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Zoonoses: Blurred Lines of Emergent Disease and Ecosystem Health

Emerging and neglected zoonotic diseases

The 20th century was a period of unprecedented ecological change, with dramatic reductions in natural ecosystems and biodiversity and equally dramatic increases in people and domestic animals. Never before have so many animals been kept by so many people—and never before have so many opportunities existed for pathogens to pass from wild and domestic animals through the biophysical environment to affect people causing zoonotic diseases or zoonoses. The result has been a worldwide increase in emerging zoonotic diseases, outbreaks of epidemic zoonoses as well as a rise in foodborne zoonoses globally, and a troubling persistence of neglected zoonotic diseases in poor countries.

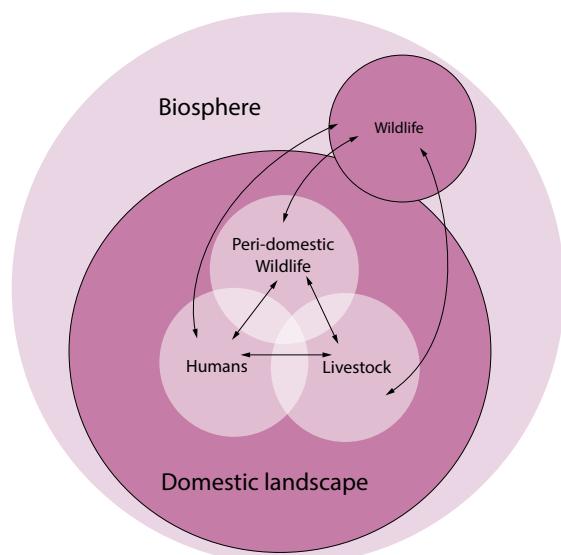
Around 60 per cent of all infectious diseases in humans are zoonotic¹ as are 75 per cent of all emerging infectious diseases.² On average, one new infectious disease emerges in humans every four months.³ While many originate in wildlife, livestock often serve as an epidemiological bridge between wildlife and human infections. This is especially the case for intensively-reared livestock which are often genetically similar within a herd or flock and therefore lack the genetic diversity that provides resilience: the result of being bred for production characteristics rather than disease resistance.⁴ An example of livestock acting as a “disease bridge” is the case of bird flu or avian influenza pathogens, which first circulated in wild birds, then infected domestic poultry and from them passed to humans. The



emergence of zoonotic diseases is often associated with environmental changes or ecological disturbances, such as agricultural intensification and human settlement, or encroachments into forests and other habitats.⁵ Zoonoses are also opportunistic and tend to affect hosts that are already stressed by environmental, social, or economic conditions.⁶

Zoonoses threaten economic development, animal and human well-being, and ecosystem integrity. Over the last few years, several emerging zoonotic diseases made world headlines as they caused, or threatened to cause, major pandemics. These include Ebola, bird flu, Middle East respiratory syndrome (MERS), Rift Valley fever, sudden acute respiratory syndrome (SARS), West Nile virus, and Zika virus disease. The pathogens causing these diseases have wildlife reservoirs that serve as their long-term hosts. In the last two decades, emerging diseases have had direct costs of more than US\$100 billion; if these outbreaks had become human pandemics, the losses would have amounted to several trillion dollars.⁷

Pathogen flow at the wildlife–livestock–human interface



Source: Jones *et al.* (2013)⁵

Another important group of zoonotic diseases are caused by foodborne pathogens such as *Salmonella* and *Listeria* bacteria that are passed from animal to humans. In 2015, the first global assessment of foodborne disease found the overall burden of foodborne disease was comparable to malaria or tuberculosis.⁸

Emerging zoonotic disease

Emerging zoonotic diseases are those that newly appear in a population or have existed previously but are now rapidly increasing in incidence or geographical range. Fortunately, most new diseases are not highly lethal and most do not spread widely. But some emerging diseases have enormous impacts. Human immune deficiency virus (HIV and AIDS), highly pathogenic avian influenza (bird flu), bovine spongiform encephalopathy (mad cow disease), and Ebola are well-known examples of particularly harmful emerging zoonoses.

Epidemic zoonoses

Outbreaks of epidemic zoonoses typically occur intermittently. Epidemic zoonoses are often triggered by events such as climate changes, flooding and other climate events, and famines. Their overall health burden is much less than that of endemic zoonoses but because they cause ‘shocks’ to food production and other systems, they can reduce the resilience of the affected communities. Examples are anthrax, rabies, Rift Valley fever, and leishmaniasis.

