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# Global Risks of Infectious Animal Diseases

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## Introduction

Animal diseases impact food supplies, trade and commerce, and human health and well-being in every part of the world. Outbreaks can draw the attention of those in agriculture, regulatory agencies, and government, as well as the general public. This paper presents information on the threat of animal diseases; their impact on animals and humans at the international, national, industry, and societal levels; and the responses to them. In addition, specific information is provided on national and international monitoring and surveillance programs.

## Global Threat of Infectious Diseases

The global risk of foreign animal and emerging diseases has increased in recent years. Examples include the 2000–2001 foot-and-mouth disease (FMD) outbreaks in Europe, South America, Asia, and Africa; the 2003–04 highly pathogenic avian influenza (HPAI) outbreaks in Asia, Europe, Canada, and the United States; and the 2002–03 Newcastle disease (ND) outbreak in the United States.

The occurrence of emerging diseases transmitted from animals to humans under natural conditions (zoonotic diseases, or zoonoses) also has increased. Examples include bovine spongiform encephalopathy (BSE), monkeypox in the United States, avian influenza, *Escherichia coli* O157-H7, West Nile virus, and severe acute respiratory syndrome (SARS). These diseases caused losses to the agricultural community and impacted other segments of society. Several social, physical, political, and biological factors contributed to this emergence. These factors and their influence will be described in this paper. Animal health issues are embedded in cultural, political, and economic factors that impact the global risk of animal diseases.

Upon discovery of a disease outbreak, the social and political impacts can outgrow the technical and scientific considerations. Consequently, the need for effective risk communication to minimize unwarranted anxiety concerning animal disease crises becomes an important con-

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sideration. Bovine spongiform encephalopathy, for instance, raised serious concerns about human health in certain countries, even though BSE has caused fewer than 200 human cases worldwide. In contrast, the SARS outbreak, which is believed to have originated from infected captive wild animals, resulted in 8,096 people becoming ill and 774 deaths worldwide (WHO 2004). The threats of foreign animal disease, emerging diseases, new zoonoses, and bioterrorism or agroterrorism have connected an uninformed public with the impact of animal diseases. Animal agriculturalists must now understand animal diseases in a new context characterized by the need for global awareness and action; the confluence of the worlds of animal and public health; and the need to develop skills and competencies in politics, media interactions, and community engagement.

The economic losses from animal disease result from

- deaths, decreased production, and treatment costs;
- human disease costs;
- food safety and environmental costs;
- decreased food supply with higher prices;
- adoption of less productive and more costly systems to decrease disease risk;
- constraints on national and international trade because of zoosanitary restrictions; and
- indirect losses to tourism and related businesses.

Where preventive animal disease control programs are technically and logistically feasible, analyses indicate the losses avoided usually far outweigh the costs of the preventive program, especially for the more serious infectious diseases. The World Organisation for Animal Health (OIE)[1] warns its Member Countries about several kinds of transmissible diseases: those with potential for rapid international spread, those with serious socioeconomic or public health consequences, and those important to international trade of animals and animal products.

Zoonotic diseases have become increasingly important. Recent examples include HPAI [subtype] H5 in Southeast Asia, monkeypox in the United States, SARS in Asia, Nipah in Malaysia and Bangladesh, and BSE in Europe. Well-known and preventable zoonotic diseases such as rabies, brucellosis, leishmaniasis, and echinococcosis remain important. These diseases continue to occur in certain countries and have a high morbidity with the potential for high mortality.

Infectious diseases can be introduced into a country or region by various means, mainly through legal and illegal importation of animals and animal products. Consequently, border control is considered an excellent defense against occurrence of many “transboundary” diseases of animals. Risk is proportional to volume of trade, and current volumes of global trade make border security less reliable than in the past. There is a need for increased ability to detect the clinical signs of highly contagious diseases and the ability to differentiate them from similar afflictions. Thus disease knowledge and awareness on the part of veterinarians and livestock producers are important steps in preventing the spread of foreign or emerging diseases. That knowledge should include an awareness of trading and tourist patterns. The application of a risk analysis process, therefore, has proved to be the most important tool in assessing the risk of the introduction or spread of these diseases.

Surveillance and monitoring of animal diseases and international disease control programs are divided among three organizations: the OIE, the Food and Agriculture Organization of the United Nations (FAO), and the World Health Organization (WHO). The OIE Animal Health Information System provides official information for early warning purposes and details of the worldwide situation for more than 100 animal diseases and zoonoses. The FAO provides technical assistance in dealing with transboundary animal diseases. The WHO has an “alert and response team” for human diseases, including zoonoses. In addition, there are unofficial networks such as ProMED-mail, which is an electronic outbreak reporting system that monitors emerging infectious diseases globally.

Countries have various organizational structures that work to prevent, control, and/or eliminate animal diseases and to monitor and promote animal health and productivity. Timely, efficient, and accurate collection of surveillance data is central to the ability to carry out this charge, and is the crux of appropriate application of animal disease control strategies. These data are needed to meet the OIE disease-reporting requirements. The surveillance for foreign animal diseases (FAD) requires reporting of suspicious lesions observed by private veterinary practitioners or producers. With current world conditions, however, that mechanism cannot be relied on as the only one to detect an FAD. Targeted surveillance

[1] The previous name of the World Organisation for Animal Health was the Office International des Epizooties and the acronym OIE has been retained in the title. In this paper the acronym OIE will be used to identify the organization.

addresses this need by identifying specifically the groups or subpopulations of animals with a high projected risk of acquiring or disseminating disease.

## Patterns of Animal Diseases and Their Control Programs

Occurrence, spread, and characteristics of an infectious animal disease are influenced by the properties of the infectious agent itself, by host population characteristics (e.g., genetics, animal demographics, movement patterns, interactions with wild animals, animal use), and by environmental factors.

