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The Costs of Animal Disease



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Table of Contents

Executive Summary	3
Introduction	5
Costs of Animal Disease	7
Salmonellosis	9
Overview and definition	9
Socio-economic impact	9
Case study.....	11
United States, 2008 – 2009.....	11
Current state of disease and control measures	12
Rabies	15
Overview and definition	15
Socio-economic impact	15
Case studies.....	17
Africa.....	17
India	18
China.....	19
The Americas	20
Current state of disease and control measures	21
Foot and Mouth Disease	22
Overview and definition	22
Socio-economic impact	22
Case studies.....	23
United Kingdom, 2001.....	23
Brazil, 2005	25
North-East Asia, 2010 – 2011	25
Current state of disease and control measures	26
Future Perspectives	28
Reintroduction of previously eradicated diseases.....	28
International agreements on animal health and food safety	28
Growth of global livestock production and trade	30
Weak investments in animal health and food safety	31
Lack of capacity.....	31
Governance of food safety	32
Use of drugs in livestock.....	32
Recommendations	33
Data collection	33
Surveillance	34
Understanding the response to regulation.....	34
Institutional implementation	34
Capacity to respond.....	35
Conclusion	37

Executive Summary

Introduction

- Livestock and companion animals are important for human health and wellbeing; as a result, consideration needs to be given to the diseases which can affect animal populations.
- Despite the importance of animal diseases to human health, the factors driving animal disease are diverse and we still know comparatively little about the actual costs of animal disease.
- The costs associated with animal disease can change as societies and economies evolve, making it important to monitor such changes in order to respond in a timely and proportionate manner.

Comparatively little is known about the actual costs of animal disease

The costs of animal disease

- The costs of animal disease can broadly be divided into direct costs – the immediate impact on livestock populations and agriculture – and indirect costs, which include mitigation or control efforts, losses in trade and other revenues, and impacts on human health.
- There are difficulties in estimating the costs of animal disease globally as livestock product prices and productivity vary widely, as do the costs of resources used for disease monitoring and control.
- Although this makes the total costs of animal disease on a global scale difficult to assess, we are able to gain a meaningful sense of the social and economic costs of recent outbreaks.

Future perspectives

- We are already seeing patterns of more successful animal disease management and, in some cases, the eradication of well-known disease agents.
- Nevertheless, persistent problems associated with the emergence and re-emergence of disease are exacerbated by a variety of factors including climate change, migration, the growth of livestock production and trade.
- Despite some successes, progress in the control of animal diseases continues to be stifled in many developing areas as a result of weak investments in animal health, lack of capacity and not yet optimal governance of food safety.

Despite improvements in disease management, problems persist



Recommendations

- A vital first step toward combating animal disease will be to improve data collection and surveillance methods as well as bolstering veterinary services, which remain inadequate in many countries.
- A better understanding of the response to regulation needs to be integrated into disease control programmes; and policymakers should endeavour to work with stakeholders such as farmers who are affected by such changes.
- The effective implementation of disease control efforts requires a clear understanding of the institutional frameworks involved, and efforts to develop those frameworks where necessary.
- Finally, better infrastructure is a pre-requisite to ensure the quick diagnosis of diseased animals, complemented by the ready availability of curatives or vaccines.

Improved data collection, surveillance and infrastructure are all needed

Introduction

Animals are important for human health and wellbeing; they sustain our populations due to their role as a food source, their labour and by-products are used in agriculture, and they serve as a form of transport and store of wealth. In addition, they can benefit human health and provide companionship. As a result, consideration needs to be given to environmental impacts and welfare problems within managed animal populations, as well as to the suite of diseases which can affect both domestic and wild animal populations.

The recent outbreaks of classical swine fever in pigs, foot and mouth disease in cattle and highly pathogenic avian influenza in poultry have underlined the broad impact animal disease can have. Moreover, 61% of animal diseases are zoonotic, meaning that they have the potential to cause human pandemics.

61% of animal diseases have the potential to cause human pandemics

These outbreaks should not overshadow the trend of success enjoyed by animal health control systems, a combination of public and private efforts, which in recent years have contributed to the global eradication of rinderpest, the suppression of foot and mouth disease and classical swine fever in North and Central America and more recently in Europe, and the control of avian diseases such as Newcastle and Gumboro (infectious bursal) disease.

But having reached a point where many animal diseases are now under control, it would clearly be a mistake to conclude that further investments in disease monitoring and impact assessment are not needed. Animal disease costs change as society evolves, and it is wise to monitor such changes to ensure that we are in a position to respond to outbreaks in a timely and proportionate manner. For example, recent societal changes, such as growing demand for meat across many developing countries, have led to an increase in poultry and pig populations and major modifications of production systems. These changes have increased food production but have also created animal disease problems such as the emergence of potentially zoonotic influenza viruses. Such examples are becoming more common and underscore the need to understand more about animal health issues, particularly the context in which animals are raised and how they interact with wildlife and humans.

The factors driving changes in animal disease are diverse, and human drivers of change as well as biological factors need to be considered when assessing the impacts of disease. Various studies have estimated the relative impact of human or animal disease, and these provide a solid foundation for learning about the true costs of animal diseases. However, relative impact is much easier to estimate than actual, and this is reflected in the number of studies published, very few of which contain fully quantifiable models.

The factors driving changes in animal disease are diverse

This report presents what is currently known about the costs of animal disease, highlights the gaps in our knowledge, and suggests ways to prioritise the use of resources for disease monitoring, control and, where possible, eradication. The report illustrates the economic and social costs of animal diseases by examining:

- a purely animal disease – foot and mouth disease;
- a disease that affects both animals and humans – rabies; and
- a disease that affects animals and humans and can be spread through food – salmonellosis.

The final sections consider the current state of disease control, examine future perspectives on animal disease and include recommendations on what should be done to improve our understanding of disease systems so that we have responses that are rational and proportionate to the level of risk posed by these diseases.

Costs of Animal Disease

Costs of animal diseases are normally associated with reductions in animal populations and production. There are also costs related to the mitigation of disease, which include the money and resources expended to monitor, control and, in extreme cases, eliminate the disease agent. Animal diseases that reduce reproductive competence increase the proportion of breeding animals that have to be maintained and thereby reduce the overall efficiency of the population. The presence of disease may also limit opportunities in the market place, either locally or internationally, and hinder the adoption of improved technologies, be they improved breeds, better management systems or more efficient processing and marketing methodologies. Finally, if the pathogen that causes an animal disease is zoonotic, consideration of resulting human morbidity and mortality must be undertaken and the costs should be assessed taking account of both human and animal impacts.

These costs can broadly be summarised as:

DIRECT LOSSES

- **Visible losses.** This includes animal deaths and illness or stunting that results from disease or subsequent control methods.
- **Invisible losses.** This includes less immediate impacts of animal disease such as reduced fertility or changes in herd which result in the need to have a higher proportion of animals in a breeding group rather than production.

Animal diseases incur a wide range of costs

INDIRECT LOSSES

- **Mitigation and control costs.** This includes the costs of drugs, vaccines, surveillance and labour needed to carry out control measures.
- **Human health impacts.** This includes the costs that arise when animal diseases affect human populations such as treatment costs and losses in productivity due to illness or death.
- **Foregone revenues.** This includes the indirect economic impacts of animal diseases resulting from curtailed market access, losses in consumer confidence, and knock-on effects on other sectors of the economy.

As with human diseases, there are difficulties in estimating the costs of animal disease globally as livestock product prices and productivity, and the costs of resources used for disease monitoring and control vary widely across countries and even across different regions within a country. Human health has partly navigated this problem by developing a unit known as a disability adjusted life year (DALY) which relates to the number of years of normal life lost either through early death or reduced ability to lead a normal life through being ill.

There are difficulties in estimating the costs of animal disease globally

No equivalent unit has been developed for livestock and there is a split of opinion about the need for such a unit. Economists would argue that, because animals are kept largely for production, costs of disease can be valued and priced through the

market. On the other hand, veterinarians often feel that this is inadequate and that units need to be developed that both capture all impacts of disease and can overcome the challenges of disease impact assessment.

Despite the complexity of calculating the costs of disease, estimates are needed to guide resource allocation at farm, national and regional levels. Some attempts have been made to compile global information on the costs of animal disease, and specific studies have been carried out on endemic disease costs in a number of developed countries. Recently the World Bank, in cooperation with the World Organisation for Animal Health (OIE), has produced a study detailing the impact of animal diseases. However, most of these studies are not regularly updated, and those which are have their utility restricted by the limited quality of data that exists on livestock populations and disease presence.

As a result of these limitations, little can be said in definite terms about the total costs of animal disease on a global scale. Nevertheless, national data are available for a number of animal diseases and by examining specific case studies it is possible to gain a meaningful indication of the social and economic costs of recent outbreaks.

Case studies can
provide a meaningful
indication of the costs
of recent outbreaks

Salmonellosis

Overview and definition

Salmonellosis is an infection caused by *Salmonella* bacteria that mainly affects cattle, sheep, goats, pigs, poultry and humans. The species associated with salmonellosis in humans can be divided into those causing typhoid fever, which are exclusively transmitted from human to human, and non-typhoidal species, for which transmission through contaminated food is thought to cause 85% of human cases. Food produced from animals that are themselves infected can be contaminated, and transmission can also occur through intermediate hosts and when animal manure is used on fruit and vegetable crops. Recent cases of *Salmonella* have also occurred from the handling of pet turtles, iguanas, and chickens infected with the disease, and unsterilised pharmaceuticals of animal origin.

