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Epidemic disease risks and implications for Veterinary Services

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Summary

Growth in the livestock sector is associated with heightened risk for epidemic diseases. The increasing spillover of new diseases from wildlife is being driven by wide-scale anthropogenic changes allowing for more frequent and closer wildlife-human and wildlife-livestock contacts. Increasing epidemics in livestock are associated with rapid transition of livestock systems from extensive to intensive, and local to global movement of livestock and their products through value chain networks with weak biosecurity. Major livestock epidemics in the past two decades have had substantial economic impacts, and the COVID-19 pandemic highlights the devastating socio-economic consequences that spillovers can have when not identified and controlled early in the process of emergence. This highlights the importance of Veterinary Services to integrated, whole-of-society efforts to control infectious diseases in animals. Emphasis within Veterinary Services must be placed on prevention and preparedness. We suggest four areas for continued improvement in Veterinary Services to meet this challenge. These include continued development of staff capacity for risk assessment and value chain analysis linked to improved policies and communication, appropriate adaptation of approaches to prevention and control in resource-poor settings, improved multi-sectoral and transboundary cooperation allowing for shared resources and expertise, and systematic approaches that enable Veterinary Services to influence decision-making for trade, markets, business, public health, and livelihoods development at the national and regional levels.

Keywords

Emerging infectious disease – Epidemic – One Health – Risk-based approaches – Systems approaches – Transboundary cooperation – Veterinary services.

Introduction

Global growth in the livestock sector is driven by population and economic growth, urbanisation, and technological advancements, with much of the increased demand for livestock derived foods occurring in low- and middle-income countries (LMIC). Positive consequences of this so-called ‘Livestock Revolution’ have included improved nutrition for children and the poor and improved income and livelihoods, while negative consequences have included environmental degradation, contributions to changing climatic conditions, and increased risk of spread of endemic and epidemic infectious diseases (1, 2, 3, 4).

The geospatial distribution and host dynamics of animal diseases are changing and new diseases are emerging, particularly at the livestock-wildlife interface (5, 6, 7). The recent global increase in reporting of epidemic livestock diseases is likely due at least in part to improved surveillance, wider and faster information sharing, and increased public awareness (8).

Due to data scarcity, the impacts of epidemic livestock diseases are difficult to quantify (9). In 2009, the World Organisation for Animal Health (OIE) estimated that disease in general reduced global food animal production by 20% (10), while a 2014 meta-analysis by Pradère (11) found that the overall disease mortality rate for livestock in low-income countries was 18%.

Under-resourced Veterinary Services continue to struggle to prepare, prevent, detect, and respond to disease epidemics. Veterinary Services play an important role in delivering direct and indirect economic, health, food security, and other societal benefits. At the same time, they face a number of threats and challenges that often extend far beyond their immediate control.

In this paper, we will focus on the drivers and risks of infectious disease epidemics, and how Veterinary Services can best manage existing and future threats. We examine the impacts and implications of seven major livestock-associated diseases in the past two decades to illustrate the need for strong Veterinary Services as part of preparedness for dynamic risks.

Drivers of disease emergence

Emerging infectious diseases (EIDs) are infections associated with new or significantly expanded geographic scope or spread of zoonotic, vector-borne, and drug-resistant pathogens. Among the key components of EID risk are exposure practices that allow for spillover of pathogens to other species and facilitate their spread. These exposures are often broadly characterised as domestic animal-human, wildlife-human, or wildlife-domestic animal.

Wildlife-origin pathogens make up over 70% of the number of infectious zoonoses emerging between 1940 and 2006 (12). While substantial progress has been made in strengthening coordination and risk management strategies for zoonotic disease threats linked to domestic animals, attention to the role of wildlife and environmental determinants and appropriate risk reduction strategies are limited to date, with the overall field of wildlife health poorly developed in terms of capacity and operations. There are several broad reasons for the increasing trend of wildlife-related zoonotic disease emergence events when compared to new diseases from livestock. These include human coexistence with domestic animals over centuries and millennia, the relatively high surveillance efforts in domestic animals compared to wild species, and, critically, the increasing frequency and changing types of wildlife-human and wildlife-domestic animal exposures associated with wide-scale anthropogenic changes (5, 13).