Disease agents can cause a variety of disease patterns of differing importance. The OIE has classified those patterns that generally are considered to be the most important to the livestock industry (OIE 2004b). The characteristics are (1) high transmissibility; (2) potential for very serious and rapid spread, irrespective of national borders; (3) serious socioeconomic or public health consequences; and (4) major importance in the international trade of animals and animal products. The pattern of these diseases, with a few exceptions, is characterized by high morbidity and occasionally a high case-fatality rate (lethality). The latter is dependent on the virulence of the agent, the host (immune status, genetic background), and other factors. In addition, infectious diseases of animals are grouped into those that affect only animals and those that affect animals and humans (zoonoses). Classical zoonotic diseases such as anthrax or tuberculosis still have serious public health impact, although in industrialized countries latent zoonoses, such as infections resulting from *Escherichia coli* O157:H7, have become more important. Because animals infected with these pathogens show only mild transient disease or no clinical signs at all, new approaches to animal production are necessary to avoid human infection. In addition, the public perception of risk of diseases from animal products has increased markedly and needs to be addressed by skillful, transparent, and frank risk communication.

The general patterns of occurrence of diseases reflect the nonrandomness of their distribution in the dimensions of time and space. Sporadic disease occurrence (distribution associated in a random fashion in both space and time) can be thought of as rare, whereas an endemic disease represents a clustering of cases in space but usually not in time. In an epidemic disease, there is a clustering both in time and in space. The number of FAD outbreaks observed in many countries has increased over the past few years. Therefore, a competent cadre of animal disease specialists that can be called in to help with a notifiable disease outbreak is needed. Because diseases respect no borders, national and international collaboration will be mandatory to control an outbreak.

The clinical features of a disease can vary, usually as a result of rapid changes in virulence of the causative agent. Responders need increased knowledge of the clinical signs of highly contagious diseases and the ability to differentiate such diseases from those with similar signs and features. Thus awareness of all potential disease threats is an important step in preparedness for preventing their spread, and this awareness also should include knowledge of important recent trading and tourism patterns that could result in the spread of disease. These changes in tourism and trade patterns can have diverse effects; one possible result is the increased risk of disease transmission by waste disposal and swill feeding.

A good working partnership has existed for many years in many countries among producers, veterinarians, national government institutions/agencies, and international organizations to deal with animal health issues and decrease the spread of animal disease both domestically and globally. But despite enormous progress in scientific knowledge and improvements in sanitary standards in livestock production, several recent disease outbreaks have caused severe economic losses.

For example, FMD entered Taiwan in 1997, necessitating the destruction of 8 million pigs, costing the country more than $25 billion, and almost wiping out the entire hog industry. That same year classical swine fever (CSF), also known as hog cholera, was discovered in the Netherlands, and more than 4 million pigs were killed to stem the spread of the disease. In 2000, FMD continued to spread globally, entering the previously disease-free zones of southern Brazil, Argentina, Uruguay, South Africa, Botswana, South Korea, Japan, and Russia. The FAO termed 2000 the "year of the global pandemic of FMD," and in 2001, FMD made headlines in the media as British farmers and their farming community dealt with a serious outbreak that led to the destruction of more than 6 million livestock.

Bovine spongiform encephalopathy, with its long incubation period, began its insidious global spread even before it was recognized as a clinical entity. Meat and bone meal from infected animals moved throughout Europe as a kind of "Trojan cow," infecting herds in multiple countries. As each new country recognized the presence of this serious problem in its cattle industries, people realized that the disease already was established and had spread to other locations. Now BSE is known to be present on three continents and should be suspected to occur beyond the borders of countries that have had cases.

Two diseases of poultry, velogenic ND and HPAI, have devastated poultry industries in many new locations during the past 5 years. In 1999, Australia experienced an outbreak of ND caused by a virus that had mutated from a preexisting low pathogenic strain. The cost was billions of dollars in lost trade. In 2002, the introduction of ND into southern California through gaming chickens precipitated the largest animal disease-control program ever undertaken in the United States. Highly pathogenic avian influenza continues to move around the world, as well as arising anew from preexisting, less virulent strains. Outbreaks of HPAI in Hong Kong and China in the late 1990s were notable, particularly because of the unexpected spread of avian strains to humans. A severe outbreak in the Netherlands in 2002 resulted in the destruction of more than 28 million birds to control spread; nevertheless, the disease spilled over into neighboring Belgium and Germany. A devastating outbreak of HPAI occurred in Asia in 2004; the infection was diagnosed in at least 11 countries and more than 120 million birds were killed. Human infections were reported in Viet Nam and Thailand and there has been a high mortality rate.

The aquaculture industry also has had outbreaks of FADs. There were two devastating outbreaks of infectious hematopoietic necrosis in the British Columbia salmon farming industry in the last 12 years. In the United States, two of the four most recent U.S. Department of Agriculture (USDA) national animal emergency declarations issued were for aquatic animals: infectious salmon anemia, in 2001; and spring viremia, which affects varieties of carp and related species, in the spring of 2003 (O'Rourke 2004).

## Factors Affecting Emergence or Spread of Livestock Diseases

### Emerging Diseases

An *emerging disease* is defined as a new disease, a new presentation of a previously recognized disease, or an existing disease that shows up in a new geographic area. The term emerging disease first was used to describe several new entities in humans that surfaced in the early 1980s, the most notable example of which was Acquired Immunodeficiency Syndrome, or AIDS. Since then, the number of emerging diseases in humans has continued to increase, but this trend is even more pronounced in animals. These new animal disease problems are having significant influence on animal populations, the environment, and the health of humans, both directly—through transfer of zoonotic agents—and indirectly—through impacts on trade that decrease the availability of animal protein.

Several underlying factors inherent in modern society are responsible for the increase in emerging diseases.

1. **Expansion of the human population**. The first and foremost factor contributing to the occurrence of new diseases is the expansion of the human population and the attendant increase in traffic of people, animals, and animal products, bringing all their microflora and potential pathogens to new locations and animals. Movement of pathogen-carrying animals is a well-recognized historical problem, with clear records of the invading armies of Genghis Khan, Attila the Hun, and Napoleon spreading contagious bovine pleuropneumonia and rinderpest into conquered territories. Today, with free trade and the interconnectedness of economies, the volume of animals and animal products crossing oceans and international boundaries is logarithmically greater than in the past. Thus the concept of border security as a total prescription for disease prevention is unrealistic. There are numerous recent, discomfiting examples of animal diseases moving into new areas.