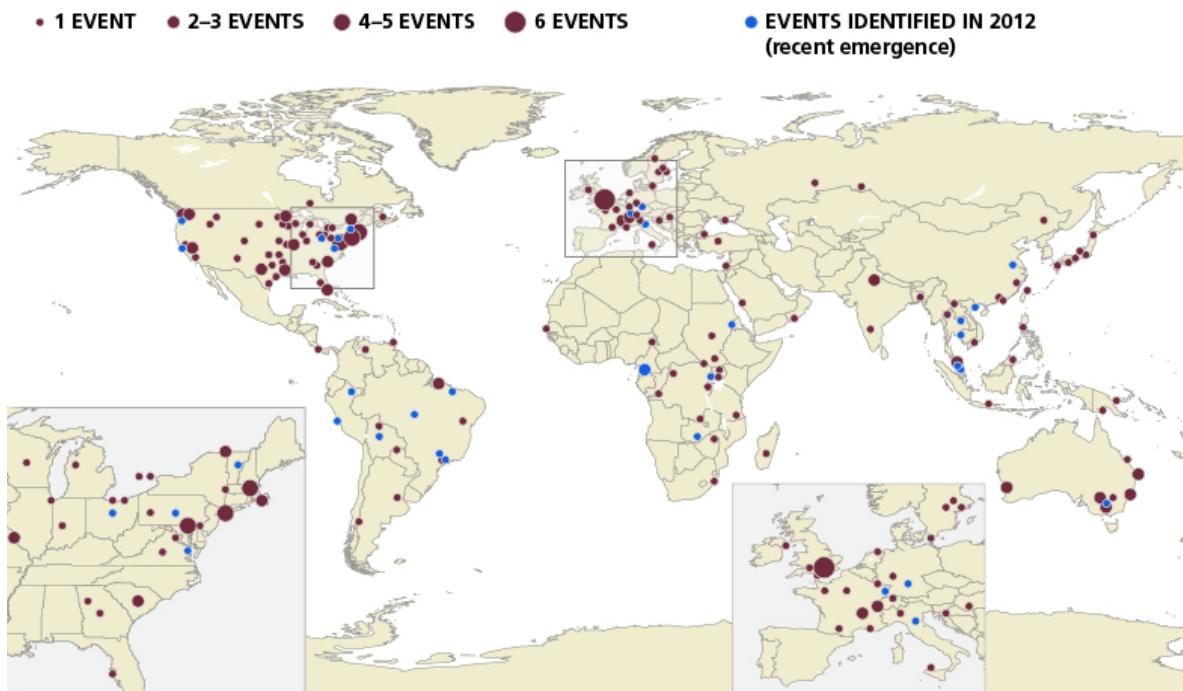
Neglected zoonotic diseases

Neglected zoonotic diseases are continually present to a greater or lesser degree in certain populations, but are often marginalised by health systems at national and international levels. Examples are anthrax, brucellosis, cysticercosis (pig tapeworm), echinococcosis (hydatid disease), Japanese encephalitis, leishmaniasis, leptospirosis, Q fever, rabies, foodborne trematodiases, trypanosomiasis and cattle tuberculosis.