Non-typhoidal *Salmonella* typically causes acute gastroenteritis resulting in diarrhoea, vomiting and abdominal pain, and occasionally more serious conditions such as septicaemia, meningitis and chronic arthritis, which require treatment with effective antibiotics. The frequency of more serious conditions is dependent on the health status of the person affected, with higher rates often linked to co-infection with HIV or malaria in developing regions such as sub-Saharan Africa.

In addition to these human health impacts, *Salmonella* can also cause production losses in livestock systems. Animals typically contract *Salmonella* when they consume contaminated feed or water. All livestock species can be affected by salmonellosis with young, debilitated and parturient animals most susceptible to clinical disease. While research shows that a relatively high proportion of feed and water are contaminated with *Salmonella*, normal adult livestock can typically tolerate small numbers of the bacteria and avoid infection.

Socio-economic impact

The societal costs of *Salmonella* outbreaks are considerable and include direct medical costs, productivity losses and premature death, as well as considerable costs associated with control efforts. These costs are higher than for many other foodborne diseases due to the large number of species of domestic and wild animals that can harbour *Salmonella*, as well as the wide variety of transmission methods.

In many cases, the impacts of *Salmonella* infections in terms of lost production are not seen, as most infections are controlled and managed with antibiotics before they become serious. Attempts to estimate the cost of salmonellosis in humans are complicated by the lack of a standard method of assessment as well as by likely under-reporting in the human population. Costs are incurred at household level when members become ill, by the healthcare and regulatory sectors and by food industries. They may be monetised, such as the cost of treatment, loss of income or the cost of introducing risk control strategies. Further losses may be incurred which are more difficult to quantify such as the pain and suffering of affected persons, the reduction in

Contaminated food
accounts for 85% of
non-typhoidal
Salmonella cases

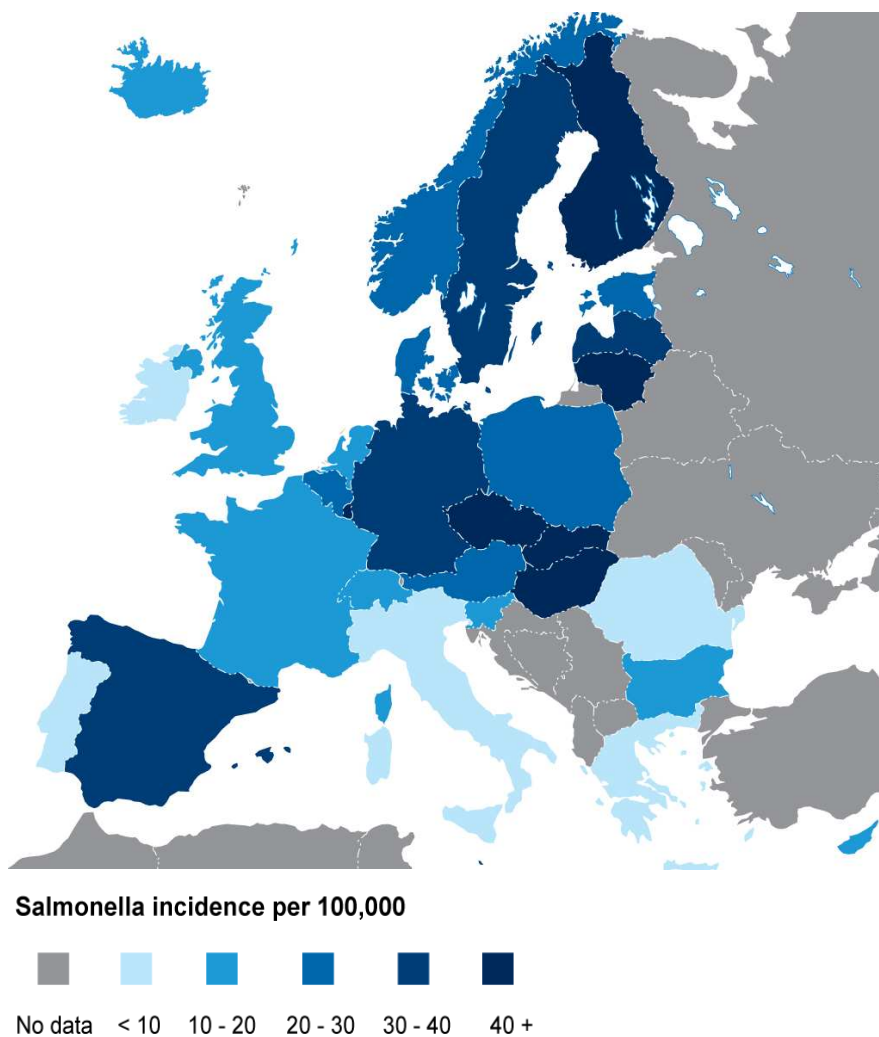
Costs of *Salmonella*
are higher than for
many other foodborne
diseases

human productivity as a result of illness, and the detrimental impact on consumer confidence following a disease outbreak.

Reliable data for the costs of *Salmonella* infections is typically available only for countries with a relatively high level of development. In addition, comparing *Salmonella* infections between countries can be problematic due to differences in the methodologies used to calculate costs. The incidence of reported cases of *Salmonella* among European Union (EU) member states is shown in Figure 1. In addition, some examples of the cost of *Salmonella* in the EU are provided in Table 1.

Reliable data is typically available only for highly-developed countries

Figure 1: The incidence of *Salmonella* in the EU, 2010



Source: European Food Safety Authority, 2012.

Table 1: The cost of *Salmonella* in the EU and member states, 2008

Country/ Region	Reported cases	Total cost*	Cost per case
European Union (27 countries)	131,468	€132,612,837	€1,009
Czech Republic	10,707	€3,497,291	€327
France	7,186	€7,856,743	€1,093
Germany	42,909	€60,029,813	€1,399
Italy	3,232	€3,432,865	€1,062
Netherlands	1,627	€3,165,728	€1,946
Spain	3,833	€3,005,939	€784
United Kingdom	11,511	€16,977,919	€1,475

* Total costs include losses due to GP visits, emergency and outpatient services, hospital admissions, and productivity but exclude costs relating to premature death.

Source: FCC Consortium, 2011.

While the main socio-economic impact of salmonellosis is borne in the human population, outbreaks of *Salmonella* in animal populations can have significant economic impacts. Infections cause illness in animals which can lead to fever and diarrhoea. This in turn can lower milk production, and cause weight loss, abortions and death. There are also costs associated with the treatment of sick animals such as the price of medicines, and productivity costs associated with increased labour for management of affected stock. Cost estimates in animals are rare, but a Dutch study in 1997 quantified average losses of 28 dollars per dairy cow per year caused by *Salmonella* infection.

Case study

UNITED STATES, 2008 – 2009

Among foodborne infections in the United States, *Salmonella* remains the most common and the leading cause of hospitalisation and death. The Center for Disease Control (CDC) estimates that non-typhoidal *Salmonella* caused an estimated 1,027,561 human illnesses in the United States in 2011 which resulted in 19,336 hospitalisations and 378 deaths, and cost the country approximately 365 million dollars in direct medical costs and over 2 billion dollars (and as much as 3 billion) in total societal costs. Unlike other foodborne infections such as *Escherichia coli*, *Campylobacter*, *Listeria* and *Shigella*, which have all registered lower rates of incidence in recent years, no discernible progress has been made in reducing the incidence of *Salmonella* in the United States.

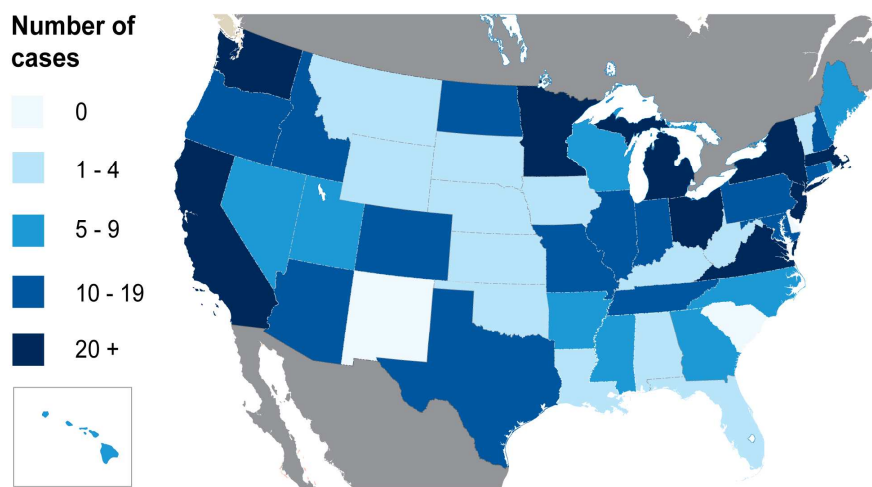
The average cost per case of human *Salmonella* in the EU is over 1,000 euros

Salmonella costs the United States as much as 3 billion dollars annually

In 2008 – 2009, *Salmonella* contamination at two American processing plants providing ingredients for other food producing companies led to 714 confirmed cases of disease and nine deaths, affecting every US state with the exception of New Mexico, South Carolina, Delaware and Alaska (see Figure 2). As the scale of the outbreak became apparent, more than 3,900 food products produced by 200 different companies were recalled. This incurred a significant cost to the companies concerned and amounted to one of the largest food recalls in US history. A short-lived market shock resulted in a decline in sales of peanut butter, which recovered four months after the detection of the initial case.

The 2008 – 2009 outbreak resulted in one of the largest food recalls in US history

Figure 2: *Salmonella* Typhimurium cases, 2008 – 2009



Source: CDC, 2009.