2. **Environmental changes**. The emergence of new diseases is related to environmental changes. Habitat destruction, causing animal populations to cluster in hitherto less preferred environments, has opened new possibilities for the spread of pathogens and has created many problems in recent years. The emergences of the Hendra virus affecting horses and humans and of the Menangle and Nipah viruses affecting pigs and humans presumably are related to habitat changes that have caused fruit bats to exist ever closer to humans and their domestic animals. Climatic events presaging changes in vector populations also can lead to the emergence of disease. The 1998 Rift Valley fever animal epidemic in east Africa was in part determined by the El Niño–Southern Oscillation phenomenon, which created increased precipitation and amplification of mosquito vector populations.

3. **Animal species interface**. As new species come into contact with one another for a variety of reasons (such as tourism and human migration, ecological disruption, shows, trade, introduction of new genetic

material, and keeping wild species in captivity), potential pathogens from one species may move into another, with subsequent disease and dissemination in the new host population. The opportunities for this transfer to take place continue to increase as species are moved around and confined to ever-dwindling available natural spaces. Canine distemper in lions on the Serengeti Plain in Africa is a prominent example in which a normally canine-only virus migrated from domesticated dog populations into large cats to cause disease (Griot et al. 2003). Influenza viruses moving from wild bird populations or perhaps from mammalian reservoirs into poultry are a constant threat with respect to disease emergence. Wildlife species play an increasingly important role in transmission of disease to livestock: examples include tuberculosis spread from deer to cattle and rabies spread into new locations by raccoons. The coronavirus of SARS presumably moved into the human population from an animal reservoir; the species remains to be determined but the civet cat is suspected. A recent review cataloged almost 1,000 pathogens of selected domestic animals (Cleaveland, Laurenson, and Taylor 2001). Of those, 77 to 90% were shown to be multihost pathogens—that is, capable of infecting more than one species. Given these figures, it is certain that diseases will continue to emerge as habitat and husbandry changes push animal species into closer contact with humans. More agents undoubtedly will migrate across new species lines, some establishing novel diseases to describe, diagnose, and control.

4. **Husbandry and technological changes**. A fourth underlying factor in disease emergence involves husbandry and technological changes in animal populations. Bovine spongiform encephalopathy is a striking, painful example of how seemingly simple changes in agricultural technology can have far-reaching impacts on animal agriculture, human health, and economies. The emergence of antibiotic-resistant strains of bacteria is being attributed, factually or not, to feeding animals growth-promoting antibiotics. The practice of aquaculture and the stocking of streams for anglers also are not exempt from disease emergence. As discussed previously, two of the four most recent USDA national animal health emergencies have been for aquatic animal diseases. Whirling disease, caused by *Myxobolus cerebralis*, has become a major threat to the survival of wild rainbow trout in many streams in the western United States, transmitted from one location to another through movement of infected hatchery fish.

## Intensive Agriculture

All these factors that drive disease emergence need to be considered against the backdrop of fundamental and global changes in agriculture. The production of food has undergone dramatic modifications over the past few decades. Historically, livestock production systems around the world have been family centered, sustainable, low input, and of relatively low efficiency. The trend now is clearly in the direction of *intensive agriculture*, loosely defined as the production of large numbers of a single species, often under confinement conditions.

These intensive systems provide significant efficiency in terms of economy of scale, monitoring animal health status, consistency, and value to consumers. Intensive systems began in the United States more than 60 years ago with the poultry industry and now have become the norm for the swine industry as well. It is more difficult to convert the cattle industries to more-intensive systems, largely because cattle are ruminants and benefit from grazing, but beef feedlots and large dairies also are examples of large-scale production for this species (Sherman 2001).

Much of the animal agriculture in the developed world is almost entirely of this intensive type, so that throughout the developed world today there are fewer farms managing larger numbers of animals. Global populations include approximately 1.2 billion cattle, 800 million pigs, and 10 billion chickens. Three-quarters of the cattle and pigs are in the developing world, usually in traditional systems. Intensive chicken production methods are used extensively, even in the developing world, so that fully one-half of all the world's chickens are reared using these methods (Mason and Crawford 1993).

The number of people in the world is projected to be 7.7 billion by 2020, with the largest increase occurring in the developing world. During the past 25 years, the quantity of meat consumed in developing countries grew three times as much as it did in developed countries. If current trends continue as predicted, diets will continue to include more meat- and dairy-based products. It is estimated that global livestock production will have to double by 2020 to supply needs. This demand-driven increase in animal agriculture has been termed the "Livestock Revolution" (CAST 1999; Delgado et al. 1999). It is anticipated that much of the increase in animal production will come from expanding intensive systems of agriculture located in the developing world (CAST 1999;

Delgado et al. 1999). Traditional systems are being replaced by intensive agriculture at the rate of 4.3% of animal holding units per year, with much of that increase in Asia, South America, and North Africa (CAST 1999; Delgado et al. 1999).

In intensive agriculture, larger quantities of raw materials and products flow within a country and between countries. A major impact of modern intensive production systems is that they allow the rapid selection and amplification of pathogens that arise from a virulent ancestor (frequently by subtle mutation), thus there is increasing risk for disease entrance and/or dissemination. The cost of increased efficiency with these systems is the necessity for heightened biosecurity and improved surveillance. Stated simply, because of the Livestock Revolution, global risks of disease are increasing.

The OIE was established in 1924 in response to postconflict dissemination of rinderpest throughout Europe. At the time it was thought that with good disease reporting, neighboring countries could remain free from animal diseases, provided that border security was well maintained. And for many decades this approach, particularly the use of quarantine stations for border control, was an effective defense against the occurrence of transboundary diseases of animals. But current volumes of global trade make the concept of intact border security less reliable. The number of animals and animal products crossing international borders is extremely large, and the establishment of more free trade throughout much of the world ensures that the possibility for halting the entrance of a disease at the borders will become increasingly problematic.

## IMPACT OF ANIMAL DISEASES ON HUMAN HEALTH

Approximately 75% of emerging reported pathogens affecting humans worldwide over the past 10 years have been caused by agents originating from an animal or from products of animal origin (Taylor, Latham, and Woolhouse 2001). A wide variety of animal species, both domesticated and wild, acts as reservoirs for these pathogens. In addition, many well-known and preventable serious animal diseases—including rabies, brucellosis, leishmaniasis, and echinococcosis—can be transmitted to humans. These diseases continue to occur in many countries, especially in the developing world where they affect mostly the poorest segment of the human population. Outbreaks of zoonotic disease involving a very large number of people are rare, as is well documented in the United States (USDHHS 1994). These outbreaks are usually associated with contamination of drinking water and/or large-scale production and distribution of contaminated processed food of animal origin.