Mapping disease emergence events in recent decades and correcting for surveillance bias indicates EID hotspots from wildlife (Fig. 1). These hotspots can provide a general geographic guide to aid in global preparedness and prioritisation; however, all countries should consider possible sources of risk with hotspot characteristics. For disease emergence from wildlife specifically, hotspots are broadly associated with areas of high mammalian biodiversity, expanding human populations, and land use change, signifying environmental and anthropogenic changes that increase the likelihood of spillover (12, 5). Analyses of the sharing of viruses among humans and various genera or species of mammals have identified some viral families (among them *coronaviridae*, *filoviridae*, *orthomyxoviridae*, and *paramyxoviridae*) and mammalian and bird groups (particularly, bats, rodents and non-human primates) which are of greatest concern for emerging zoonoses globally (14). In the process of disease emergence, livestock can serve as amplifier hosts, either remaining asymptomatic or developing disease themselves (15).

Livestock disease epidemic risks

Risk factors for epidemics of infectious diseases in livestock include human population growth and prosperity creating increasing demand for livestock derived foods and resulting in increases in the global production and movement of livestock and livestock products. The intensification of livestock production has been made possible in part by the control of endemic infectious diseases, yet represents one of the greatest risks for epidemic disease spread in concentrated animal populations linked by networks of service providers (8). Genetically homogenous naive animal populations, reared in high densities in intensified systems, promote increased selection of key mutations as the pathogen transmits through the population, which may lead to evolution to highly pathogenic variants (16). Conversely, extensive farming practices with complex networks of animals moving to and from numerous small- to medium-size producers and markets also facilitate disease spread and complicate surveillance and response efforts.

Ecological disturbance creates conditions for epidemics resulting from otherwise rare or low-level endemic diseases (8). Of particular interest is natural habitat fragmentation due to agricultural expansion, where an increased interaction at the wildlife-livestock interface can facilitate the spread of pathogens. Changing climatic patterns also facilitate the spread of some diseases, or shift of some diseases, including northward where certain vector-borne diseases have long been temperature-limited and increased incidence may be seen (17). At the same time, suitability of some ranges will contract, along with changing precipitation patterns, potentially reducing disease risk and prevalence in some instances (see Stephen *et al*., this issue, for greater coverage on climate-related disease trends [18]). The uncertainty climate change presents at a local level, along with other possible effects of a warming climate on livestock production (e.g. feed and water sourcing, extreme heat) underscores the importance of preparedness.

The movement of livestock and their products is an important risk for the domestic and transboundary spread of infectious diseases. Livestock markets have been shown to be important nodes for disease spread, and associated value chains are often connected across borders. Risk pathways include direct spread by animals themselves, through insect vectors accompanying animals and equipment, and on the surfaces of equipment such as vehicles, crates, and on clothing.

Major epidemics associated with livestock in the 21st century

In Table I we present seven diseases that are emerging or have caused recent major epidemics. We consider how these drivers and risks influenced emergence, spread, and impact, and consider their implications for Veterinary Services in order to support risk-based approaches.

In low-income countries, more than one in seven livestock keepers is infected by zoonotic diseases (28). The economic sense of zoonotic disease prevention was demonstrated in a recent paper in 2020 by Dobson *et al.* (29). The World Bank (23) found that losses from outbreaks of Nipah, West Nile fever, severe acute respiratory syndrome (SARS), highly pathogenic avian influenza (AI), rift valley fever (RVF), and bovine spongiform encephalopathy from 1997 to 2009 were at least US$ 80 billion. Prevention would have avoided losses of US$ 6.7 billion per year, substantially more than the estimated US$ 1.9–3.4 billion needed for investing in human and animal health systems for zoonotic disease prevention and control in 139 LMICs. Clearly, animal disease epidemics have substantial direct and indirect health, social, and economic consequences. This highlights the importance of Veterinary Services within a more integrated whole-of-society response that recognises these linkages and potential direct and indirect effects.