Little evidence of any longer term effect on prices or production volumes of peanuts or peanut products could be detected. However, the outbreak forced the liquidation of the Peanut Corporation of America with the loss of 90 jobs and contributed to the initiation of a food safety legislation review which culminated in the introduction of the Food Safety Modernization Act in 2011. Implementation of this legislation is expected to involve direct costs of 1.4 billion dollars over a five year period. In addition, further costs will be incurred by the private sector in making technological and procedural changes to comply with the new legislation. Payment of mandatory registration fees alone by the private sector is expected to total 100 million dollars annually by 2015.

Current state of disease and control measures

Estimating the burden of disease caused by *Salmonella* infection on society has inherent problems. Firstly, the disease is self-limiting, that is it runs a definite and limited course. As a result, the majority of cases are never reported to healthcare services. For instance, the CDC has estimated that the incidence of *Salmonella* infections in the United States is approximately 38 times greater than the number of cases actually reported. Secondly, to positively identify *Salmonella* as the causative agent of illness requires the submission of stool samples for laboratory analysis. This is a costly and time-intensive process, usually undertaken only in the most serious

The vast majority of human *Salmonella* cases are never reported

cases. Thirdly, the results of these analyses must be recorded centrally to allow a total count of confirmed cases. In most jurisdictions, this is not done at all. As a result, national data on *Salmonella* infections remains haphazard and difficult to compare.

Estimates of the societal burden therefore tend to calculate back from confirmed cases, adjusting for the proportion of patients that report to the doctor and submit samples for laboratory testing. Developed nations have better healthcare provisions and laboratory services as well as the infrastructure for recording and analysing case numbers over time. However, a paucity of data exists for developing nations. Attempts to calculate the true burden of *Salmonella* infection on society are therefore subject to a large degree of conjecture. A 2010 study supported by the World Health Organisation estimated that the burden of diarrhoeal disease was 2.8 billion cases per year, with 93.8 million cases attributed to non-typhoidal *Salmonella*.

Calculating the true burden of *Salmonella* is subject to a large degree of conjecture

Table 2: Estimates of non-typhoidal *Salmonella* infections

Region	Cases per 100,000	Deaths	Population
Global ¹	1,140	155,000	6.9 billion
Australia ²	44	8*	21.6 million
Netherlands ³	212	40	16.7 million
Japan ⁴	32	No data	127 million
Jordan ⁵	122	No data	6.0 million
United Kingdom ⁶	220	93	58.7 million
United States ⁷	357	378	313 million

*Attributable to all foodborne disease outbreaks.

Sources: ¹ Majowicz et al, 2010; ² OzFoodNet, 2009; ³ Havelaar, 2012; ⁴ Kubota et al, 2008; ⁵ Gargouri et al, 2009; ⁶ Wheeler et al, 1999, HPA, 2007; ⁷ CDC, 2012.

Analysis of worldwide foodborne disease outbreaks between 1988 and 2007 indicated that *Salmonella* was responsible for nearly half (46.9%) of the outbreaks. Contaminated eggs were most often associated with *Salmonella* infections but other food items, such as fresh fruit and vegetables, dairy and bakery products and chicken were identified as vectors for transmission.

In many countries in Europe, North America and Australasia, sophisticated *Salmonella* control programmes have been in place for many years, with varying degrees of effectiveness. Within the EU, many national *Salmonella* control programmes in poultry have generated positive results. Human infections declined for the sixth consecutive year in 2010, with total confirmed cases dropping from 166,819 in 2006 to 99,020 in 2010, the latest year for which data is available. This decline is attributed principally to the reduction in *Salmonella* infection in egg-laying hen flocks following mass vaccination campaigns and improved hygiene at handling and packaging facilities. In contrast, despite active *Salmonella* control programmes at federal, state and local levels, there has been no discernible drop in the overall incidence of human *Salmonella* in the United States over the last 15 years.

Salmonella control programmes have varying degrees of effectiveness

Outside of Europe, North America and Australasia very little data exists on the importance of *Salmonella* as a cause of disease. Sophisticated targeted control programmes have been largely limited to these regions. In 2001, the WHO established a programme, now known as the Global Foodborne Infections Network, to increase the capacity to conduct surveillance in developing nations and gather information on the current situation regarding foodborne disease prior to implementation of any efforts at control.

Attempts have also been undertaken in many countries to reduce the prevalence of *Salmonella* in livestock populations. However, despite the introduction of comprehensive control programmes, most of these have had only limited success. In several instances, the high costs of implementing effective control strategies in animal populations have been shown to outweigh the costs of *Salmonella* infections. While some countries have been successful in limiting or reducing levels of *Salmonella* in animal populations, for many developing countries comprehensive animal *Salmonella* control programmes are neither financially viable nor cost effective.

In developing countries, *Salmonella* control is not always cost-effective

Rabies

Overview and definition

Rabies is a disease caused by *Lyssavirus* that affects the central nervous system of mammals. First recorded in the Eshumna Code of Babylon in the 23rd century BC, today rabies remains one of the most widespread animal diseases, with all regions of the world apart from Antarctica being affected. As a result of the implementation of comprehensive control measures, a number of countries are now free of the infection, while several others – including Iceland, New Zealand and Papua New Guinea – have never reported cases of the disease.

Although rabies in domestic livestock creates significant costs in some countries, it is rabies in humans that is of major concern on a global level. Dogs transmit the majority of human infections, although there are occasional transmissions from other animals. Humans exposed to the disease through infectious saliva from rabid animals, through bites, scratches or licks to broken skin or mucous membranes, require rapid treatment without which exposure is almost always fatal. Nonspecific initial symptoms are followed by an acute stage characterised either by hyperactivity, hydrophobia, confusion, hypersalivation and hallucination (furious rabies) or muscle weakness, loss of sensation and paralysis (dumb rabies). In both forms, people eventually fall into a coma and die from respiratory failure.

A related virus to that which normally causes rabies is present in bats worldwide and can also be transmitted to other mammal populations, including humans. The threat to humans posed by bats is far lower as our interaction with these mammals is very limited in comparison to our contact with dogs.

The first rabies vaccination was administered in 1885. Today, rabies vaccines are available that are safe and highly effective, although some countries still produce and use poorer quality and cheaper nerve tissue vaccines which are less potent and require a series of injections. In addition to vaccines, post-exposure treatment (PET) based on local wound care, timely administration of rabies immunoglobulin and serial vaccination has also been developed and is nearly 100% effective before the onset of clinical symptoms. Unfortunately, in many low income settings, the provision of PET remains inadequate, because of the prohibitive price of the treatment, unavailability of immunoglobulin and/or vaccines as well as lack of disease awareness. Consequently, many victims in developing countries receive no treatment at all.

Socio-economic impact

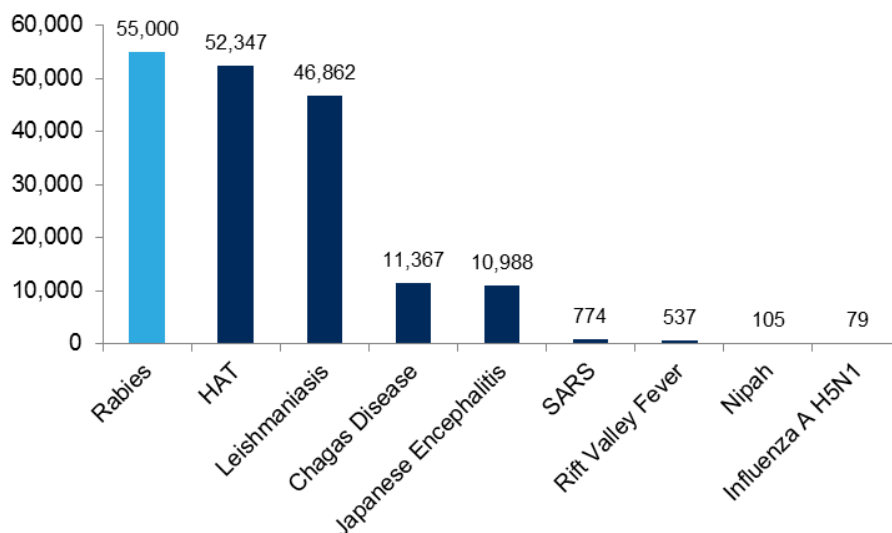
The economic burden of rabies in humans is mainly due to mortality, commonly expressed as Disability Adjusted Life Years (DALYs), and direct and indirect costs related to medical treatment. Human rabies cases in highly developed countries, such as EU member states, are rare and the handful of cases that do occur each year are often imported from abroad. The vast majority of human rabies cases – as high as 99% – occur in the developing world, mostly in Africa and Asia. Globally, some

Without rapid and effective treatment, rabies is almost always fatal

As many as 99% of human rabies cases occur in developing countries

55,000 people die every year as a result of rabies, representing a burden of over 1.7 million DALYs.

Figure 3: Annual human deaths for selected zoonotic diseases



55,000 people die from rabies infections each year

Source: Lembo et al, 2010.