Recent zoonotic outbreaks have been devastating to the animal industries but have resulted in relatively few human cases. Examples include the 1997–98 Hong Kong outbreak of avian influenza virus H5N1 with fewer than 20 human cases, including six deaths (WHO 1998); the 2003–04 Asian H5N1 HPAI outbreak with 34 human cases and 23 deaths; the 1998–99 outbreak of Nipah virus infection responsible for the "barking pig syndrome" in Malaysia with 154 human cases, including 55 deaths (WHO 2001); and the February 2004 Nipah outbreak in Bangladesh. The Nipah virus in Malaysia in 1998 had a case-fatality rate in humans of 36%; it reappeared in Bangladesh in 2004 with 53 cases and 35 deaths, a case-fatality rate of 66%. Even though there were relatively few human cases, these zoonotic diseases were publicized widely and generated anxiety in the human population. This anxiety contributed to the decision to conduct large-scale eradication programs that have resulted in the deaths of thousands of animals. It also resulted in severe disruption of market and trade restrictions that has cost the animal industry millions of dollars.

Forecasting with some precision the human death toll from an emerging zoonotic disease often is difficult because reliable observational or experimental data usually are missing. For example, at the end of 2003, the number of definite and probable cases of new variant Creutzfeldt-Jakob disease (vCJD) caused by the BSE agent was fewer than 150 in the United Kingdom. During the late 1990s, various vCJD predictive models were developed that led to a wide range of estimates on the impact of the disease in the United Kingdom, ranging from a few hundred cases to tens of thousands (WHO 2003). It seems that the epidemic is receding, and specialists are becoming more optimistic regarding the future evolution of vCJD.

In many instances, the direct impact on health of these new emerging or reemerging zoonoses has been relatively small compared with the impact of many other more common fatal human diseases; death due to major infections and parasitic diseases was estimated at approximately 15 million in 2002 (WHO 2002). Nonetheless, the classical zoonotic diseases continue to have a serious impact. These diseases include rabies (the leading cause of reported death in the zoonoses group, accounting for approximately 55,000 deaths per year in Asia and Africa) and Japanese encephalitis (estimated to cause approximately 15,000 deaths per year) (WHO 2002). Because of the emphasis and attention these zoonotic diseases have received from health professionals and politicians, the public's perception of the significance of the health impact often is not commensurate with the actual numbers of cases and deaths. One factor contributing to such high public anxiety is the fact that etiological agents and modes of transmission are not understood (e.g., for vCJD or Nipah).

A recent zoonotic disease that received major attention in the U.S. is monkeypox. The disease is a zoonotic viral agent, outbreaks of which occur regularly on the African continent. In 2003, this poxvirus was imported into the United States, where 71 human cases were reported after contacts with sick pet prairie dogs infected by imported African (Gambian) wild rats (CDC 2003). This outbreak underscores the need for comprehensive, standardized guidelines to regulate trade of wildlife species and to prevent the spread of wildlife animal disease internationally.

## National and International Economic Impacts of Animal Diseases

Many economic impacts are difficult to quantify, and valuation also may be problematic. Such factors as animal welfare, human health, and the environment are of obvious importance but do not have market values, and different people have different perceptions of their value. It is therefore impossible to provide objective assessments of the total cost of most animal diseases, especially the most serious ones that have wide-ranging effects.

But the cost of animal disease can be enormous. The 2001 FMD disease outbreak in the United Kingdom was estimated to have cost more than $12 billion; this figure was intended to cover all costs, including approximately $4.5 billion that resulted from the loss of tourism (Anderson 2002). Many underlying assumptions used to develop this estimate are debatable, and it would be possible to argue that the estimated cost should be much higher or much lower. This figure of monetary loss addresses neither the suffering of many livestock owners who had to watch the destruction of their animals nor the environmental cost of burning or burying millions of carcasses. Although nonmonetary, these issues were of great public importance and would have a strong bearing on decision making in future outbreaks. In developing a risk analysis, the cost of any future outbreak would depend on the scale of the outbreak, and this cannot be predicted.

The indirect costs of animal disease are borne by people other than the owner of the animal, and therefore are less likely to influence disease control decisions of animal owners. The impacts of both animal disease (such as pesticide and drug residues in animal products) and human cases of zoonotic diseases tend to affect the national, or even the international, community. This explains why governments and international organizations are involved in decision making on the control of many animal diseases.

Epidemic diseases, such as FMD, also have economic impact on countries free from the disease. The existence of diseases in other countries results in the imposition of requirements for preventive measures at the borders, development of contingency plans, and stockpiling of resources such as vaccine stocks. At the international level, these preventive measures and the restrictions on trade account for much of the economic impact of some diseases.

It can be difficult to secure funding to maintain the vigilance necessary to combat diseases that do not exist in a country. In certain instances, importing countries have imposed additional costly, unwarranted requirements on countries without evidence of specific diseases, requirements more stringent than the OIE Standards. Countries without evidence of specific diseases also have imposed additional unjustified "disease control" restrictions on exporting countries. These restrictions can serve as costly nontariff barriers to trade.

Economic assessment of the overall cost of individual diseases is difficult. National disease control programs often are designed to combat several diseases, and it is difficult to apportion the costs among them. It may not be feasible to eradicate a disease, so the total economic loss caused by the disease may have to be an ongoing burden. In certain instances, it is more useful to evaluate the costs of a program to decrease the impact of one or more diseases. Then the incremental costs of control can be compared with the projected decrease in disease losses to determine whether the investment in control is justified.

It has been estimated that an FMD outbreak in the United States, similar to the U.K. outbreak, would decrease U.S. farm income by $14 billion, or approximately 9.5% of the total (Paarlberg, Lee, and Seitzinger 2002). Of this amount, 58% would fall on the swine industry and 37% on the beef industry. It was noted that this loss assumed a 10% decrease in consumption of red meat and dairy products. With a 20% decrease in consumption, the loss in farm income would rise to $20.8 billion. Further, the modeled outbreak would decrease exports of susceptible U.S. products by $6.6 billion. As examples of losses to associated industries, government support payments directed primarily at the grain industry would increase by $1.8 billion (an increase of 8%), and revenue earned by animal slaughter and processing industries would decrease by 15.9%.