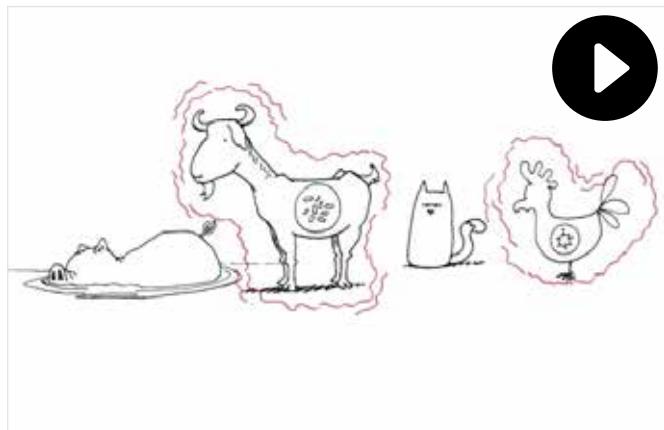
ZOONOSES: BLURRED LINES OF EMERGENT DISEASE AND ECOSYSTEM HEALTH

However, emerging diseases and those with the potential to cause pandemics are not the only problematic zoonoses. Neglected zoonotic diseases are endemic in affected poor populations, yet they receive much less international attention and funding than emerging diseases. Neglected zoonoses persist in communities with complex development problems.⁶ Global concern currently focuses on anthrax, bovine tuberculosis, brucellosis, human African trypanosomiasis, Taenia solium cysticercosis (pig tapeworm), cystic echinococcosis (hydatidosis), leishmaniasis, and rabies.⁹ These diseases are common where poverty, the proximity of people and domesticated animals, low resilience, and people's reliance on livestock or wildlife converge to enable transmission.¹⁰

Emerging zoonotic disease events, 1940-2012



Video: How can animals make you ill?



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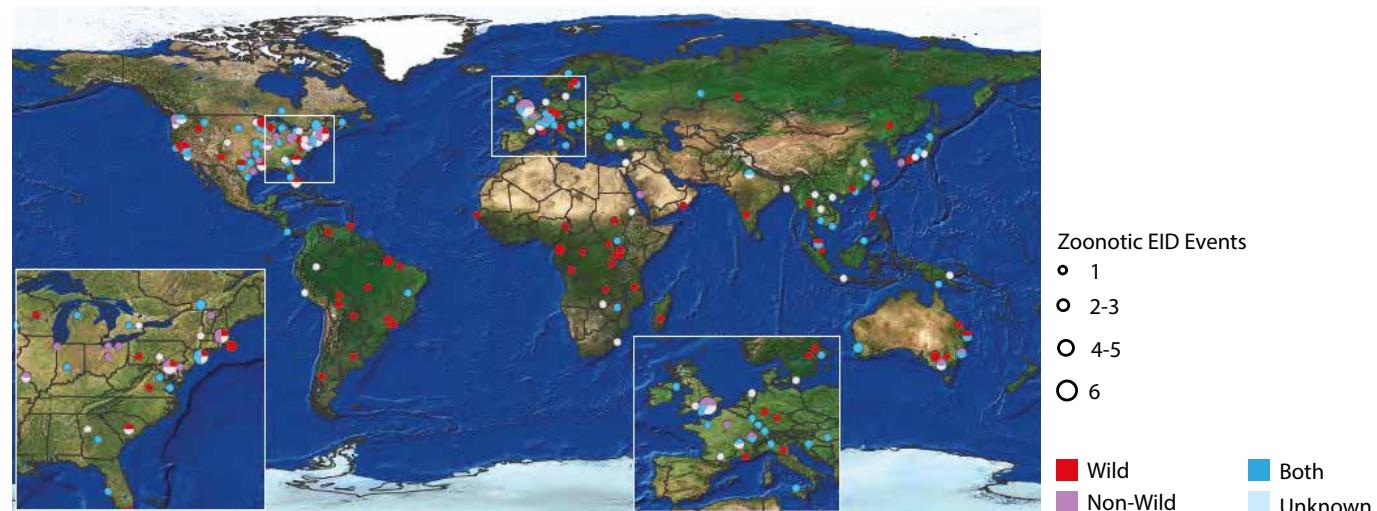
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Impacts of zoonoses

Zoonosis	Primary transmission/ reservoir species	Impact
Avian Influenza		The 2004 outbreak in East Asia resulted in economic losses of US\$ 20 billion over the following five years. ⁴⁸ The 2015 outbreak in the US has cost the poultry industry US\$ 3.3 billion and led to the death of 48 million birds either from the flu itself or from culling. ^{46,47}
Bovine tuberculosis		US\$ 15 billion of economic losses from 1986-2009 in the UK. ⁷
Ebola		The 2014-2015 Ebola outbreak in Guinea, Liberia and Sierra Leone led to 11,310 deaths and 28,616 confirmed cases. ⁴⁸
MERS		Since September 2012, 27 countries have reported confirmed cases, with about 624 deaths. ⁴⁹
Nipah virus		US\$ 671 million of economic losses, one million pigs culled, and 100 people died from the 1998 outbreak in Malaysia. ⁷
SARS		The impact of the 2002 outbreak was estimated at US\$ 41.5 billion, with 8,000 confirmed infections and 800 deaths. ⁷