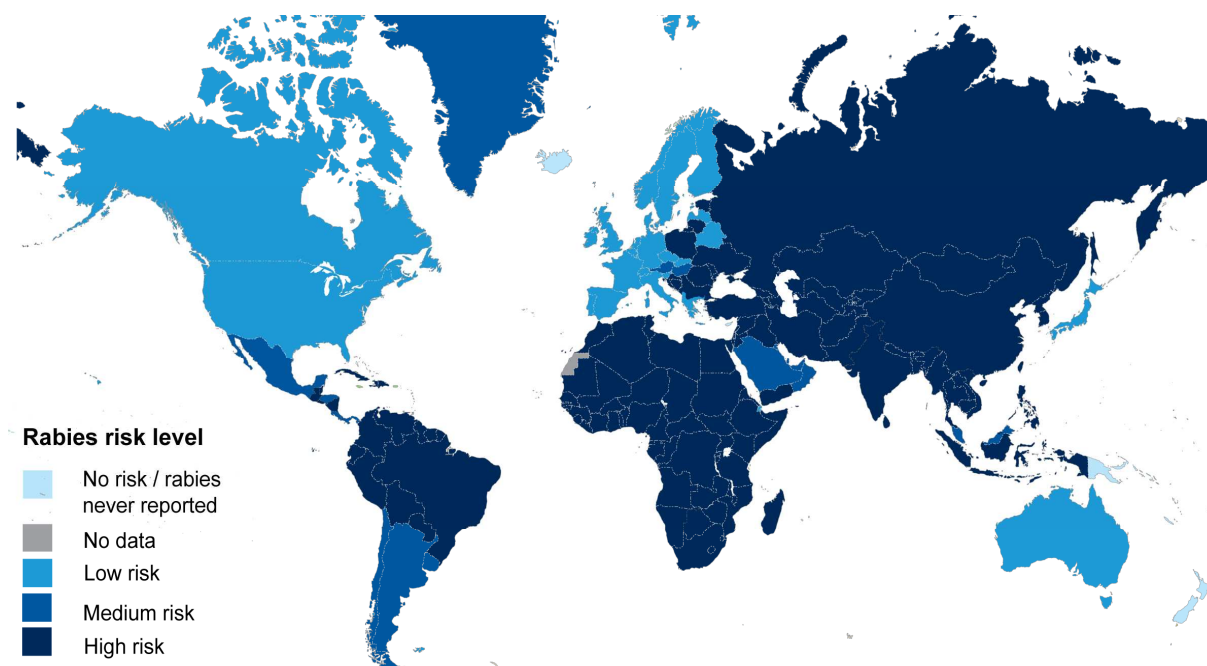
Direct medical treatment costs include labour, overheads, and materials for treatment. Indirect medical costs include the number of working days lost for the patient and his or her carers as well as transport and accommodation costs when seeking treatment. Psychological distress experienced by both the victim and family members and friends add to the costs of rabies. In 2004, the WHO estimated the burden of psychological distress of rabies to be equivalent to 32,285 DALYs in Africa and 139,893 DALYs in Asia. In both high and low income settings a certain proportion of rabies victims die; an additional cost is therefore the loss of potential production incurred by each death.

Major economic costs also arise from diverting resources, which could be used elsewhere, to surveillance, vaccination and the culling of dog populations and other host groups with the objective of reducing the spread of the disease. Further economic costs accrue from the negative impact of rabies on dog welfare as well as the transmission of rabies to livestock and the resulting reduction in food productivity.

While there have been few comprehensive studies on the costs of rabies to livestock populations, it clearly remains a significant problem in a number of areas. Bovine rabies remains a serious issue in Central and South America, where an estimated one million cattle die of infection every year, largely as a result of bites from vampire bats. This heavy toll has led to the development and application of rabies vaccines for cattle and a number of control programmes are now underway across the region.

1 million cattle die of rabies in Central and South America each year

Figure 4: Rabies risk level



Sources: Based on OIE and WHO data, 2012.

Case studies

AFRICA

Nearly all African countries have reported recent clinical infections of rabies and have a relatively high risk of human infection. Some, but not all have implemented national rabies control plans based on dog immunisation and dog population control, with PET programmes. For example, Morocco's rabies control plan has aimed to vaccinate all dogs, control the stray dog population and make PET more widely available. It also includes public health education and coordination of ministries. The economic costs of this plan were estimated to be 2.93 million dollars in 2008, but rabies cases in animals and humans have continued, likely as a result of relatively low levels of dog vaccination.

In an effort to improve rabies control efforts in Africa, a number of charities have established pilot programmes. In recent years, the Gates Foundation started funding pilot rabies control projects in South Africa, Tanzania and the Philippines as part of the Global Alliance for Rabies Control, with the aim of eliminating human and dog rabies over a five year period.

Rabies control programmes in Africa have often been ineffective

Table 3: Estimated annual expenditures due to rabies

Category	Africa	Asia	Total
PET costs	9.1	475.9	485.0
Direct (medical)	5.9	190.3	196.2
Indirect (patient)	3.2	285.6	288.7
Income loss	1.3	113.5	114.7
Transport costs	1.9	172.1	174.0
Dog rabies control costs	9.7	77.0	86.7
Vaccination costs	8.7	52.0	60.7
Population control costs	1.0	25.0	26.0
Livestock losses	1.7	10.5	12.3
Surveillance costs	0.03	0.09	0.12
Total	20.5	563.0	583.5

Annual expenditures due to rabies in Africa and Asia total an estimated 583.5 million dollars

* All costs in millions of US dollars.
Source: WHO, 2005.

While some African countries have made substantial efforts to address rabies, success has been difficult to achieve. Implementation requires not only technical solutions, but also depends on intersectorial coordination and development of institutions that can manage the delivery of vaccines for humans and dogs. Too often, experience shows, responsibilities for diseases with the capacity to affect both humans and animals tend to fall between human health and animal health services leading to poor coordination and a lack of success. Developing a means of addressing this continues to be a challenge.

INDIA

Dog rabies is present in all countries on the Asian continent, with an annual estimated 20,000 human deaths in India alone, representing over a third of the global total. Globally, 91% of human rabies cases are attributed to dog bites, of which approximately two thirds are from stray dogs. Despite these dangers, many Indians are opposed to stray dog control programmes other than neutering as a result of religious and ethical beliefs. A 2004 survey in India also found that only a minority of dog bite victims chose to receive PET, with the majority preferring to seek less effective treatments based on local beliefs and customs.

91% of human rabies cases are attributed to dog bites

The annual cost of rabies in India in terms of human vaccines and other drugs for PET was estimated to be 44 million dollars plus a loss of 38 million man-days. Despite this heavy toll, India has made some progress in recent years. In Chennai, rabies vaccination and the neutering of stray dogs reduced human rabies cases from over 100 per year in 1996 to zero in 2008. The Association for the Prevention and Control

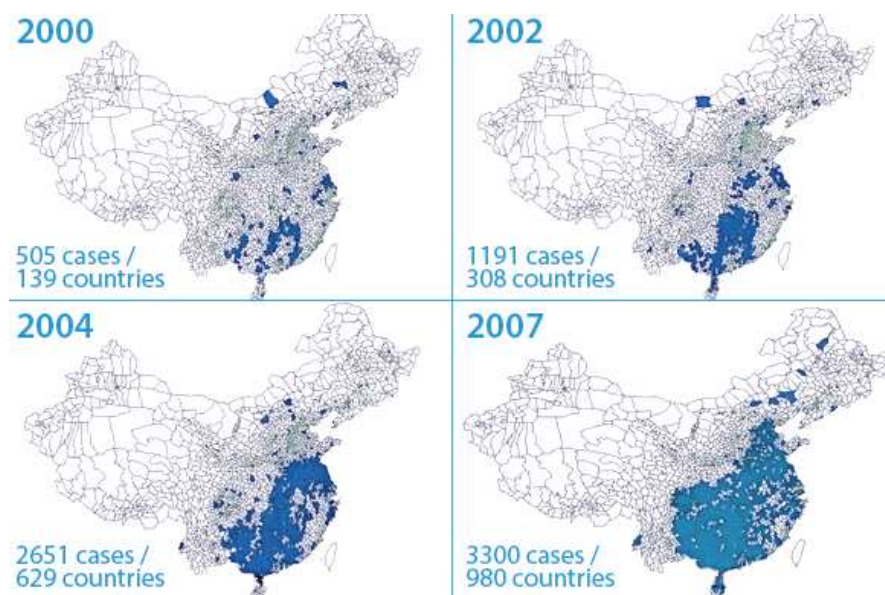
of Rabies in India (APCRI) is currently campaigning for rabies eradication by 2020 through traditional measures as well as the training of medical personnel, education campaigns in primary schools, media campaigns, improving the availability of PET and waste management to limit stray dog population growth.

CHINA

China is currently second only to India in terms of the number of people who die from rabies every year. There has been a rapid rise in the number of human rabies cases in China in the last fifteen years – from 159 reported cases in 1996 to 3,279 a decade later. This sharp rise in human rabies cases corresponds to a major increase in the rate of dog ownership; a very low rate of vaccination; a poor understanding of the transmission dynamics of rabies; and inadequate treatment of infected patients. A recent study estimates that the rabies related mortality rate increased by an average of 26% per year during 1999 – 2008. Nearly 60% of these cases occur in just five south-eastern provinces where the human to dog ratio is much higher than in the rest of the country, although the number of cases is also rising in northern provinces (see Figure 5).

China is second only to India in human deaths due to rabies

Figure 5: Rabies cases in China, 2000 – 2007



Source: Yu et al, 2012.

Although the government has expended a large amount of resources on controlling rabies, and the death toll has dropped markedly from a high of 3,300 in 2007, the incidence of human rabies remains high, with 1,917 cases and 1,879 deaths in 2011. This is largely as a result of inadequate control methods. In many places, large scale culling of dogs continues to be used as a primary response to human rabies. In 2006, 50,000 dogs were slaughtered in Yunnan Province after three people died of rabies.