The potential impact of an FMD outbreak in California has been reported (Ekboir 1999). The estimate of total losses in this study ranged from $8.5 to $13.5 billion. Direct production losses and allied industry losses ranged from $1.5 to $4.1 billion, and approximately $6 billion of the total impact was attributed to the loss of export markets for U.S. livestock products.

The results of such partial analysis usually show that where an animal disease control program is technically and logistically feasible, the losses avoided would far outweigh the costs of the program, especially for the more serious infectious diseases. Thus, although it is not possible or meaningful to try to obtain an estimate of the global cost of FMD, numerous analyses (James and Rushton 2002) have shown that investment in controlling this disease would produce positive returns in many countries. In a sense, these potential benefits of control represent the true economic impact of the disease, in that they are losses that could be avoided. Priorities in disease control should be assigned not on the direct impact of the disease, but on the economic return that would result from additional investment in control programs. This would be comparable to the cost of an insurance policy, which in this instance would be to prevent disease.

The most critical issue in evaluating the avoidable losses caused by animal diseases is the technical and operational feasibility of implementing control. A recent review of the economics of FMD (James and Rushton 2002) found that all studies reviewed concluded that some degree of control would produce positive economic returns. Where eradication was feasible, this policy generally produced the highest economic returns because it saved the long-term costs of vaccination. Where eradication was not considered feasible, however, long-term vaccination strategies still produced positive economic returns.

## Impact of Foreign Animal Diseases at the Industry Level

The industry-level impacts of an FAD outbreak depend, by definition, on the bounds placed on the term "industry." Specific diseases will have different industry-level impacts because they affect different species or groups of species. Foot-and-mouth disease, for instance, potentially would impact the "cloven-footed livestock industry," which includes such animals as cattle, pigs, sheep, goats, and domesticated elk, deer, and buffalo. Similarly, exotic ND would affect the "poultry industry," which can include broilers, turkeys, layers, ducks, and other avian species. Conversely, BSE would affect the "beef and dairy industry" directly, and CSF or African swine fever would affect the "swine industry." Therefore, industry-level impacts of animal diseases must be evaluated in the context of all species susceptible to the disease in question. It also should be noted, however, that a change in cost and availability of one animal protein source or a loss of consumer confidence in that product has the potential to impact other animal protein industries not affected by the disease.

The industry-level effect of any FAD is the sum of its effects on the separate economic units that comprise the industry's input supply, production, processing, and marketing system. Industry-level effects would not include government costs or costs associated with disrupted travel or tourism or general economic activity. For clarity, potential industry-level impacts will be divided into two categories: direct and indirect impacts.

### Direct Impacts

All firms in an FAD-affected industry would incur some measure of direct costs comprising increased expenses and decreased income or asset values. All these losses will depend on the scope of the disease outbreak, which itself depends on the specific disease, the number of affected species, the number of locations involved in the outbreak, how quickly the disease is detected, whether the disease poses a direct human health risk, and many other factors such as the preparedness of public and private agencies to fight the outbreak and the success they realize, especially in the hours and days immediately after diagnosis. Direct losses could include

- productivity losses and inefficiencies (mortality, decreased growth, lower milk yield, infertility, etc.);
- decease in market prices;
- fair market value of animals either destroyed for disease control or depopulated for animal welfare reasons;
- carcass disposal costs;
- vaccination costs;
- facility cleanup and disinfection costs; and
- profits lost because of the interruption of normal business operations for producers, suppliers, and processors, including those from movement controls.

Depending on specific governmental policies, certain costs may be borne by the public sector in the form of indemnification payments or cost reimbursements. Insurance or other risk management tools may be in place to address the difference in value of animals and the actual indemnification payments or to address business interruption losses. It is important to note that in addition to producers whose herds actually are exposed and/or infected with the disease and therefore potentially eligible for some type of compensation, there are producers who may be impacted negatively economically because of movement restrictions that disrupt the normal flow of animals. Most of these costs or profit losses would fall on the producers.

### Indirect Impacts

In addition to facing direct impacts, the entire affected industry would encounter substantial indirect costs that are manifested much more subtly. These costs do not require a cash outlay and may not show up as an immediate decrease in producer sales. It should be noted that indirect costs are, in general, more long-term in nature than direct costs. Indirect costs would include

- loss of exports sales and foreign demand. These losses would result in lower prices for products and animals in the short and intermediate term and a smaller industry in the long run.
- loss of domestic sales and domestic demand. This impact would depend completely on the reaction of domestic consumers to the disease in question. Diseases such as BSE have had a significant impact on beef consumption in some countries even though the risk of causing disease in humans is very low. Informed consumers with confidence in their government's food safety system may not pose a risk for decreased demand; an example would be the 2003 BSE case in Canada and the 2004 case in the United States. For diseases that are not a threat to human health, publicity surrounding the destruction of thousands or millions of animals still could affect consumer demand for products.
- loss of competitive position in domestic and/or export market(s). The position of a country in foreign markets is the result of technology, the structure of the production and processing sectors, product development, and long years of cultivation. The exclusion of a country's products from a market would impact the current industry structure severely and open opportunities for other countries to move into the market; these suppliers would be difficult to displace after an outbreak of disease has been controlled and/or eliminated.
- costs to rebuild production capabilities. Decades of investment in production technology, such as improved genetics, could be lost in an animal disease outbreak. The more-consolidated industries, such as poultry and swine, face greater risk of the loss of genetic material because of the use of fewer genetic lines and having animals in larger, more closely concentrated production sites. If the genetic nucleus is affected by an outbreak, the loss may take many years to replace.
- decreased demand for processing/marketing services and production inputs. Any decrease at the production levels would impact input suppliers (e.g., decreased demand for feed, pharmaceuticals, veterinary services, and equipment), packers, processors, and retail and foodservice establishments.

The losses from the 1997–98 CSF outbreak in the Netherlands were estimated to be $2.3 billion (Meuwissen et al. 1999). Of these losses, 37% consisted of compensation paid for pigs that were destroyed for welfare reasons resulting from movement restrictions, and 25% were in allied industries.

The 2001 FMD outbreak in the United Kingdom cost agriculture and the food chain £3.1 billion (roughly $5.9 billion) (Thompson et al. 2002). This figure includes both direct and indirect costs to the industry but not the other costs to society discussed earlier. Although many of these costs were compensated by the British government, agricultural producers still suffered £355 million ($675 million) or approximately 20% of the United Kingdom's estimated total income from farming in 2001. Additionally, the food industry suffered losses of £170 million ($323 million).