Events of zoonotic disease emergence by type of animal hosts



Source: Grace *et al.* (2012)⁶

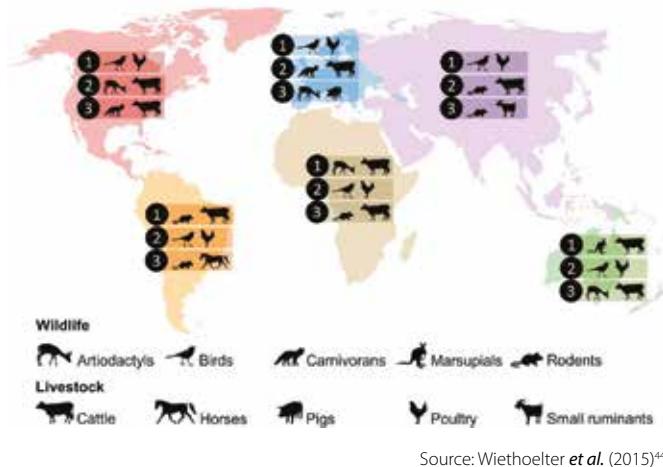
Drivers of zoonotic disease emergence

Researchers studying records that date from 1940 to 2004 detected an increase in the rate of emerging infectious disease over those years. Of the 335 documented events, 60.3 per cent were zoonotic and 71.8 per cent of the zoonoses originated in wildlife.¹¹ Generally scientists consider three different types of change that allow virulent pathogens to initiate a new move from animal host to human host: changes in the environment, in either host, or in the pathogen itself.

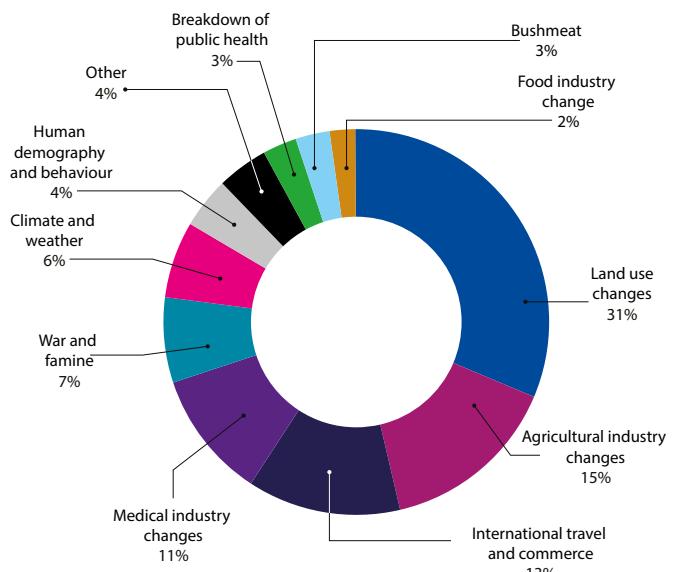
Changes in the environment are usually the result of human activities, ranging from land use change to changing climate. Encroachment on natural ecosystems through resource exploitation, agricultural activity, and human settlements provides opportunities for pathogens to spillover from wild animals to people, especially when the natural disease resistance that may result from rich biological diversity is lost.^{5,12,13} Examples of zoonoses emerging when land is cleared for human activity can be found in many regions and on most continents.^{5,14-16} Climate change is a major factor for disease emergence. It influences the environmental conditions that can enable or disable the survival, reproduction, abundance, and distribution of pathogens, vectors, and hosts, as well as the means of disease transmission and the outbreak frequency.¹⁷ Growing evidence suggest that outbreaks or epidemic diseases may become more frequent as climate continues to change.¹⁷⁻¹⁹

Changes in animal or human hosts are often the result of human action as well. Zoonotic transmission from wildlife hosts directly to human host is uncommon: domestic animals can bridge the gap.²⁰ Increasing demand for milk and meat, driven mainly by fast-growing populations of urban consumers in developing countries, is projected to double by 2050.²¹ The Livestock Revolution paradigm is leading to rapid increases in livestock populations in developing countries, which increases the likelihood of disease transmission.²² Demand for livestock products leads to more intensive production, that is greater populations of high yielding and

Top 3 reported zoonoses, based on 13,293 research publications dated from 1912 to 2013



