smolinski et al., 2003). The origin of human immunodeficiency virus (HIV) is widely thought to be linked with the human consumption of nonhuman primates (Feng et al., 1999). Recent Ebola hemorrhagic fever outbreaks in humans were traced to index case contact with infected great apes hunted for food (Leroy et al., 2004). The severe acute respiratory syndrome (SARS) coronavirus was associated with the international trade in small carnivores and bats (Bell et al., 2004; Lau et al., 2005) and a study comparing antibody evidence of exposure to this coronavirus demonstrated a dramatic rise from low or zero prevalence of civets at farms to an approximately 80% prevalence in civets tested in markets (Tu et al., 2004). The inadvertent movement of infectious agents due to wildlife trade is not limited to human pathogens but includes those that can infect domestic animals as well as native wildlife that serve as biological linchpins in environmental integrity. Highly pathogenic avian influenza H5N1 virus was isolated from two mountain hawk eagles (*Spizaetus nipalensis*) illegally imported to Belgium from Thailand (World Organization for Animal Health, 2004) as well as from passerines shipped from east Asia to the United Kingdom (Dudley, 2006). Newcastle's disease entered Italy via a shipment of undetermined species of parrots, lovebirds, and finches imported from Pakistan for the pet trade (World Parrot Trust, 2004). Monkeypox was introduced to a native rodent species and subsequently humans in the United States by importation of wild African rodents from Ghana for the pet trade (Guarner et al., 2004). Merit release of wild birds and reptiles (the intentional release of animals as part of religious or cultural practices) that have passed through mixed animal markets provides another avenue for introducing novel infectious agents into the wild (Karesh et al., 2005; Mather, 2005). This warrants further investigation. Released scaly-breasted munias (*Lonchura punctulata*) along with other munia species tested positive for HPAI H5N1 in Hong Kong in 2007 (Promed-Mail, 2007a). Also in 2007, a black francolin (*Francolinus francolinus*), a species commonly captured and sold in markets as caged songbirds, tested positive for HPAI H5N1 in Pakistan (Promed-Mail, 2007b).

Many diseases are transmitted via parasites carried by imported animals. For example, between November 1994 and January 1995, U.S. Department of Agriculture personnel inspected 349 reptile shipments from 22 countries containing 117,690 animals (U. S. Animal Health Association, 1995). Ticks were removed from animals in 97 shipments and infested shipments included 54,376 animals (U. S. Animal Health Association, 1995). Information is not available to determine if the above-mentioned ticks were tested for pathogens; however, ticks carry many diseases that threaten livestock and human health, including heartwater disease, Lyme disease, and babesiosis.

The threat of emerging infectious diseases spreading among people and other animals is rising, fueled by human activities ranging from the handling of bushmeat and the trade in exotic animals to the destruction of wild habitat (Walsh et al., 1993; Lilley et al., 1997; Patz et al., 2000). In a list of 1,415 human pathogens, 61% are known to be zoonotic, and multiple host pathogens are twice as likely to be associated with an emerging infectious disease of humans (Taylor et al., 2001). Seventy-seven percent of pathogens found in livestock are shared with other host species (Haydon et al., 2002).

In addition to the direct health effects, disease outbreaks destabilized trade, had devastating effects on human livelihoods, and caused hundreds of billions of dollars of economic damage globally. The rash of livestock disease outbreaks around the world since the mid 1990s, including bovine spongiform encephalopathy, foot and mouth disease, avian influenza, and swine fever are estimated to have cost world economies over $80 billion (Newcomb, 2004). This figure does not include the additional costs due to avian influenza over the last 2 yr. In early 2003, the United Nation's Food and Agriculture Organization reported that more than two-thirds of global meat trade was embargoed as a result of mad cow disease, avian influenza, and other livestock disease outbreaks. Early efforts to control the spread of HPAI H5N1 in Asian countries included culling more than 140 million chickens (World Health Organization, 2005), with considerable additional impact since then. The projected growth of industrial livestock production to meet global protein demand in the coming decades will increase the economic and food security impacts of future disease outbreaks.

Traditional approaches to reducing disease prevalence or exposure risks such as culling or vaccination are not feasible for the myriad of species around the world included in the wildlife trade. Rather than attempting to eradicate pathogens or to eradicate the wild species that may harbor them, a practical approach to decrease the risk of spreading disease would include decreasing the contact among species. Closing retail poultry markets in Hong Kong for just 1 day per month reduced the rate of H9N2 avian influenza virus in market birds (Kung et al., 2003). Wang et al. (2006) demonstrated the presence of HPAI H5N1 in cages used for marketing live domestic poultry in Guangzhou, China. Little equivalent work has been conducted in market systems selling wildlife, but an analogous approach to the precautionary principle (Convention on Biological Diversity, 1992) might be appropriate for taking action prior to the next outbreak or pandemic. Wild bird markets appear to present the same risks, if not more, due to a lack of clear regulations and monitoring in many countries around the world. Major hubs associated with wildlife marketing provide control opportunities to maximize the impact of regulatory efforts (Dezso and Barabasi, 2002). Control strategies based at such hubs could include surveillance for species and sanitary regulation compliance, strengthening and enforcing disease-control regulations, developing and implementing quarantine procedures, and creating mechanisms to shift costs of

controlling disease outbreaks from the public to the animal suppliers or vendors. Focusing efforts at markets to regulate, reduce, or eliminate the trade in wildlife could provide a cost-effective approach to decrease the risks of disease for humans, domestic animals, wildlife, and ecosystems.

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