Veterinary Services and epidemic prevention and control

Emphasis must be placed on prevention, given the impacts of epidemic diseases and difficulty of achieving control once they are established. Nevertheless, epidemics will occur and therefore preparedness for effective early detection and control is needed. The importance of prevention and preparedness is evidenced in the public health systems of Asian countries that had experienced SARS. Several Asian countries were better prepared for COVID-19 because they put in place measures for early detection and response to EID outbreaks. Preparedness for early detection and control allowed for appropriate opening of these economies once COVID-19 was under control, and for a more rapid economic recovery than much of the rest of the world.

The large-scale epidemics of H5N1 AI in Southeast Asia in 2004–2005 pushed for improved prevention, detection, response, and control efforts for infectious animal diseases specifically by adapting tools and approaches to the contexts of LMICs. This led to improved surveillance and emergency preparedness capacity in LMICs, particularly in Southeast, South, and East Asia (30). However, in many other countries, capacity has remained limited or specific to selected diseases, supported by donor funded programs. Nonetheless, the introduction of African swine fever (ASF) to the same geographic region in 2018 resulted in rapid spread to many countries and enormous socio-economic consequences. These experiences highlight advances that have been made, but also suggest four areas for continued improvement in Veterinary Services that will allow for better epidemic prevention, preparedness, and control.

Risk analysis

The risk analysis framework has been promoted by the OIE since the 1980s in support of livestock associated trade between countries. Since then, the central role of risk assessment has been recognised for facilitating an evidence-based prioritisation of disease prevention and control within countries and even for individual farms. One example is the role of risk assessment in informing risk mapping, risk-based surveillance, movement control and trade restrictions, zoning, and compartmentalisation. The risk assessment approach has been strengthened by recognising the importance of understanding the value chains that are relevant for a particular disease or commodity to inform the identification of risk pathways. In addition, understanding anthropogenic and economic factors in generating, perpetuating, and amplifying disease risks is important. The challenge for national Veterinary Services now is to continue developing their national capacity for risk assessment and value chain analysis, and then linking them with policies. It is notable that decisionmakers often struggle in dealing with the need to separate risk into its components of likelihood and consequences, and how important each is when it comes to deciding on acceptable risk or any risk mitigation measures. Furthermore, the inherent uncertainty associated with risk estimates is difficult for decisionmakers to consider when formulating their policies.

A further advance has been in the area of surveillance systems, where including risk-based surveillance has been recognised by the OIE in order to promote implementation of more cost-effective animal health surveillance (31). This will be extremely useful for LMICs, but it requires sound risk assessment to inform design of surveillance systems. Improving local capacity for risk-based surveillance, in particular community-based approaches, ensures relevance to local contexts (32, 33). For surveillance to be useful, it needs to be complemented by the capacity to conduct outbreak investigations that generate meaningful data which can inform prevention and control activities. Unfortunately, this is still an area where more investment into the development of staff capacity is required.

The COVID-19 pandemic highlights the importance of effective risk communication and community engagement (RCCE) to disease prevention and control, not only for informing decisionmakers but for guiding and influencing public behaviours. The COVID-19 'infodemic' spread rapidly, facilitated by the spread of misinformation via social media challenging effective public health messaging and costing lives (34). Effective RCCE includes transparency, the presentation of trusted evidence by authoritative voices, and the clear articulation of knowns and unknowns to help the public understand the nature of a risk and respond appropriately. Poorly formulated messages about risks associated with meat consumption contributed to steep drops in demand for meat with resulting economic impacts during the 2006/2007 and 2018 RVF outbreaks in East Africa (35), as did global consumer fears about poultry consumption in 2003 at the start of the H5N1 AI epidemic (36).