## Social and Political Impacts of Animal Diseases

As nations have moved into the twenty-first century, society has become progressively more complex and interdependent. This complexity is vividly apparent in U.S. agriculture. The driving forces of technology, globalization, restructuring of agricultural systems, consumerism, and a group of contemporary socioeconomic issues are creating a new dynamic between agriculture and the general public—a dynamic characterized by changing social and political conditions. Within this dynamic, the impact of animal diseases provides an insight to understand these conditions better.

A feature of globalization for animal agriculture has been the emergence of an international standard-setting system to serve as the framework for global trade. Many assumptions that underlie international standards are based on fair and safe trade practices and the prevention of animal and human diseases, with special consideration placed on disease introduction.

### A Shift Toward Interdependence

This new reality has created tension based on a fundamental shift from independence to interdependence—economically, scientifically, socially, and politically. Thomas Friedman, a foreign affairs columnist, believes that the big question of the new global era is whether it is possible to combine the freedom and opportunities that are available with the necessity for a new and dynamic interdependence (Friedman 1999). The contemporary issues of trade and dealing with animal diseases are dependent largely on successfully mastering this duality.

The continual unfolding of the BSE story is an excellent example of an animal disease threat caught up in the difficult issues of sovereign rights and freedom versus global standards and interdependence. The creation of the European Union and its dominance over the sovereign rights of individual Member Countries is a study in global tension in which BSE became the battleground and the source of an ever-changing political landscape. The BSE story also points out that de facto alliances can form and disappear rapidly over specific issues and often amplify reactions to events (Naisbitt 1994). As stated earlier, this reaction can lead to unwarranted restrictions on trade that act as nontariff trade barriers.

Animal health and disease issues cannot be viewed in isolation. The animal agriculture industry needs to be better connected to the world around it and acquire a new cultural competence and political acumen to continue to be successful. Animal diseases and the activities associated with them are embedded firmly in the explicit values of society and politics. Scientific knowledge, political values, and cultural values all are imperfectly known and imperfectly separable, which can create an "uncertainty gap." This gap represents a realm outside the limits of what is known where values, politics, and opinions form societal perspectives and influence public policy as well as those who format the policy. Consider the response to FMD and BSE in the United Kingdom and to BSE across Europe, or the recent struggle to counter the SARS epidemic worldwide. These disease problems illustrate the changing dynamic among politics, public policy, and science. Although some people may wish to avoid the world of politics, it needs to be appreciated and mastered by animal agriculturalists because it often reflects public opinion and human behavior.

### Political Impacts

Disease outbreaks quickly can become political stories rather than scientific events. A major medical or disease situation often becomes a political issue after the initial discovery of an outbreak, and the social, political, and economic impacts outgrow their technical and scientific base (Garrett 2000). The focus often shifts to the pronouncements, actions, and policies of animal health officials and politicians who oversee programs and resources. Under these circumstances, the media also play an increasingly important role. Public opinion and attitudes in the United States can change depending on the media and public communications. One should not underestimate the need to excel in risk communications and to put a "human face" on animal disease crises.

In much of modern society, most people are estranged from agricultural production and have little contact with food animals. Yet, ironically, societal dependency on these animals and vulnerability to them has increased progressively. Emerging diseases, new zoonoses, foodborne pathogens, and the fear of bioterrorism have connected a naïve public directly to the impact of animal diseases. The confluence of animal health with public health has created a new set of challenges for both, and the political and social impacts become important considerations.

The combination of monkeypox, SARS, and West Nile virus appearing at the same time in the United States from other parts of the world was an unprecedented event and one that illustrates the tendency for a problem in one part of the world to emerge as a problem in another. The result is that exotic animal diseases from far away are, in essence, right next door and can arrive almost immediately. The ramifications of such events extend far beyond animal agriculture.

A serious animal disease epidemic could have other wide-ranging negative impacts: losses to wildlife populations if multiple-host disease agents, such as FMD or HPAI, were introduced; concerns about sustaining biodiversity and potential threats to the environment and ecosystems; possible public health effects associated with zoonotic agents such as West Nile or Rift Valley Fever viruses; and potential detrimental impacts to the social and economic health of rural communities.

### Social Impacts

Animal diseases have definite economic consequences for agriculture, but less appreciated and understood are the human dimensions and impacts. Whereas preparedness and responsive activities focus naturally on agents of disease and hosts, there often are no preparedness activities addressing stress and mental health issues in a manner consistent with the seriousness of this risk.

Recent epidemics of FMD and BSE in the United Kingdom have illustrated the critical social issues of an animal disease epidemic. Livestock owners suffered bereavement over losing their animals, sometimes entire herds or flocks. There were animal welfare concerns, a sense of loss of control over lives, isolationism and worries about an uncertain financial future, a distrust of government and science, and feelings of helplessness. There can be a stigmatization of people connected with diseases, resulting in residual personal hardships. There arose new appreciation and awareness of the complexities and interconnectiveness of people's lives as they tried to cope with life-altering experiences associated with these animal diseases. The environmental implications of carcass disposal, effects on biodiversity, contamination of groundwater, and changes to the landscape were additional concerns. Animal health officials and other personnel at the frontline also suffered stress because of working long hours, culling large numbers of animals, and dealing with distraught owners and families (U.K. Department of Health 2002). Long after the immediate impacts of diseases subside, an epidemic may leave lingering social and economic scars in affected communities. These scars have led to the evaluation of control methods that do not require the destruction of large numbers of animals.

The ability of animal agriculture to counter contemporary threats of animal diseases is more complex and challenging now than in the past, creating an even greater vulnerability for animal agriculture. Animal agriculturalists now must understand animal diseases in a new context characterized by

- a shift from independence to interdependence;
- the need for global awareness and actions;
- the confluence of the worlds of animal and public health;
- the demand for greater public participation in decision making;
- the formation of new strategic partners and alliances;
- interrelated impacts on the environment and ecosystems;
- a need for a new sensitivity to respond to animal diseases and especially to the people involved and impacted in their control; and
- the mandate to develop skills and competencies in politics, media interactions, and community engagement.