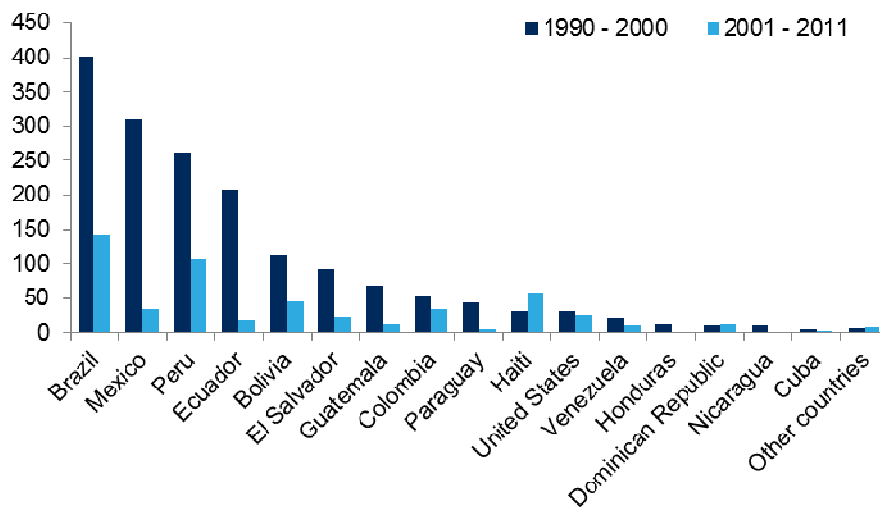
Thousands more were killed in response to eight cases of rabies in Hanzhong City in 2009. In August 2011, public outcry led Jiangmen city to revoke a plan to cull 30,000 dogs in response to a spate of human rabies cases. Indeed, the culling of dogs in China has been increasingly criticised by pet owners and animal protection organisations, who cite a lack of evidence to support its effectiveness as a rabies control strategy.

THE AMERICAS

Unlike in Africa and Asia, where rabies continues to be rampant in many places, rabies control in the Americas has generally been successful. Over the last decade, there has been a marked reduction in human rabies cases in every country in the Americas with the exceptions of Haiti and the Dominican Republic (see Figure 6). This success is the result of the implementation of large-scale, synchronised mass dog vaccination campaigns such as the 23 year Pan American Health Organisation (PAHO) programme.

Rabies control in the Americas has been very successful

Figure 6: Number of reported human rabies cases in the Americas, 1990 – 2000 and 2001 – 2011



Source: PAHO, 2012.

The PAHO programme cost 40 million dollars per year and aimed to vaccinate both dogs and humans and support surveillance. Annually it provided medical services to one million people bitten by animals with a quarter of these receiving PET. It also helped to annually vaccinate 44 million dogs (68% of the total population), including 17 million in Brazil and 16 million in Mexico, the two countries with the largest canine populations. In addition, rabies surveillance programmes across the region collected and analysed nearly 74,000 canine samples per year.

While rabies was not eliminated during the programme, it gave Latin American governments the confidence to set a target in 2008 to eradicate canine rabies in Latin America by 2012. After 30 years of systematic control, reported human rabies cases originating from dog bites have dropped from 251 in 1990 to 24 in 2011, and reported dog rabies cases from 16,468 in 1990 to just 466 in 2011.

Human rabies in the Americas dropped from 251 cases in 1990 to 24 in 2011

Current state of disease and control measures

Control of rabies varies considerably across the world. Dog rabies in the United States, Canada and Western Europe, as well as fox rabies in Western and Central Europe, has largely been controlled through quarantine programmes, movement controls, vaccination – typically injections for dogs and aeriially-dropped oral baits for wild species such as foxes – and monitoring. Coordinated control measures in other parts of the developing world including Latin America have also been successful. However, rabies remains rife in many other parts of the developing world as a result of the presence of diverse feral carnivore populations that maintain the disease, while a lack of human and financial resources and poor coordination of control efforts have limited the success of rabies eradication.

Measuring the true burden of rabies is complicated by a number of factors. Firstly, the vast majority of deaths from rabies occur in developing countries that have inadequate health infrastructure and governance. Many of these countries lack diagnostic capacity and surveillance programmes, making an accurate estimation of the real number of rabies cases nearly impossible. In addition, in many areas, rabies continues to be a neglected disease as it primarily affects dogs, which have little financial value when compared to livestock and are often considered to be pests rather than pets. Finally, while control of rabies through mass vaccination has been successful in many parts of the world and has consistently proven to be a cost-effective means of reducing the burden of disease in human and animal populations, it requires a significant financial investment and large-scale coordinated efforts that often necessitate the involvement of multiple countries to be effective.

Measuring the true burden of rabies is complicated by a number of factors



Foot and Mouth Disease

Overview and definition

Foot and mouth disease (FMD) is a viral disease of livestock, affecting cattle, small ruminants (sheep and goats) and swine. FMD is considered to be one of the most infectious animal diseases: it can be transmitted through contact between animals, by contaminated meat and products, via environmental contamination and over long distances as an aerosol blown by wind. The clinical signs of the disease include fever, loss of appetite and the appearance of blisters on the mouth and around the hooves of affected animals. In addition, the disease reduces milk yield, induces weight loss and impairs fertility. Mortality in adult animals is low, but high in young stock. FMD is considered to be among the most economically significant livestock diseases due to its impact on production, its importance as a barrier to the international trade of livestock and animal products and the high costs of control.

FMD is considered to be one of the most infectious animal diseases

FMD was first described in Italy in 1546. Prior to the 1950s when vaccines became available, control through stamping out or culling was implemented in Great Britain, Scandinavia and North America. Vaccination campaigns in the EU from the 1960s to the 1990s effectively resulted in FMD eradication. Prior to this, there were periodic European epidemics such as during 1937 – 1939 when over 2 million livestock premises were reported to be infected. FMD was introduced into the Americas around 1870. Control by culling of infected animals was successful in North America and no outbreaks have been reported since 1929 in the United States and 1953 in Canada. FMD is also absent in Mexico and Central America and has been largely controlled in South America through long-standing vaccination programmes.

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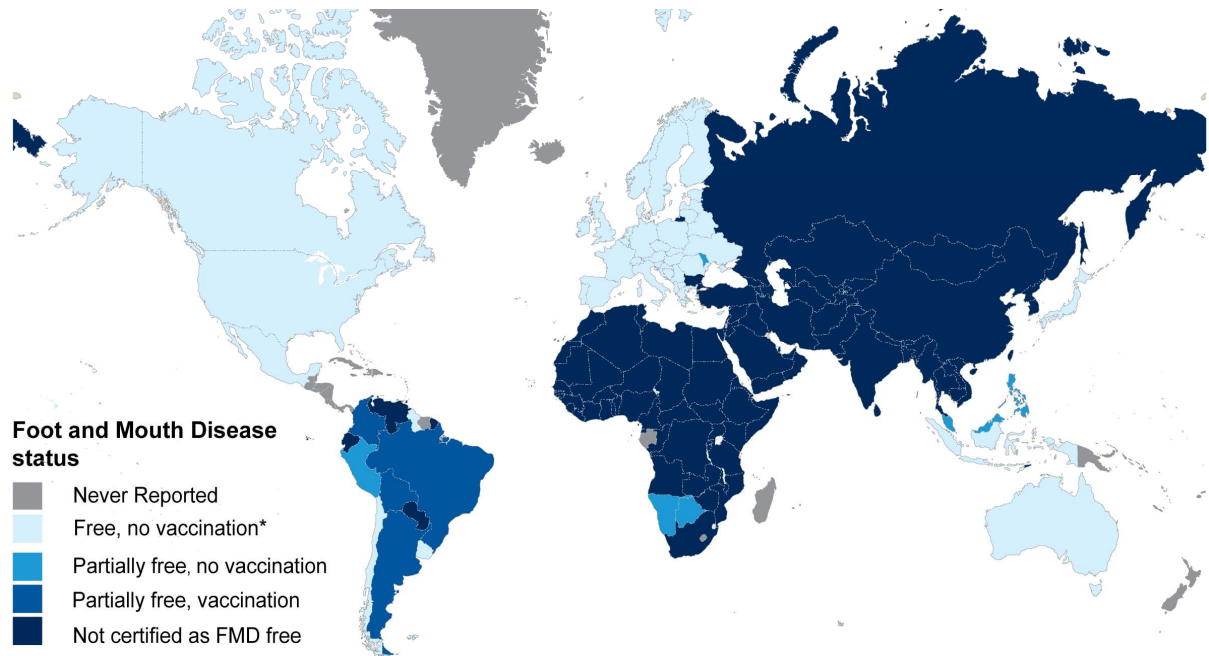
Socio-economic impact

FMD causes losses in production by reducing the fertility of breeding females, lowering milk production and causing death, particularly in younger animals. In addition, efforts to combat the disease are costly and involve running vaccination campaigns, developing and maintaining surveillance systems and responding to outbreaks. Furthermore, in countries that have eradicated the disease there are large populations of animals that have no prior exposure to FMD and are highly susceptible. In the recent past this has generated catastrophic FMD epidemics (see Table 4).

FMD's infectious nature and ease of transmission combined with the economic costs it creates have also led to it being a significant animal disease from a trade perspective. FMD-free countries are entitled to refuse imports of animal products from those affected, closing lucrative export markets to producers in many developing economies where FMD has not been controlled. Despite ongoing control efforts, in 2012 outbreaks of FMD have occurred in Libya, Egypt, South Africa, Botswana, Kazakhstan, Paraguay and Taiwan.

FMD outbreaks have significant trade implications

Figure 7: Foot and mouth disease status



* With the exception of Uruguay, where vaccination is practised

Source: Based on OIE data, 2012.

Case studies

UNITED KINGDOM, 2001

The costs of FMD during the 2001 outbreak in the United Kingdom are largely related to the response to the disease rather than the disease itself. This response is based on FMD control legislation that was introduced in the 19th century. This legislation was designed before vaccines were available and stipulates movement restrictions and the culling of animals and payment of compensation to farmers. This approach was successful in containing past FMD outbreaks and eradicating the disease in 1968, the last major epidemic prior to the 2001 outbreak.