Appropriate adaptations in low- and middle-income countries

It is still common that prevention and control approaches that work in HICs are promoted in LMICs. This can be inappropriate in settings with very heterogenous livestock production structures, where value chain actors have limited technical knowledge and fewer means or incentives for making improvements to facilities or processes. Veterinary Services are often constrained by limited resources, poor infrastructure, lack of chain of command, insufficient and/or aging technical capacity, and ineffective regulatory enforcement ability. It is in these environments where epidemic risks are most often generated, and therefore more effective prevention and control approaches that are adapted to the transitioning production systems of LMIC countries need to be developed. For example, broad-scale culling measures may be impractical and understandably met with resistance due to the economic costs for farmers and society, as well as the apparent waste of animal protein and adverse environmental impact as a consequence of having to dispose of large numbers of carcasses. A more flexible concept of compartmentalisation is now also likely to play an increasing role when dealing with ASF since it allows individual businesses to continue to operate within high risk or infected areas.

The impacts of increasingly frequent epidemic animal diseases demonstrate the importance and urgency of shifting animal health policies from targeting single diseases towards multi-hazard detection and response. A key element of such strategies has to be improved animal husbandry, including biosecurity, but also a reversal of the continuing trend towards intensified meat production and land use change practices that provide new pathways for known and novel disease epidemics. In that context, the Sustainable Development Goals (SDG) define important targets that are also relevant to livestock production. These are in particular SDG 1 (No poverty), SDG 2 (Zero hunger) and SDG 3 (Good health and wellbeing) and SDG 12 (Responsible consumption and production).

In resource-poor settings, recent innovations in digital surveillance offer opportunities for increasing data capture from remote areas and widening the surveillance network to include animal health providers, livestock owners, actors involved in the wildlife trade, and consumers (37). In Kenya, community disease reporters are using a smartphone app for syndromic surveillance to report disease outbreaks to Veterinary Services (38). Thailand has been an innovation hotbed of smartphone apps for One Health surveillance crowdsourcing, such as the participatory One Health Disease Detection app (39).

To assist countries with strategic and systematic capacity development, globally accepted standards and tools have been developed by the OIE and the Food and Agriculture Organization of the United Nations (FAO). The main international standard setting mechanisms for animal health and zoonoses are the OIE *Terrestrial Animal Health Code* and *Aquatic Animal Health Code* (standards for disease prevention/control and trade), and *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals* and *Manual of Diagnostic Tests for Aquatic Animals* (biological standards) (40), enforced under the World Trade Organization and requiring reporting for 117 OIE-listed diseases, infections, and infestations.

To target animal health investments, the Performance of Veterinary Services (PVS) Evaluation serves as an independent external evaluation to identify gaps and weaknesses in countries' capacity to comply with OIE standards. The PVS Evaluation is typically followed up with a PVS Gap Analysis, a quantitative and costed evaluation of a country's needs and priorities (41). Similarly, the Joint External Evaluation helps countries identify gaps in both human and animal health services to improve public health response capacities (42), serving as a basis for multi-sectoral national action planning for health security. The One Health Assessment for Planning and Performance tool allows national One Health platforms to assess their own coordination performance and capacity (43).

Other key tools for assessing capacity include FAO's Laboratory Mapping and Surveillance Evaluation Tools (44, 45). Countries are also encouraged to increase their resilience to animal health threats through the FAO Good Emergency Management Practice workshops, guiding them in developing preparedness and response plans (46). While these tools support animal health capacity assessment processes and implementation standards, they are primarily focused on domestic animals and a gap remains in supporting Veterinary Services in wildlife epidemic disease prevention and control.