Primary drivers of past disease emergence



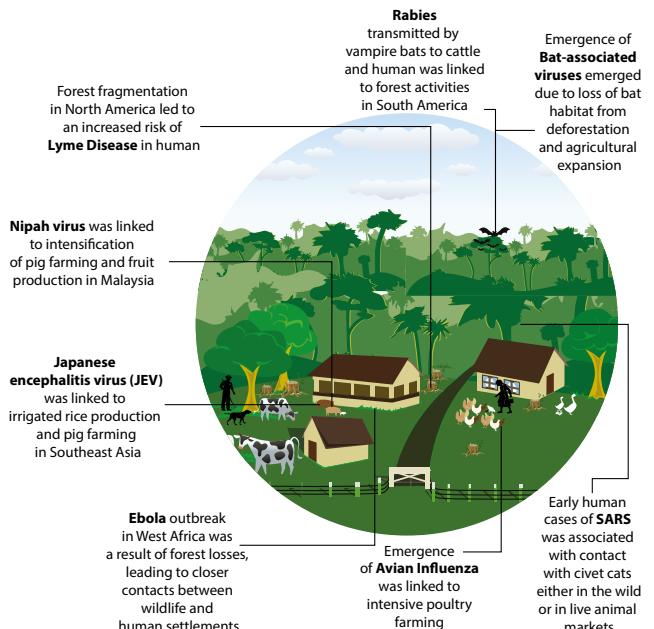
Source: Loh *et al.* (2015)⁴³



genetically similar stock kept close together. Thus the animals are not only exposed to more contact opportunities but they also lack the genetic diversity that helps resist the spread of disease, a vulnerability known as the monoculture effect. Intensification of livestock production systems also results in increased fertiliser use (for feed and fodder) and increased production of livestock waste, which can create nutrient-rich environments that foster certain pathogens.²³ Changes in human host behaviours are also drivers of emerging zoonotic disease, including travel, conflict, migration, wildlife trade, globalization, urbanization, and changing dietary preferences.²⁴

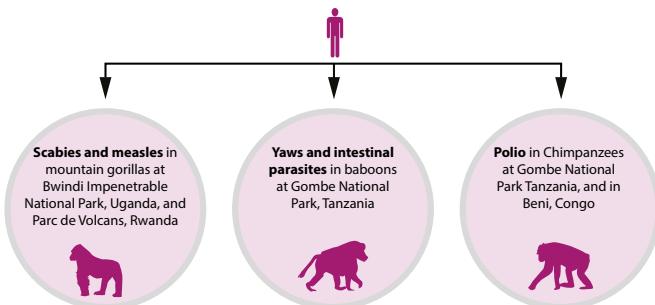
Changes in the pathogens themselves occur as they evolve to exploit new hosts or adapt to changing evolutionary pressures. An example of this is the emergence of resistance to antimicrobial drugs.²⁵ Antimicrobial resistance is the result of

Primary drivers of disease emergence associated with the past emerging zoonotic disease events



pathogens being exposed to antimicrobial drugs and building resistance over their short-lived generations. This most commonly occurs when people are prescribed antimicrobials or buy them without prescription and self-treat incorrectly. Antimicrobials are also widely used, or misused, in veterinary medicine, often as preventatives, and resistance to them is growing in domesticated animals especially in industrial-style production systems.²⁶ Antimicrobial resistance created in livestock can then affect humans, so when people get sick antibiotics no longer work.

Suspected disease transmission from people to primates



Source: Kalema-Zikusoka (2005)⁴⁵

Video: Zoonotic Diseases Among Pastoralists in Uganda



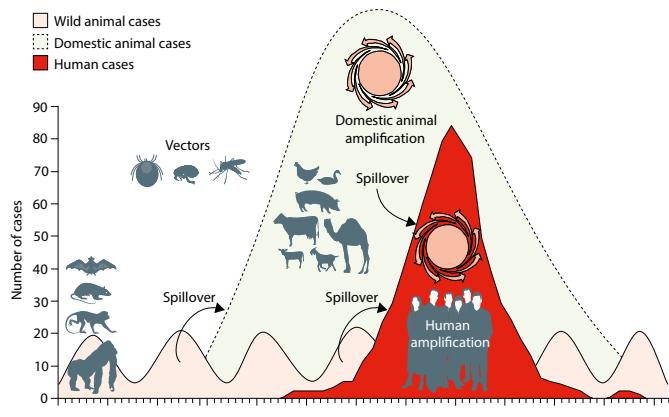
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Video Link: <https://www.youtube.com/watch?v=fp4BhQTNjwQ>
 Photo Credit: ILRI/ Stevie Mann