In 2001, reliance on stamping out, advocated as the quickest way to contain and eradicate the disease and reacquire disease-free status, resulted in the slaughter of over 6 million animals. Restrictions on the movement of animals meant approximately 2.9 million had to be slaughtered for welfare reasons. Furthermore, as the epidemic continued to grow, the decision was taken to cull animals pre-emptively on premises adjacent to those where the disease had been detected, resulting in the culling of a further 3 million mostly healthy livestock. Estimates of the total costs of the outbreak vary significantly. A 2002 study by the National Audit Office estimated the direct costs of the outbreak at 3 billion pounds sterling and the indirect costs at 5 billion pounds, or 8 billion pounds (11.5 billion dollars) in total.

FMD in the UK in 2001 resulted in the slaughter of over 6 million animals

Due to the capability for the virus to be transmitted on inanimate objects, such as clothing or vehicle wheels, the public were discouraged from visiting the countryside during the epidemic and many public footpaths in rural areas were closed. As a result, rural tourism was significantly reduced. International tourism receipts dropped by 14.5% in 2001 compared with the same period the previous year. One study estimated that the loss of tourism revenue alone in 2001 was as high as 179 million pounds sterling per week or 7.7 billion pounds over the year as a whole.* This decline in the British tourism sector also induced effects in other economic activities, as a result of close linkages between different sectors of the economy.

Tourism was the worst affected UK sector following the 2001 FMD outbreak

The epidemic lasted five months and a total of 2,026 premises were confirmed infected, a marginally smaller number than the total for the 1967 – 1968 epidemic. However, the number of animals slaughtered in 2001 in an effort to control the disease increased by a factor of approximately 18 over the earlier outbreak. Veterinary and rendering services had to be assisted by the army in the slaughter and disposal of carcasses.

Intangible costs were also incurred in terms of the psychological wellbeing of those involved in the control of the outbreak. A study of 3,071 weekly diaries of individuals with direct experience of the 2001 outbreak found that, for farmers and others affected by the crisis, life after the epidemic was accompanied by distress, feelings of bereavement, fear of a new disaster, and loss of trust in authority and systems of control. Beyond the trauma incurred from the outbreak itself, further costs arose as a result of the disruption of normal life as events and shows were cancelled, children missed school, families were divided, and access to the countryside was prohibited.

Intangible costs were incurred in terms of psychological wellbeing

Table 4: Costs of recent foot and mouth disease epidemics

Location	Taiwan ¹	Uruguay ²	United Kingdom ¹	Japan ³	South Korea ⁴
Year	1997	2001	2001	2010	2010 - 2011
Direct costs	254	456	4,320	550	2,780
Indirect costs	6,363	274	7,200	N/A	N/A
Total cost	6,617	730	11,520	> 550	> 2,780
Duration	4.5 months	4 months	7.5 months	4 months	5 months
Control Method	S.O. + Vacc	S.O. + Vacc	S.O.	S.O. + Vacc	S.O. + Vacc
Slaughtered Animals	4,000,000	20,000	6,240,000	290,000	3,470,000

All values in millions of dollars. S.O.= stamping out, Vacc = vaccination. N/A = Data not available.

Sources: ¹ FAO, 2002. ² MGAP, 2004. ³ Muroga, N. et al., 2011. ⁴ Yonhap News Agency, 2011.

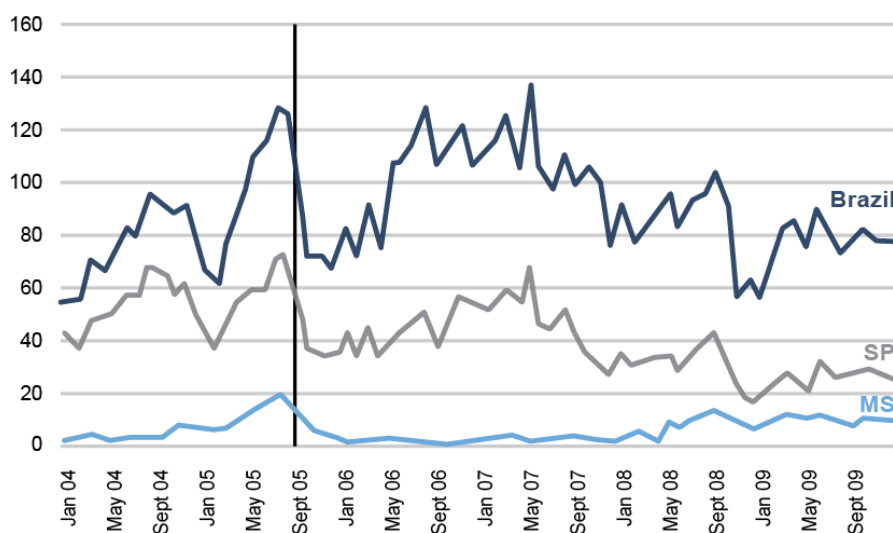
* While this overall decline is linked in part to the attacks on the World Trade Center, studies show that the overall effect of September 11 on British tourism receipts was no greater than the effects of FMD.

BRAZIL, 2005

In 2005, FMD was detected in the Brazilian states of Mato Grosso do Sul and Paraná, a region of the country heavily involved in the production and export of beef. While the outbreak was quickly contained and no new cases were reported after 2006, lingering costs related to the loss of export markets and the subsequent changes in the level of production impacted the Brazilian economy. The 2005 outbreak led to several countries banning imports of Brazilian beef including Russia, Brazil's main market. Exports dropped and led to a reduction in national beef prices, which did not recover until the Russian market was regained in December 2007 (Figure 2). These major changes in the market led to the dispersal and slaughter of cattle herds as farmers left the industry. The loss of breeding animals subsequently reduced calf production during 2006 and 2007, with levels only recovering in 2008.

Lingering costs relating to loss of export markets can follow FMD outbreaks

Figure 8: Export volumes of beef from Brazil, 2004 – 2009



1,000,000 kgs

The vertical line represents the date of detection.

SP = São Paulo (SP); MS = Mato Grosso do Sul (MS).

Source: Costa et al, 2011.

NORTHEAST ASIA, 2010 – 2011

In 2010, FMD spread from China to Mongolia, South Korea and Japan. In South Korea, a pig farmer reported a case of the disease on 26 November. The disease spread rapidly and by 1 January 2011, cases were being detected nationwide. In response, approximately 3.5 million animals were culled and emergency vaccination applied. The last case was reported in April 2011.

FMD outbreaks can spread rapidly across state borders

Direct losses to agriculture and the costs of control have been estimated to be 2.8 billion dollars. The slaughter and disposal of so many affected animals overburdened Korean animal health systems and there were widespread reports of the live burial of pigs. In addition, domestic pork production was disrupted with large consumer price



rises in pork and also in chicken, leading to a relaxation in import tariffs. In 2011, South Korea met only 60.3% of demand for pork with domestic production, compared with 80.9% in 2010.

In Japan, the outbreak centred on one of the main beef production areas, but unlike in Brazil in 2005 did not occur in a region reliant on exports. In this instance, emergency vaccination was applied successfully when it became apparent that stamping out would not contain the disease. As in South Korea, detection of the disease was slow and the total costs of disease control were estimated to be 550 million dollars.

Current state of disease and control measures

The OIE categorises countries as FMD-free without vaccination (65 countries) and FMD-free with vaccination (1 country). In addition, since 1992, countries have been able to partition into zones which can be recognised as FMD-free with (4 countries) or without (10 countries) vaccination, independently of the disease status of the rest of the country. This recognition of zonation has allowed entry to export markets for countries with only partial FMD-free status and provides an incentive to FMD control programmes. For example, as Brazil progressively expanded its number of FMD-free zones, Brazilian beef production doubled from 4 million tonnes to 8 million tonnes between 1988 and 2007. Brazil became the world's top beef exporter in 2003.

Despite these designations, OIE data on country disease status is recognised as incomplete because FMD is not controlled or effectively monitored in many countries.

Numerous evaluations of the impact of FMD in regions where the disease is endemic have been performed (see Table 5). In these areas, where the disease is not controlled, the capacity remains for FMD to spread rapidly across international borders via the movement of animals and products, as evidenced by the 2010 – 2011 epidemic in Northeast Asia. A recent study has estimated that if a large-scale FMD outbreak were to erupt in cattle populations in California, it would result in total losses (including those related to international trade) of between 2.3 and 69.0 billion dollars depending on how early the infection were to be detected.

As a result of the potential massive costs of an FMD outbreak – recent conservative estimates indicate that FMD production losses and costs of vaccination alone on a global scale are in the region of 5 billion dollars annually – huge incentives exist for countries to initiate FMD control programmes, particularly where there is the potential to export livestock, the ability to prevent disease reintroduction and livestock are held in easily managed, intensive production systems.

Zonation policies have allowed partially FMD-free countries to continue to export

An FMD outbreak in California could cost as much as 69 billion dollars



Table 5: Impact of foot and mouth disease in selected endemic regions

Country	Impact
Cambodia ¹	Reduction in household income of 4.4 – 11.7% annually following FMD outbreak. Loss of 54 – 92% of animal value following FMD infection.
India ²	Losses of between 450 million pounds sterling and 2 billion pounds sterling per year.
Laos ³	Loss of 22 – 30% of animal value following FMD infection.
South Sudan ⁴	Loss of 25 dollars per cow per year in a region where 90% of the population have income less than 1 dollar a day.

In endemic regions, FMD incurs significant losses in income and productivity

Source: ¹ Shankar et al., 2012; ² Ganesh et al., 2010; ³ Rast et al., 2010; ⁴ Barasa et al., 2008.