Transboundary cooperation

Given the increasing transboundary nature of epidemics, coordination between Veterinary Services of different countries is necessary for effective disease prevention and control, allowing services challenged by resource scarcity to improve their networks, share information, and mobilise expertise. The Global Framework for the Progressive Control of Transboundary Animal Diseases (GF-TADs) coordinates guidance, resources, and other technical assistance to progressively control and reduce the impact of regional and global priority diseases (47). Perhaps the best example of regional and global collaboration between Veterinary Services was the Global Rinderpest Eradication Program established in 1994, which led to the successful eradication of the disease and declaration of global freedom in 2011 (48). Key to eradication were institutional changes that allowed Veterinary Services to share information, target interventions, and adopt public-private-community partnerships for disease surveillance and control (49). Additional examples include the Progressive Control Pathway for Foot-and-Mouth Disease, and the more recent GF-TADs initiative for the global control of ASF which supports regional alliances, partnerships, and progressive disease elimination (50).

The engagement of Veterinary Services in regional trade initiatives, such as the African Continental Free Trade Area that came into effect in 2019 for 28 countries (51), is also necessary to ensure that economic and livelihood benefits are realised while transparent control of animal diseases is maintained. Regional Economic Communities play crucial roles in fostering regional cooperation, policy dialogues, and ownership amongst member states. For example, the Association of Southeast Asian Nations (ASEAN) Ministers of Agriculture and Forestry issued a Ministerial Statement highlighting the importance of ASEAN cooperation on animal health and zoonoses (52), which translated into several regional strategies and action plans that led to improved regional coordination and reduction of animal diseases such as H5N1 AI.

One Health

The complex drivers, risks, and resulting impacts of epidemics underscore the importance for global and national organisations to adopt a One Health approach to risk governance. Animal diseases, including EIDs, zoonoses, and those that impact human nutrition, food security, and wellbeing require holistic approaches to the development of prevention and control policies. That means truly integrated policies that consider human, animal, and environmental factors, as well as social, economic, ethical, and judicial ones. Veterinary Services can address the economic and wider societal impacts of epidemics through linkages between economic and veterinary policies. In many countries, the responsibility to prevent and control zoonoses is spread across several agencies, and collaboration amongst them is often neither promoted nor rewarded. Currently, government departments may consult with each other when it comes to disease response, but rarely develop integrated approaches that optimise prevention and detection upstream with mandates, information sources, resources, stakeholders, and policies required for more comprehensive strategies from risk assessment to risk reduction.

A systems approach needs to be mastered if the next livestock or zoonotic epidemic is to be prevented or at least controlled more effectively, with Veterinary Services engaging in risk-based linkages with other sectors, particularly wildlife and environmental services. The Animal and Human Health for the Environment and Development programme exemplifies the One Health approach to linking Veterinary Services and other sectors, particularly wildlife and environmental services, and emphasising the importance of a sustainable livelihoods approach that includes addressing the socio-economic and disease priorities – both human and animal – of frontline communities (53, 54). A growing number of national One Health multi-sectoral coordination mechanisms are linking Veterinary Services with critical counterparts in public health, wildlife, and environmental services for joint evaluation, planning, and disease prevention and control (55, 56). The One Health Workforce approach in Southeast Asia and Central and Eastern Africa is creating future capacity for cross-sectoral approaches to training, disease surveillance, and outbreak response (57).

Conclusions

The COVID-19 pandemic serves as a reminder of the importance of investing in epidemic prevention and preparedness, calling for systematic approaches in areas such as risk assessment and One Health. Such challenges are global, but particularly acute in LMICs where fostering and sharing of innovations, the sharing of resources at national and regional levels, and the support provided by regional and international collaboration and alliances are necessary for Veterinary Services to meet the challenges posed by epidemic diseases.

Recent experiences with epidemic disease emergence and spread highlight the risks posed by our increasingly globalised and industrialised livestock production systems, and expansion of extensive and intensive livestock production at the wildlife interface. Interactions and dynamics are not one-directional, as seen with wildlife epidemics linked to disease introduction from livestock. These have the potential to be devastating to wildlife conservation efforts; for example, the mass die-off of saiga antelope in Mongolia in 2016–2017, linked to peste des petits ruminants that spilled over from unvaccinated livestock, caused a saiga population decline estimated at 80% or greater (58).