## National Monitoring, Surveillance, and Response

The responsibility of the veterinary services of a country is to protect and improve the health, welfare, quality, and marketability of livestock, animal products, and veterinary biologics. This work is done by preventing, controlling, and/or eliminating animal diseases, and by monitoring and promoting animal health and productivity. Central to the ability to carry out this charge, and the crux of appropriate application of animal disease control strategies, are surveillance programs.

### Definitions

Although definitions of *surveillance* vary, the Centers for Disease Control and Prevention's current formal definition related to public health surveillance states: "Public health surveillance is the ongoing systematic collection, analysis, and interpretation of health data essential to the planning, implementation, and evaluation of public health practice, closely integrated with the timely dissemination of these data to those who need to know. The final link in the surveillance chain is the application of these data to prevention and control. A surveillance system includes a functional capacity for data collection, analysis, and dissemination linked to public health programs" (Meriwether 1996).

Animal disease surveillance is similar in that it is an active system, where directed action will be taken if the data indicate that disease prevalence or incidence exceeds a predetermined threshold (Salman 2003). In contrast, disease monitoring describes ongoing efforts at assessing the health status of specific animal populations. The line between disease monitoring and disease surveillance is not very sharp. Both activities commonly are used in combination with intervention strategies in government-administered disease control programs.

### Surveillance Activity Categories

Surveillance activities can be divided into two major categories: scanning and targeted. Scanning surveillance accesses available livestock or poultry populations, and thus available biological samples (e.g., blood and other tissues), to estimate the extent of disease in that population, or as a case-finding mechanism. The collection of serum samples at cattle slaughter establishments for bovine brucellosis testing is an example. Targeted surveillance specifically identifies groups or subpopulations of animals with a high projected risk of acquiring or disseminating disease; these populations then are sampled at a higher rate than populations considered at lower risk of disease. The sampling of pigs from noncommercial or backyard operations identified to be at higher risk of CSF (hog cholera) infection is an example. The balance between scanning and targeted surveillance depends on the prevalence of the disease, the risk of infection, and the availability of resources.

### History of Surveillance Efforts

In developing surveillance mechanisms, it is first imperative to establish the goal of the system. In the United States, for example, the USDA's Animal and Plant Health Inspection Service–Veterinary Services historically has conducted animal health surveillance through a number of systems, mostly focused on disease eradication programs and passive reporting of FADs. Although both of these systems have met their established goals effectively and have served well to advance disease eradication programs, they do not provide for the comprehensive, coordinated, and integrated animal health surveillance system needed today.

Historically, FAD surveillance in the United States—as in most countries that have always been FAD-free or have been free for some time—has been dependent primarily on the reporting of suspicious lesions observed in livestock and poultry by private veterinary practitioners or by individual producers. This "passive" system relies on the knowledge, understanding, and goodwill of those outside of the government's direct influence. With current world conditions, there is a need to enhance this mechanism to detect FAD incursions, because potential cases may not be reported early enough to ensure that appropriate control strategies can be implemented in a timely manner. Efforts have been made for producers and veterinarians to have an increased knowledge of the clinical signs of highly contagious diseases and the ability to differentiate such diseases from those with similar signs and features. There is a need to expand these efforts to increase the capability of these first responders to detect and report FADs.

Eradication efforts in the United States, as in many countries, have been focused on pseudorabies, brucellosis, and tuberculosis and have nearly eliminated these diseases from the nation's livestock. Surveillance has played a key role in the success of these eradication programs, and it focused on testing samples collected from primary animal concentration points such as livestock markets and slaughter establishments. Animals testing positive were traced to farms of origin, with subsequent herd testing and depopulation where indicated. Targeted surveillance through circle or area testing of livestock operations in locations where disease had been detected, with subsequent depopulation of infected herds, dramatically decreased disease prevalence. With the current low prevalence of these diseases in most states, surveillance testing now is done almost exclusively on samples collected at slaughter establishments. To complete these eradication programs successfully, it is imperative that surveillance be ongoing and efficient so that the last few cases will be detected before the disease spread occurs.

### Enhancement of Animal Health Surveillance

The increased international movements of animals and people, the increased threat of intentional introductions, and the continued recognition of new diseases or manifestations have increased the risk of introduction of diseases to livestock and poultry. In addition, the near completion of government-mandated eradication programs requires a transition from a focus on eradication efforts to one of effective surveillance, to ensure that any remaining cases of the targeted disease will be detected. To address these challenges, approaches to animal disease surveillance must be modified. As an example, in the United States the transition from the historical model for surveillance to a new National Animal Health Surveillance System (NAHSS) is under way. The system will be a comprehensive, integrated, flexible, efficient network that will collect, manage, analyze, and distribute national animal health information. It is anticipated that this system will enhance the collaboration of agencies and professional groups toward the goal of national monitoring and effective intervention to control animal diseases. Responses to the NAHSS findings may include the triggering of eradication efforts in the event of an FAD incursion or alterations to existing eradication or control strategies for endemic livestock diseases. In addition, the use of surveillance data for risk assessment or to affirm the health of the nation's livestock is paramount to facilitating trade in animals and animal products.

Rapidly evolving technological advances in disease diagnostics, animal identification, and database management will improve the animal disease surveillance system's ability to supply information to decision makers. Molecular techniques that can detect multiple nucleic acid targets in a single polymerase chain reaction assay not only decrease the time to diagnosis but also permit testing for different diseases simultaneously. The key to accurate surveillance is an animal identification system that accurately links an animal to its farm of origin, to animal concentration points it may have transited (e.g., livestock markets), and to slaughter establishments. Barcoding, radio frequency identification, and geospatial information systems currently are used effectively in many countries. The United States is developing and implementing a national animal identification system with a goal of being able to identify all animals and premises exposed to a disease of concern within 48 hours.

## International Monitoring, Surveillance, and Response

Three international organizations have responsibility for the worldwide monitoring and surveillance of animal diseases and the emergency responses to them. These organizations are the OIE, the FAO, and the WHO.