Future Perspectives

Animal diseases create costs in terms of losses in production, resources needed to monitor and control outbreaks, restrictions on trade and negative impacts on human health and welfare. As livestock production and marketing evolve and animal health control systems develop and mature the balance of the different aspects of animal diseases costs alters. For example, greater spending on disease surveillance and control leads to smaller losses in animal production and lower impacts on human health when outbreaks occur. In general, we are seeing patterns of more successful disease management and the eradication of well-known disease agents in significant livestock producing populations around the world, but with continuing problems associated with the emergence and re-emergence of disease.

The main cost of animal diseases in these situations is largely related to the spending of money and utilisation of resources to monitor and control disease. However, control of animal disease is not uniform across the world, with many countries continuing to experience serious outbreaks and, in the process, losing part of their potential production, incurring costs of treatment, losing attractive export markets and resulting in death or disability when the disease passes to humans.

Many countries continue to experience serious disease outbreaks

Reintroduction of previously eradicated diseases

One area of greatest concern is the regular occurrence of large scale epidemics with dramatic responses as diseases that have been eradicated from an animal population in the past are reintroduced through human population movement, trade or illegal activities relating to the movement of livestock and livestock products. For example, diseases such as rabies now typically recur in rabies-free areas as a result of the transportation of pets or as a result of the migration of wild animals from higher risk areas.

There is also the possibility that climate change, particularly rising temperatures, will modify distribution of disease-spreading insects and render certain environments more suitable for the spread of disease, increasing their already significant burden. This has already been a concern with the recent emergence of diseases caused by viruses such as bluetongue and Schmallenberg in Europe and West Nile in the Americas. A further concern is that certain diseases may be introduced into geographic areas where they had previously been eradicated.

Climate change may contribute to the emergence of new diseases

International agreements on animal health and food safety

The spread of disease through trade and the subsequent problems that this creates are well-known costs associated with animal diseases. The response has been to create trade barriers which have been formalised internationally through legislation such as the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS). This calls for consistency in the protection of health risks and requires that animal health barriers should not be discriminatory or used to disguise restrictions on international trade.



In the mid-1990s, when the SPS agreement came into force, developed countries had been moving towards a set of international standards on food safety (through Codex Alimentarius) and animal health and zoonoses (via the OIE). However, these advances in the setting of international standards on animal health and food safety were accompanied by an increasing divergence among countries in terms of approaches to animal health systems. Three country groups are beginning to emerge that have very different needs:

- **Group 1.** Countries that are free from the majority of animal diseases affecting trade, and that have reasonably strong animal disease surveillance systems and relatively high capacity in terms of human, logistic and financial resources to stamp out contagious animal disease re-emergence. These correspond to developed countries where livestock are largely held in intensive units with high capital investments, and production systems are vulnerable to small changes in demand and output. These countries are also major importers of livestock products and, if other trade barriers were removed, would be attractive markets for countries in Group 2.
- **Group 2.** Countries that have recently declared disease-free status of the major transboundary diseases and have surveillance systems based on vaccination campaigns. Their abilities to control and eradicate the re-emergence of transboundary diseases are variable. Group 2 countries include Mexico, Argentina, Chile, Uruguay and potentially South Africa and Thailand. They are exporters of livestock products and in some cases are aggressively searching for new markets.
- **Group 3.** Countries that have poor control over livestock diseases and have weak animal health systems. They have low levels of general investment in livestock systems, with most animals held in a large number of relatively small and under-developed units. Some of these countries are importers of livestock products and most have a weak capacity to export. Most of the developing world falls into this category.

Most countries still
have weak animal
health systems

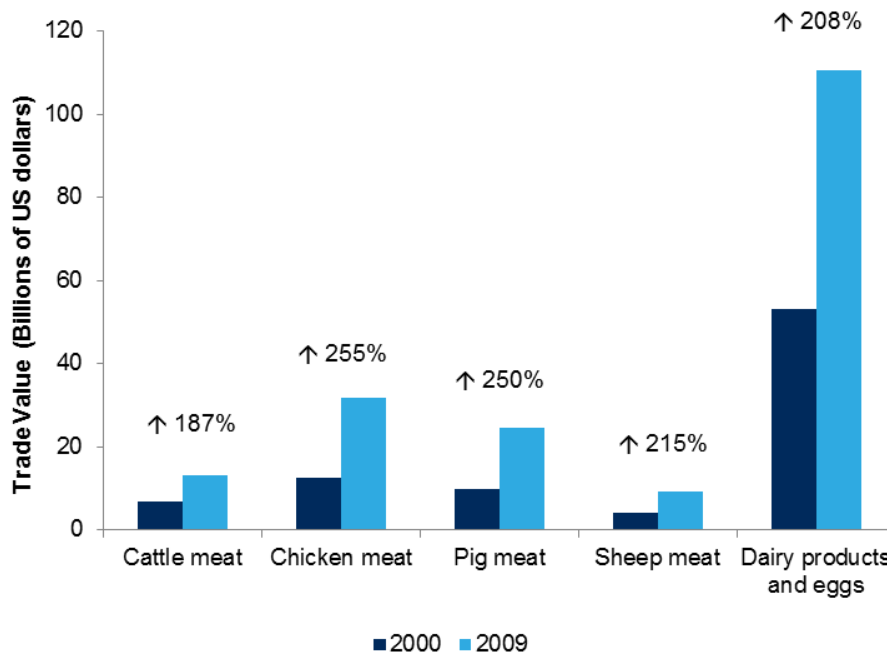
If we are to allocate resources for the global good then we need to consider which parts of the world are struggling in the management of animal diseases. The above classification indicates that additional funding in the countries that belong to Group 1 is unlikely to lead to high returns, although these countries need to ensure the maintenance of their existing systems of surveillance and response. Countries in Group 2 are at a critical stage of disease management and for some disease eradication, further funding and technological support are important in these areas. For those in the final group, serious thought is needed on how infrastructure and human skills can be developed and supported in order to improve disease management.

Growth of global livestock production and trade

Liberalisation and clearer rules on technical trade barriers that relate to animal health have helped to increase trade in livestock products in recent decades. This trade more than doubled between 2000 and 2009 and was dominated by industrialised countries. The most significant exporters of animal products include Brazil (beef, poultry and pork), China (pork), Argentina (beef), Thailand (poultry) and, more recently, India. In addition, live animal exports are an important aspect of trade for many countries, such as those in the Horn of Africa, which serve the demands of the Middle East.

Trade in livestock products more than doubled between 2000 and 2009

Figure 9: Global trade in livestock products, 2000 and 2009



Source: FAO, 2012.

Three important trends in global livestock production and trade can be identified:

- A growth in demand for livestock products in developing countries and the meeting of that demand, mainly through an increase in pig and poultry populations kept in intensive production systems, as well as an expansion of dairy cattle and intensification of milk production.
- An ever increasing concern for food safety in developed countries, reflecting the importance of foodborne diseases both in terms of human health and shocks to demand for specific food products.
- Developments in international law that increasingly incorporate food safety issues.

Increases in livestock production and trade can raise the costs of animal disease



It is also worth considering that as livestock sectors become more efficient and productive they will supply products that are more available, relatively cheap and more palatable and safe. As a result, we need to balance the positives of greater access to high quality nutrient-rich animal-based food products with the need for general food policies that discourage overeating. In addition, changes in diets create other costs that are not related to contagious disease but the burden of non-communicable diseases such as diabetes, cancers and heart disease. Investigation of how livestock are reared and processed, from “farm-to-fork” could determine ways in which meat production, processing and marketing could be modified to reduce the associated risk of non-communicable diseases.

Weak investments in animal health and food safety

Rapid expansion in livestock production in many countries has not been accompanied by commensurate investments in veterinary service development and, perhaps as importantly, investments in the processing and marketing of livestock products. This imbalance has created a context where pathogens such as highly pathogenic avian influenza H5N1 have emerged in Southeast Asia and have been spread and maintained. This has created costs in terms of lost production and reduced trade as well as resulted in human deaths.

Lack of investment in animal health has contributed to the spread of pathogens such as avian influenza

Until further investments are made in animal health control and livestock marketing systems these dramatic costs of animal disease are likely to continue. Diseases that have no zoonotic potential will impact human welfare costs through instability of supply and high prices, while those with zoonotic potential can cause serious human health problems, severe acute respiratory syndrome (SARS) being the most extreme case in recent years. Zoonotic diseases remain a serious worry as the emergence of pathogens that can be maintained in the human population and lead to significant morbidity and mortality would create costs in labour markets, trade and control measures. Such threats need to be assessed and active contingency plans put in place.

Lack of capacity

In some regions livestock production is limited by a high disease burden and a lack of capacity to lower this burden, with FMD and Peste des Petits Ruminant (PPR), a highly contagious viral disease affecting sheep and goats, constituting key examples at the global level, tsetse and trypanosomiasis an example in continental Africa, and East Coast Fever and other tick-borne diseases examples of localised problems in eastern and southern Africa. Similar to regions with rapid expansion of livestock production, these problems need significant investments in animal health systems to alter the balance between production losses and control costs. If this can be achieved then livestock food systems will become more efficient and consumers will gain, particularly in areas where there are problems of stable food supplies.

Governance of food safety

It is probable that governance of food safety will also lag behind the expansion in production, leading to an increasing burden of foodborne disease in developing nations as consumption of meat rises. By contrast, in many developed countries, significant progress has been made in alleviating the burden of *Salmonella*. While still problematic and expensive, the disease is being actively monitored in order to mitigate risks; in some cases, disease levels have been reduced to a level at which further progress to minimise risk appears difficult to achieve.

