DISEASE RISKS ASSOCIATED WITH INCREASING FERAL SWINE NUMBERS AND DISTRIBUTION IN THE UNITED STATES

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Midwest Association of Fish and Wildlife Agencies

Wildlife and Fish Health Committee

July 11, 2006

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INTRODUCTION

Feral hogs or “wild boars” come from several sources and include released or escaped domestic swine and the truly wild European boar. When free-roaming in North America, all are included in the term “feral swine,” as are hybrids of the two types. Although morphologically distinct, both the feral swine and European wild swine are recognized as *Sus scrofa*. The physical damage caused by feral swine has been well documented and includes damage to vehicles, vineyards, tree plantings, archaeological sites, agricultural crops, turf, soils, rare plant communities, and wildlife habitat (Seward et al. 2004). In addition they compete with livestock and native wildlife for food resources; prey on domestic animals and wildlife; and carry diseases that affect pets, livestock, wildlife and people (Seward et al. 2004). Texas, the state with the largest feral hog population, reports the annual damage to agriculture at $51.8 million (Adams et al. 2005). The total damage caused by feral swine in the United States is estimated to be approximately $800 million annually (Pimentel et al. 2000). This estimate is approximate, and probably conservative, because environmental damage costs attributable to feral swine are not easily quantified nor are the costs of potential disease outbreaks.

The Midwest Association of Fish and Wildlife Agencies, Wildlife and Fish Health Committee, is greatly concerned about the expanding populations and range of feral swine in member states and elsewhere. This review of the potential disease impacts was undertaken to inform administrators and biologists of the threats this exotic mammal poses to companion animal, livestock, native wildlife, and human health. Feral swine could also play a role in the spread and amplification of several foreign animal diseases, which could severely limit opportunities for hunting, fishing, and other outdoor recreation; reduce agency income; require substantial public funds for eradication and thereby severely reduce resources available for traditional wildlife management.

FERAL SWINE POPULATIONS AND DISTRIBUTION

Feral hogs in North America are believed to have originated from domestic hogs introduced by early settlers from Europe. Christopher Columbus probably made the first introductions in 1493 in the West Indies and Desoto in 1593 in Florida (Towne and Wentworth 1950). Domestic hogs reportedly were also released in California by Spanish explorers in 1769 (Hutchinson 1946) and in the Hawaiian Islands by Captain Cook in 1778 (Kramer 1971). Since their introduction, feral swine populations in the United States have increased both in size and distribution. This expansion has been possible because of their omnivorous feeding habits, reproductive capacity, behavioral adaptability, the absence of large predators over most of their range, and through releases by humans (Bill Kohne, Missouri Conservation Department, pers. com., Mayer and Brisbin 1991).

Pimental et al. (1999) thought that there were 4 million feral pigs in the United States, while Muller et al. estimated in 2000 that 3 million were present in Texas alone. In 1988, twentythree states reported having feral swine populations (SCWDS 1988, Mayer and Brisbin 1991). Invasive swine have continued to expand their range and were present in more than 30 states in 2002 (Bergman et al. 2002) and in 39 states in 2004 (SCWDS 2004). Since the 2004 update, feral swine have also been reported in Iowa (Bill Bunger, Iowa DNR, pers. com.), Michigan (Timothy Wilson, APHIS, pers. com.), Pennsylvania (Chris Croson, APHIS, pers. com.), Maryland (Dan Emanueli, APHIS, pers. com.) and New Jersey (Beth Jones, APHIS, pers. com.). In most states, feral swine populations are distributed unevenly, with densities varying from abundant to sparse, depending on the quality of the habitat and the history of the local population. Feral swine and European boar are also held in enclosed hunting preserves or private collections in several states (Nettles 1997) and have been released in several locations within the continental United States, particularly in the Appalachian Mountains (Lewis et al. 1965). The expansion of feral swine range can be attributed to several factors; 1) intentional releases by misguided citizens attempting to create sport hunting opportunities, 2) range expansion as population numbers increase, 3) escapes from domestic swine facilities and wild boar shooting operations, and 4) habitat alteration due to human activities and global warming.

In the Midwest, feral swine have been reported to occur in Iowa, Michigan, Nebraska, Missouri, Kansas, Wisconsin, Illinois, Indiana, Kentucky, and Ohio, with populations in most of these states occurring within the last 10 years. The continued advance of feral swine range, coupled with habitat alterations related to human activity and global warming will insure that this range expansion continues unless action is taken to halt it soon. Once a population of feral swine becomes established in an area, eradication is difficult, time consuming, and expensive. Prevention of escapes and releases and timely eradication of new populations is the best management practice known at this time.