### World Organisation for Animal Health (OIE)

One of the objectives of the OIE, an intergovernmental organization created in 1924, is to improve accurate knowledge of the world animal health situation. From its headquarters in Paris, the organization manages an international animal disease-reporting system for the main animal diseases, including zoonoses. This system is based on official animal disease information that veterinary authorities of OIE Member Countries have an obligation to report to the OIE. The strength of the OIE Animal Disease Information System is its "legal" basis, as defined in Chapter 1.1.2 of the OIE *Terrestrial Animal Health Code* (OIE 2004b). The OIE Animal Health Information System has the following two components:

1. The International Early Warning System, which has an alerting process to warn of exceptional epidemiological disease occurrences (natural or intentional) in Member Countries. Information is aimed at decision makers and other stakeholders to enable them to take necessary preventive measures. Under this system, the following should be reported immediately to the OIE Headquarters in Paris:

   - the first occurrence of a disease in a country or zone of the country considered to be free from a particular disease;
   - the reoccurrence of a disease in a country or zone that had previously been declared free;
   - any evidence of changes in the epidemiology of a disease (including host range, pathogenicity, and strain of the causative agent), in particular if a disease may have a zoonotic impact;
   - emerging diseases with significant morbidity/mortality or zoonotic potential; and
   - a sudden and unexpected increase in morbidity or mortality caused by an existing disease.

   The OIE then circulates the information through a variety of channels. Follow-up reports are provided weekly so that users can track the epidemiology situation as it develops. To improve transparency, the OIE has set up a verification procedure for nonofficial information from various sources on the existence of disease outbreaks that have not yet been reported officially to the OIE.

2. The International Monitoring System, which includes monthly and annual animal health data from around the world. Monthly incidences are collected for the OIE reportable diseases because of their potential for very rapid spread, whereas annual information is collected for more than 100 less-serious animal diseases, including selected zoonoses (OIE 2004a).

Although every effort is made to improve the OIE Animal Information System, the major difficulty encountered is the quality of information, especially from countries where the resources available for veterinary services are inadequate (such as a lack of trained veterinarians/epidemiologists, insufficient equipment and laboratory facilities, poor involvement of stakeholders in national surveillance systems, or the absence of disease control programs). In such countries , potentially dangerous situations might go unnoticed or not be dealt with quickly, thereby increasing the risk of the disease spreading to other countries.

The OIE has a limited source of emergency funds for use in rapidly assisting Member Countries faced with exceptional epidemiological situations. Typically, these funds are used to send experts from OIE Reference Laboratories or Collaborating Centers immediately to assess the epidemiological situation in the field and prepare for the actions of national authorities and other international organizations.

### Food and Agricultural Organization

The FAO of the United Nations, through its Emergency Prevention System–Livestock (EMPRES–Livestock) program, promotes the containment and control of the most serious epidemic diseases of livestock (transboundary animal diseases) and their progressive elimination on a regional and ultimately global basis through international cooperation. The cooperative efforts include early warning, early reaction, enabling research, and coordination. The EMPRES–Livestock program focuses on rinderpest but also includes other important transboundary diseases such as contagious bovine pleuropneumonia, FMD, peste des petit ruminants, Rift Valley fever, ND, lumpy skin disease, and African swine fever. Early warning messages are posted on the Internet and distributed via the EMPRES–Livestock mailing list. The program also provides assistance in training national epidemiologists and advises on the setting up of surveillance programs in the least-developed countries. In the event of a disease emergency, the EMPRES also can intervene at the request of an FAO Member Country to assist in combating diseases by means of FAO Technical Cooperation Programs.

Although efforts are made to build capacities in certain least-advanced countries, what has been achieved so far is well below the real needs of many countries for assistance in strengthening their national surveillance and monitoring systems and improving their contingency plans to an acceptable level. Furthermore, the available resources to tackle emergency situations and avoid the spread of transboundary diseases to other countries are far from sufficient.

### World Health Organization

The WHO global alert and response team systematically gathers official reports and rumors of suspected outbreaks from a wide range of formal and informal sources. With the advent of modern communication technologies, many initial outbreak reports now originate in the electronic media and electronic discussion groups. The Global Public Health Intelligence Network, developed for WHO in partnership with Health Canada, is a semi-automated electronic system that continually searches key websites to identify early warning information about epidemic threats and rumors of unusual disease events. When the WHO is requested to respond to a major disease outbreak, its Global Outbreak Alert and Response Network (GOARN) often is mobilized. As a technical collaboration of existing institutions and networks, GOARN pools human and technical resources for the rapid identification, confirmation, and response to human disease outbreaks, including zoonoses, of international importance. The network provides an operational framework to link this expertise and skill to keep the international community constantly alert to the threat of outbreaks and ready to respond.

The International Health Regulations currently require WHO Member Countries to report to WHO the occurrence of three infectious diseases of humans: cholera, plague, and yellow fever. The WHO has proposed a revision of the International Health Regulations to include reporting of the emergence of new diseases and other microbiological threats of possible international consequence.

## Conclusion

Animal diseases impact food supplies, trade and commerce, and human health in every part of the world. Exotic disease outbreaks in livestock have recently had catastrophic economic effects in some countries. The impacts of animal diseases often are understated; in addition to causing economic and health effects these diseases also may

- threaten food security;
- shake confidence in the food supply;
- cause changes in the social structure;
- influence long-term consumer eating habits;
- lower tax revenues, particularly in local, rural communities; and
- affect tourism.

In many instances, the risk of these impacts can be expected to grow as the balance between disease control and the factors favoring the development and expansion of disease are tipped toward the latter. In addition, new diseases have emerged and some that previously were controlled have reappeared—sometimes in unexpected locations. The use of a risk analysis process is becoming an essential element both in assessing the risk of the introduction of the diseases and in determining their impacts. The risk analysis, however, requires collection of reliable data and evaluation of the surveillance system. There is need to provide effective risk communication to give accurate information on disease risk and to minimize unwarranted anxiety concerning animal disease crises.

To address the increased risk of infectious animal disease, the following groups must work together:

- international organizations,
- elected officials,
- animal health officials,
- practicing veterinarians, and
- producers.

Taking as their goal to promote animal health and productivity, these groups must develop and implement programs for the identification, prevention, control, and/or elimination of animal diseases. These programs should include the timely, efficient, and accurate collection of surveillance data that form the basis of the OIE Animal Health Information System and provide early warning of disease risks.

Countries and regions should be prepared for introduction or incursion of diseases that are considered exotic. Such preparation should include intensive monitoring, assessment of options to prevent introduction, contingency plans for control, and response to emerging diseases.

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