Managing zoonoses for human, animal and ecosystem health

Zoonotic diseases affect human health, agriculture, the economy, and environmental integrity. In just the last decade, around US\$20 billion have been directly spent in responding to emerging zoonoses and in implementing initiatives for better progressive control of zoonoses, with a further estimate of US\$200 billion in indirect costs to affected economies.²⁷ Zoonoses management requires an integrated and inter-sectoral approach. At the global level, three organizations have mandates that cover zoonotic disease: the World Health Organisation (WHO), the World Animal Health Organisation (OIE), and the Food and Agriculture Organization of the United Nations (FAO).

Environmental health initiatives have been less well represented in global zoonoses control programs. However, ecosystem integrity is a key factor in the innovative approaches taken by One Health and EcoHealth initiatives that are spearheading zoonoses control at regional and national levels. Applying inter-sectoral approaches has had some notable successes, which ultimately improved human health, such as controlling rabies in the Serengeti ecosystem, understanding the burden of brucellosis in Mongolia, and controlling leishmaniasis in Tunisia using ecosystem-based approaches and community-based interventions.²⁸⁻³¹ There has also been a surge in novel surveillance of wildlife and livestock health and reporting tools that draw on a wide range of field reports. These include the Program for Monitoring Emerging Diseases (ProMed), GeoChat, the World Animal Health Information Database (WAHIS) interface and WAHIS-Wild interface, HealthMap, Wildlife Health Australia and US Wildlife Health Information Sharing Partnership event reporting system (WHISpers).

Transmission of zoonotic diseases and amplification in people



Source: Karesh et al. (2012)²⁵

There have been many cases of successful management of endemic zoonotic disease such as pig tapeworm and rabies. Several developed countries have succeeded in reducing zoonotic foodborne disease over relatively short periods by instituting control mechanisms all along the food value chain, with an emphasis on reducing disease in the animal host. However, if such control measures are not maintained, the diseases will recur after an initial suppression. For this reason, several high-priority zoonoses have been targeted for 'progressive control towards elimination', including bird flu, rabies, and pig tapeworm.^{32,33}

The track record on managing emerging zoonoses is mixed. For example, the rapid containment of SARS is considered one of the biggest success stories in public health in recent years. In 2003, WHO alerted the world that a severe acute respiratory syndrome of unknown cause was rapidly spreading from Southeast Asia. Within six months, this entirely new disease



had been identified as a coronavirus, its transmission and risk factors had been elucidated, treatments developed and the disease spread stopped.³⁴ The more recent case of Ebola, however, shows control is not always straightforward. The Ebola outbreak at the intersection of Liberia, Sierra Leone, and Guinea affected some of the world's poorest and least developed countries. It took over three months just to confirm that Ebola was the cause of many severe illnesses and untimely deaths and by then large numbers of people were already affected. War, population growth, poverty, and poor health infrastructure likely contributed to the unprecedented expanse, duration, and size of the epidemic.³⁵