Improvements in our understanding of epidemic disease drivers, including economic and anthropogenic ones, and the bolstering of Veterinary Services' capacity have supported advances in reducing epidemic disease but warrant additional attention. Moving forward, emphasis must be placed on risk-based approaches to the targeting of scarce resources. Ultimately, these approaches will require moving further upstream for cost-effective prevention and early detection, including greater attention to wildlife, environmental, and climate-sensitive dimensions of animal health risks in line with a One Health approach. Other sectors (e.g. social sciences) can add insights on private sector incentives and motivation for uptake of prevention, reporting, and impact mitigation strategies. It is also important to recognise that changes in socio-economic systems can happen very rapidly, as demonstrated during the COVID-19 pandemic which is taking us into a highly uncertain and potentially very different future. This has enormous implications for emerging infectious disease risks and the essential role of national, regional, and global One Health risk governance, since it requires truly integrated risk management policies that can be developed rapidly and are informed by a highly effective interface between interdisciplinary science and policy.

Knowledge of drivers of EID emergence and known hotspots provides an initial indication of areas that require greater attention and capacity enhancement, especially in the context of changing climatic patterns. As with the utility of targeting certain high-risk practices (the 'what') and taxonomic groups (the 'which') as a starting point for designing prevention, detection, and response efforts, hotspot information can be helpful when prioritising the 'where' for intensified efforts in a country or region. As more information is collected, hotspots maps and other predictive tools can be refined and downscaled to finer-scale resolutions.

The high return on investment from epidemic and pandemic risk mitigation through animal and human health systems strengthening has been articulated in prior reports from the World Bank (22, 59, 60), though wildlife dimensions have continued to be a largely neglected area of focus. Operationalisation of One Health is a priority moving forward, including better incentives for multi-agency collaboration.

Animal disease epidemics have substantial direct and indirect economic consequences. To meet these challenges from both known and novel threats, Veterinary Services must emphasise integration and cooperation with broader economic planning and decision-making for trade, markets, business, public health, and livelihoods development at the national and regional levels.

Résumé français: titre

Résumé

Mots-clés

Resumen español: título

Resumen

Palabras clave

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Table I

Seven diseases that are emerging or have caused major epidemics in the 21st century

Aetiology	Risk factors for spillover to livestock or people	Main risk factors for epidemic spread	Impacts of note	Implications/recommendations for Veterinary Services
African swine fever (ASF)	Spillover/spillback- wild and domestic suids	Trade in livestock and contaminated pork products Pig production systems with low biosecurity Movement of wild suids	Severe losses to pig production in China after 2018 detection, and significant increase in pork price; spread to many other countries in Asia and the Pacific	– Import screening – Livestock and wildlife surveillance to determine pathways of introduction and spread – Risk-based approaches for domestic and international trade restrictions – Improved biosecurity focusing on backyard and small-scale settings
Avian influenza (AI)	Wild-domestic bird mixing	Re-assortment or genetic drift of virus strains Inadequate/ inappropriate vaccination strategies Low biosecurity poultry value chains Long-distance spread via infected wild birds	Major epidemics in the past 10 years have included the H5N8 2014-2015 epidemic in the United States of America, and the 2016-2017 H5N8 epidemic in domestic and wild birds in Europe affecting 30 countries (19)	– Biosecurity measures to reduce wildlife-livestock exposures – Monitoring of domestic and wild bird strains – Poultry sector investments in low-risk geographic areas – Appropriate vaccination strategies – Transition to safer practices (e.g. away from live animal markets where viral amplification may occur)
Crimean Congo haemorrhagic fever (CCHF)	Transmission to humans via infected ticks or animal blood	Domestic or international spread via animal trade	No/Negligible clinical impacts impact on livestock Estimates of ≥1,500 human cases per year, with case fatality rate up to 40%	– Tick control measures – Surveillance reporting to public health services – Promote biosafety measures for animal handlers and laboratory workers
Lumpy skin disease (LSD)	n/a	International spread via	Major reductions in milk production (20)	– Mass vaccination across countries, combined with strict