In developing nations, systems to monitor foodborne disease remain embryonic

The ubiquity of bacteria capable of causing human disease in animal populations; the multitude of factors governing their persistence in animal populations; variations in the readiness of consumers to accept some methods of disease eradication; and multiple routes by which contamination of food may occur means acceptable cost-beneficial strategies for disease elimination are not easy to identify. In most developing nations, systems to monitor and manage foodborne disease are at an embryonic stage. While advice is being given on high risk products and there has been no discernible rise in foodborne diseases alongside dietary changes, this may well be due to under reporting. Experience suggests that the mechanisms needed to manage foodborne disease in these countries remain underdeveloped.

Use of drugs in livestock

With the rise of antibiotic-resistant bacteria in human therapy, concerns over livestock being a source of such resistant bacteria have risen in the past 30 years in Europe and North America. As a result, in Europe and North America, steps have been taken to increase regulation governing the use of antibiotics in animals. This response is far from global, yet systems of production are now similar across a majority of countries as is the use of antimicrobials. Initiatives for better regulation of veterinary medicines are underway as part of the OIE initiative for better veterinary legislation, but have a long way to go in many countries.

Unregulated use of antimicrobial drugs can have adverse consequences

While the role of international trade in the spread of bacteria has not been investigated in great detail, live animals and animal products have been shown to carry harmful antibiotic-resistant bacteria. Such work deserves further investigation, as does the need to gain a better understanding of the relevance to human health of animals or animal-produce carrying resistant bacteria. In zoonotic diseases such as rabies there is some optimism that current scientific understanding of the biology of the disease combined with greater pragmatism in policies to implement control strategies may lead to better control. However, this will require a shift of costs of animal disease to resources for control rather than accepting losses generated by these diseases as part of an intractable problem. Further comments on how improved control efforts might take place are included in the following section.



Recommendations

Managing disease in domesticated animal populations requires an understanding not only of the biology of the disease, but also of the systems in which the animals are kept. Global consumption of protein from animal sources is now increasing rapidly and production systems are adapting to cope with this increase in demand. One way demand can be met is through increased efficiency of production. The animal health sector can play a key role in this process. Animal disease causes significant losses not only to livestock production, but also further down the food chain, in the travel and tourism industries and in the case of zoonoses, to the human health sector.

Data collection

In many regions, adequate surveillance and reporting capabilities for animal diseases do not exist. As a result, extrapolation from small-scale studies produces impact estimates which are surrounded by a high degree of uncertainty. In many cases, these estimates are produced using conservative methodologies and are likely to be underestimates of the true burden of disease.

Nevertheless, animal diseases have been shown to cause significant losses. As society becomes increasingly globalised, internationally funded disease control initiatives present an opportunity to fulfil overseas aid and development commitments while simultaneously reducing the risk of disease introduction by the movement of travellers, animals and products from abroad. Gathering data to estimate the true impact of disease in livestock systems globally would be an initial step in this process. Training of local personnel would improve the capacity of veterinary services to deliver any subsequent control initiative.

Better data is needed to adequately assess the costs of animal disease

Systematic assessments of the economic costs of rabies and associated intervention and surveillance measures worldwide will help to demonstrate to policy-makers the extent of the rabies burden and encourage them to prioritise resources towards its control. The Global Alliance for Rabies Control is currently leading a project to generate the economic and epidemiological evidence in support of global rabies elimination. This evidence is expected to contribute towards a global strategy for rabies that may bring together partners already committed to rabies control from the WHO, OIE and the Food and Agriculture Organisation (FAO) as well as government ministries, industry, research teams, non-government organisations and citizens in an effort to build interdisciplinary strategies to better understand and ultimately eliminate rabies.

Similar efforts are underway for FMD, with the assessment of the global impact of the disease and a growing momentum to begin a global control programme with the support of the OIE and the FAO. For *Salmonella*, the efforts for control have tended to be either national or regional, with the most recent successes seen in Europe where increased control of *Salmonella* in poultry has driven down the rate of human infection.

Surveillance

Surveillance provides vital intelligence in order for resources to be deployed most effectively. Surveillance systems can be used in several ways. Firstly, they can be used to gather information about the nature and scale of problems within a particular population; secondly, they can be employed to determine whether disease control activities are having the desired impact; and thirdly, surveillance systems can capture the introduction or re-introduction of a disease in order to control its spread. Early warning of disease outbreaks has been shown to be critical to mitigating impact, whether it limits the spread of a highly contagious production disease such as FMD or reduces the number of human cases affected by a zoonotic disease or foodborne pathogen.

Effective surveillance is vital to mitigating the impact of disease

Use of risk assessments to inform decision making is now commonplace using methods standardised by the OIE and FAO. However, lack of adequate surveillance systems mean many risk assessments are based on expert opinion or informed guesswork. Furthermore, as has been demonstrated in the past, a disease outbreak can often be traced to the actions of a single individual operating extra-legally (for example, the 2001 FMD outbreak in the United Kingdom was most likely introduced by illegally imported pork being fed as swill without the requisite pre-treatment). Further work is required to integrate the economics governing the movement of animals and animal products with the biology of disease transmission in order to develop sound risk mitigation strategies.

Further integration of the economics and biology of animal diseases is required

Understanding the response to regulation

A better understanding of the response to regulation should also be integrated into disease control programmes. For example, investments to reduce foodborne hazards throughout the production chain can create benefits for producers, who may be able to charge a premium for quality products. An externality also exists in that the cost of foodborne disease to society is reduced. Efforts should be made to capture this externality since many producers lack an incentive to initiate costly control programmes unless they face punitive measures such as denial of market access.

A better understanding of the response to regulation is needed

It is also important that the drafting of new regulations, whether they govern food safety or trade, should be accompanied by consultation with actors in livestock value chains. Raising transaction costs without the support of those affected may drive the development of informal or illegal trade networks by which animal and zoonotic disease can be transmitted.

Institutional implementation

Zoonotic diseases raise questions about how institutions should take ownership of control programmes. Rabies is one such case where there is a need for an integrated policy at a higher budgetary level in order to effectively manage the disease. In the case of rabies, there is also the need for collaboration of human and animal health services in the control of a disease that affects both animals and humans. This intersectoral approach, often described as One Health, is rare across the world yet crucial for zoonotic disease control. Such an approach also takes into account

Intersectoral work is crucial for zoonotic disease control

community acceptance for strategies such as vaccination, culling and sterilisation; possibilities for funding and ownership of public and animal health ministries and non-governmental organisations; presence and interaction of domestic and wildlife reservoirs; physical settings and the quality of local infrastructure.

An understanding of the institutional and socio-economic reality is required and needs to be used to develop pragmatic processes of implementation. In short, interdisciplinary approaches to widespread diseases such as rabies are needed to address the lack of surveillance, adequate reporting structures, laboratory capacity, resources and enforcement. At the strategic level, control programmes should be built around an understanding of the economics governing the systems in which animals live as this will determine the movements and contact networks of the affected animals and thus the likely patterns of disease spread. Where different technical options for control exist, such as stamping out or vaccination, assessments should be made of the efficacy, costs and benefits of each in different scenarios. This kind of methodology is already being used to produce tools to aid decision making in the face of future FMD outbreaks in countries such as the Netherlands and the United Kingdom, and should be extended to other countries.

Assessments should be made of the efficacy, costs and benefits of different control options

Capacity to respond

In many parts of the world, lack of veterinary services remains a key impediment to animal health. It is possible to improve capacity in veterinary services in cases where production systems are able to expand and demand for veterinary services increases. However, in many developing countries, where the disease burden is over-whelming, increasing provision of veterinary services may be a prerequisite for increasing production. Increasing knowledge of the burden of disease and supply and demand for commodities would also serve to highlight cases where disease and inadequate veterinary services combine to produce stagnation in this manner. Stimulation would then be required for growth in both the veterinary and agricultural sectors.

As discussed in the context of surveillance, rapid responses to disease outbreaks are also critical to minimising impact. Large-scale stamping out – as practised during FMD outbreaks in the United Kingdom in 2001 and South Korea in 2010 – 2011 – has often been seen as the most rapid and effective method of containing the spread of disease. However, stamping out is increasingly seen as socially and ethically unacceptable. As our technological capabilities advance, vaccines are now being developed which allow differentiation between vaccinated animals and those exposed to disease, rendering large-scale stamping less necessary. Thus vaccination, which hitherto was rejected as a strategy, as it hindered the re-establishment of disease-free status and had detrimental trade implications, should be considered among the available control options.

Implementing new technologies will improve capacity to respond to disease

In addition, infrastructure should be put in place to ensure the rapid development of vaccine and its availability in sufficient quantity, complemented by the capacity for rapid diagnosis of diseased animals. Assessment of the disease in question, the structure of the population at risk and likely patterns of spread, and the technology available to combat the outbreak, can serve to identify where opportunities for control

by vaccination exist, where establishment of stockpiles in vaccine banks is necessary, or where further investment in vaccine and diagnostic development is required. In the case of the developing world, the infrastructure for delivery of vaccination often does not exist. As a result, procuring the investment needed to develop vaccines which are heat-stable and confer long-term immunity is essential to achieving sufficient coverage.

Conclusion

The diverse nature of disease pathogens, their animal hosts and the systems in which they live result in a complex range of strategies which can be employed to mitigate their impact. In many parts of the world, reporting systems are either rudimentary or non-existent, making estimates for the global impact of animal disease problematic. Successful disease control programmes have been introduced where the political, economic and social structures exist to allow their implementation. Future efforts should be made to assess disease control and mitigation activities not only on their technical merits, but also in terms of their impact on the systems on which they are being imposed. Zoonotic diseases will continue to present a challenge in that conflict for resources between human and animal health authorities often results in neglect in the control of these diseases. However, improving technology, such as vaccines and diagnostic and surveillance capabilities, offers greater flexibility in approaches to tackling disease problems and will allow disease control options to reach populations previously marginalised.

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