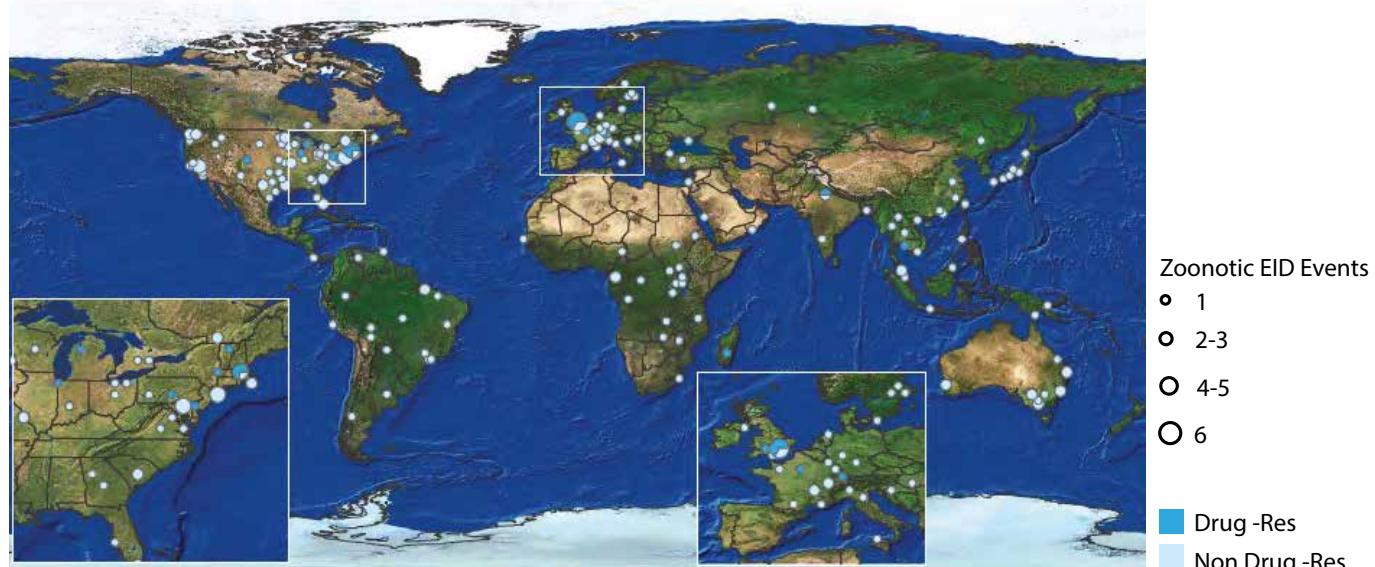
Video: Hotbed of Disease



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Video Link: <https://www.youtube.com/watch?v=9kGH7iC-7TQ>
Photo Credit: Travel Stock/ Shutterstock.com

Events of zoonotic disease emergence classified in terms of drug resistance



Source: Grace *et al.* (2012)⁶

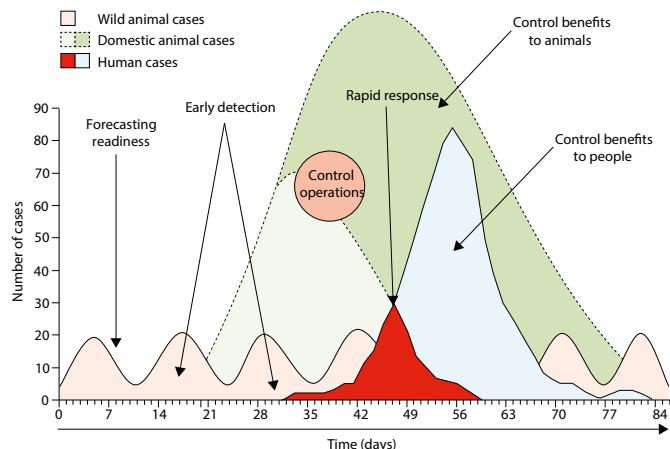
Ecosystem integrity underlines human health and development

Ecosystem integrity can help regulate diseases by supporting a diversity of species so that it is more difficult for one pathogen to spread rapidly or dominate. As the human population grows, ecosystems change. Forests are exploited for logging, landscapes are clear-cut for agriculture and mining interests, and the traditional buffer zones – once separating humans from animals or from the pathogens that they harbour – are notably reduced or lost. Because of historic underinvestment in the health sector of developing nations, and rapid development often at the cost of natural capital, disease emergence is likely to continue; hence, the importance of public health within the development and conservation continuum.³⁶

Zoonotic diseases are particularly complex disorders that concern the three, often siloed, sectors of environment, agriculture, and health; so policy frameworks for dealing with these diseases are often weak.^{37,38} In addition, in many developing countries there are major disconnects between policy and implementation. Successful control of zoonoses requires a judicious legal and policy framework, well-functioning institutions, adequate financing, rapid detection, and an intervention implementation plan. Collaborative multidisciplinary and multinational research will also be needed to explore the linkages among environmental dynamics, disease vectors, pathogens, and human susceptibility.³⁶