		livestock trade Introduction and spread by blood-feeding insect vectors	threaten food security and nutrition (21) Spread to major bovine producing countries, i.e. India and China	movement control, modified stamping out, and awareness campaigns – Trade risk analysis
Middle East respiratory syndrome (MERS)	Human and other ruminant contact with infected camels	Domestic or international spread via livestock trade (mainly camel trade)	Negligible clinical impacts on camels; Approximately 2,500 human cases to date and 850 deaths since first detection in 2012; US$ 12 billion in losses from human introduction into the Republic of Korea (22)	– Trade risk analysis – Import screening – Reporting of emerging infections – Promote biosafety measures for animal handlers
Nipah	Swine or human contact with infected bat secretions Human contact with infected swine	Domestic or international spread via trade Human-human transmission	Over 1 million pigs lost to control; >100 human deaths; US$ 671 million in losses; Spread to Singapore (23)	– Designate safe areas for livestock production – Biosecurity measures to reduce wildlife-livestock exposures (e.g. distancing of orchard trees and livestock holding areas) – Biosafety measures for animal handlers – Ensure access to laboratory facilities for novel pathogen screening
Rift Valley fever (RVF)	Ecological disruption and/or changing climatic conditions creating new habitat for mosquito vectors Potential introduction of vectors beyond current range Human contact with blood/tissues of infected animals	Domestic or international spread via live animal trade Low vaccine coverage or prior immunity levels	A ban on livestock imports imposed by Middle East countries on the Horn of Africa in 1998-1999 caused losses amounting to US$ 109 million (24) US$ 32 million in losses in Kenya in 2006/2007 (25) Up to 11,958 human disability-adjusted life years lost in 2005 (26)	– Vaccination and screening requirements for traded animals from endemic regions – Develop early warning systems for vaccine deployment, and other risk reduction measures – Reporting of animal disease to inform public health risk analysis – Biosafety measures for animal handlers – Develop infrastructure to prevent and prepare for climate-sensitive diseases

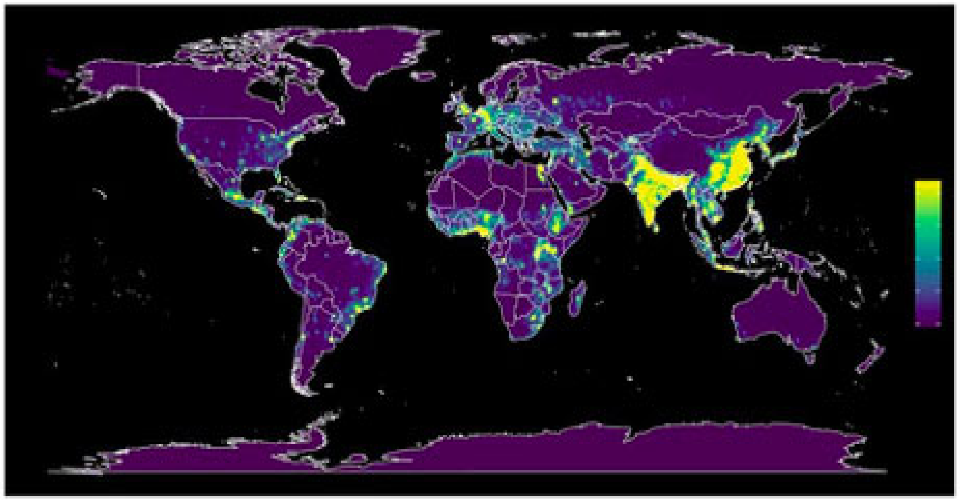

Fig. 1

Predicted distribution of zoonotic disease emergence risk from wildlife. Adjusted for reporting bias. Warmer colours (toward yellow) represent higher relative risk (5, 13).