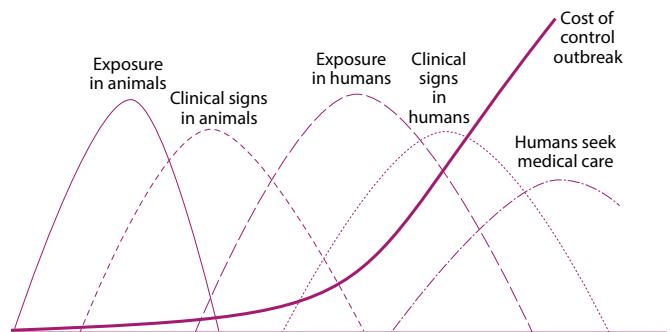
Both logic and experience suggest that zoonoses can be best tackled through interventions involving the livestock hosts of the disease pathogens—but, while there are many local success stories, a sound evidence base is lacking regarding the costs, benefits, acceptability, and scalability of such interventions.³⁹⁻⁴² A significant constraint to involving agriculture in the control of zoonoses is the lack of collaboration between medical and veterinary authorities, leaving zoonoses concerns sidelined,

Early detection and control efforts reduce disease incidence in people and animals



Source: Karesh et al. (2012)²⁵

Early control of zoonotic disease is both cost-effective and prevents human disease



Source: World Bank (2012)⁷



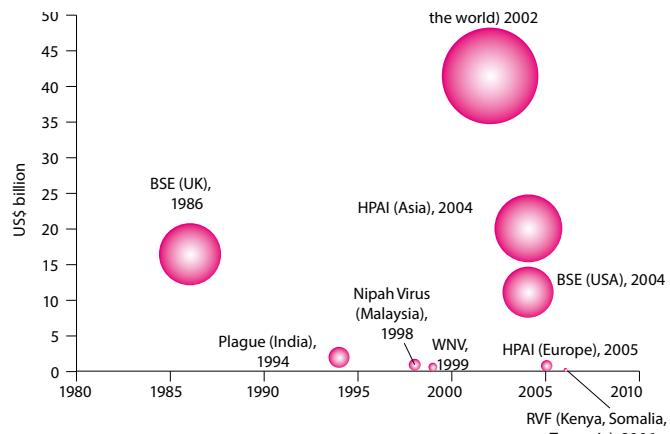
despite the promise of One Health and Ecohealth initiatives. These approaches have been widely endorsed, but are rarely used at local levels, where they are most needed.

Effective strategies already exist for controlling most neglected zoonoses; the main constraint is lack of investment rather than method.³⁶ The costs of controlling zoonoses can seem high when compared to public health benefits alone, but these costs are easily outweighed when a full cross-sector analysis is carried out and the benefits of control to the agricultural sector, to wildlife, and to society are taken into account.^{36,41,42}

In the case of emerging diseases, investment in surveillance and in human and animal health services are needed to ensure 'emergence events' do not lead to large-scale zoonoses epidemics. The World Bank has estimated that an investment of US\$3.4 billion in animal health systems per year would avert losses incurred through delayed or inadequate responses to zoonoses—losses estimated at US\$6.7 billion per year.⁷

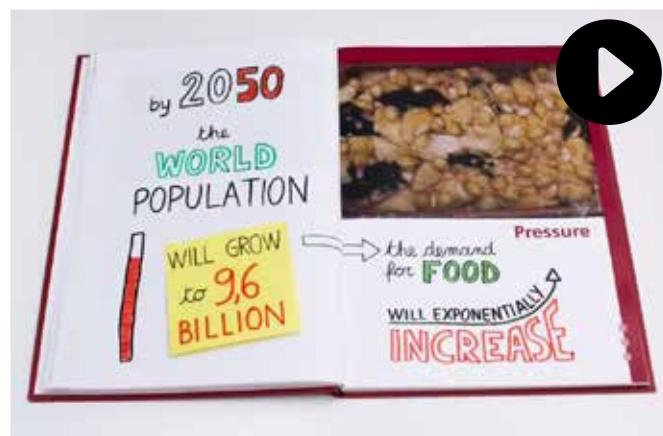
While improved surveillance and rapid response capacities are important and urgently needed, they, too, are insufficient means to controlling the emergence of zoonotic diseases. Success requires addressing the root causes of disease emergence—the fact that human activities are imposing extreme stresses on ecosystems and their ability to function. Addressing the problem at the necessary foundational level calls for reconciling human development within the biophysical environment. The ecosystem services on which the health of animals, people, and the planet depend must be restored, safeguarded, and prized.

Estimated costs of emerging zoonotic diseases (1986 - 2006)



Source: World Bank (2012)⁷

Video: FAO: Changing disease landscapes - Towards a Global Health approach



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Video Link: <https://www.youtube.com/watch?v=vHvSW5HwmZM>

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