The Southeast Cooperative Wildlife Disease Study mapped feral swine distribution in 1982, 1988, and 2004 (SCWDS 1982, 1988, 2004a, 2004b). Figure 1 depicts the increased distribution from 1982 to 2004. While the increase is evident and substantial, the 2004 status is more discernable in Figure 2 that shows feral hog distribution by county (SCWDS 2004b).

Figure 1. US Feral Swine Distribution per SCWDS – 1982 & 2004.

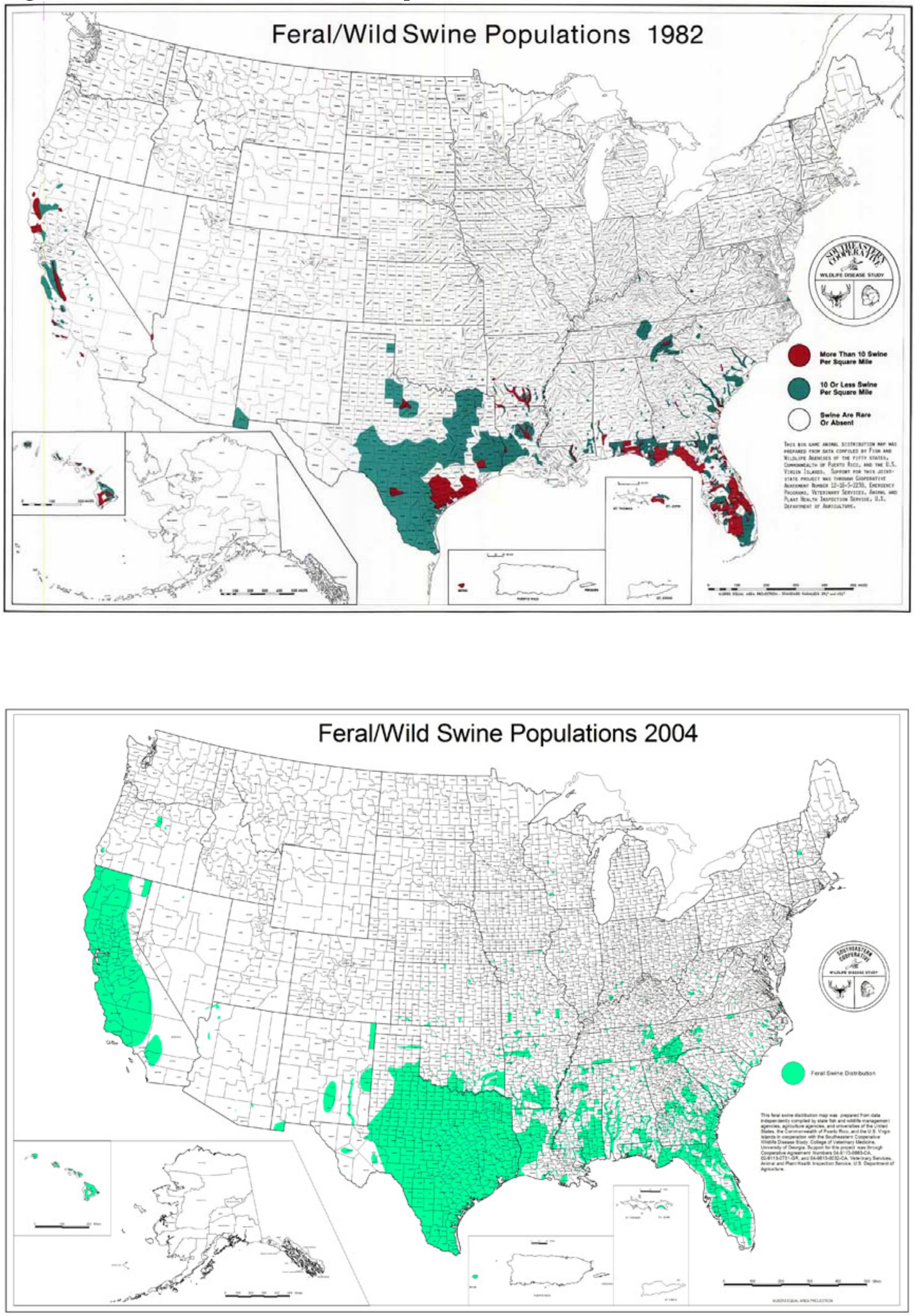
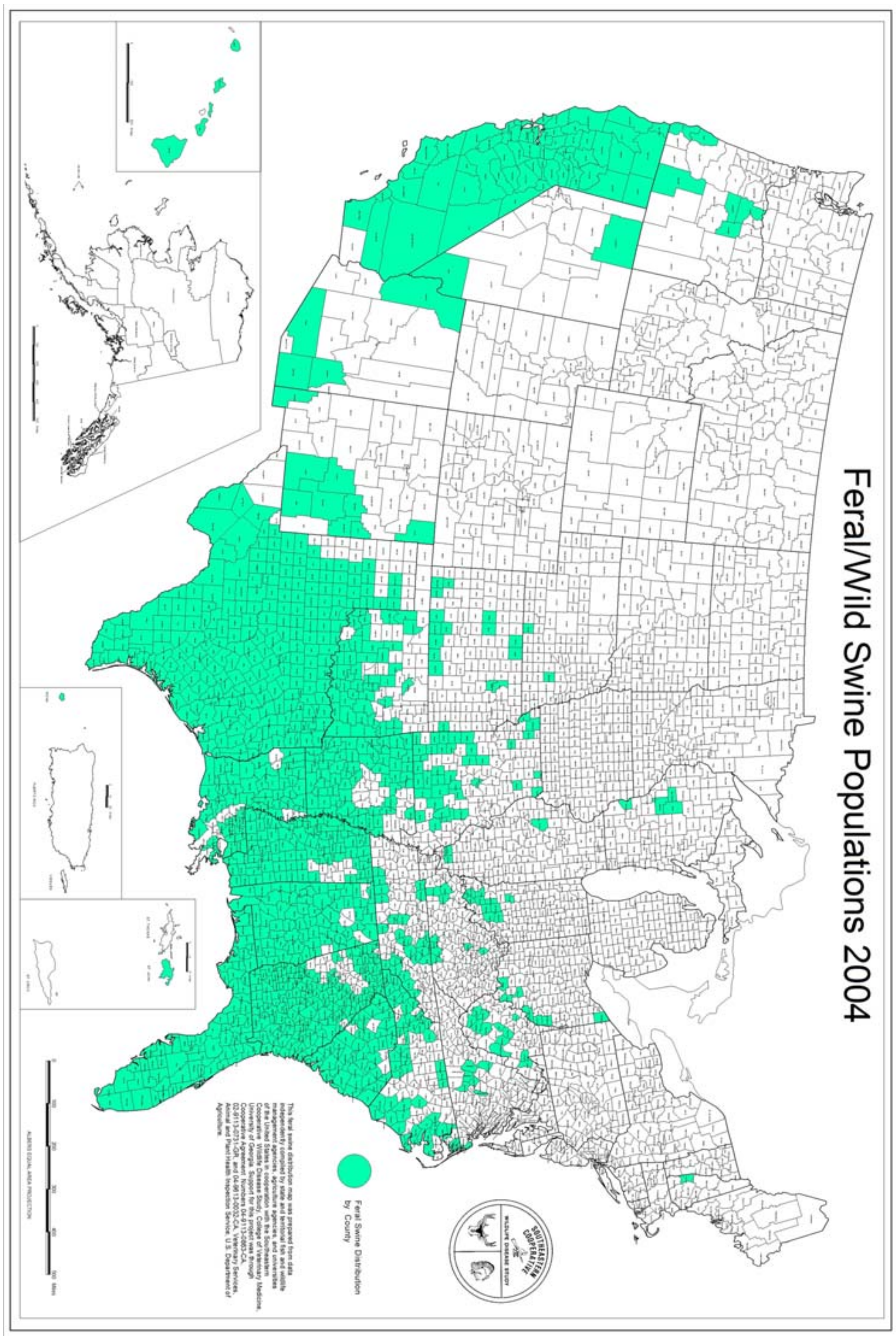


Figure 2. ’04 Feral Swine Distribution by County.



FERAL SWINE DISEASES

Feral Swine are highly mobile disease reservoirs and can carry at least 30 important viral and bacterial diseases (Davidson and Nettles 1997, Samuel et al. 2001, Williams and Barker 2001) in addition to a minimum of 37 parasites that affect people, pets, livestock, or wildlife (Forrester, 1991). Witmer et al. (2003) compiled the list of important feral swine diseases in Table 1 from Williams and Barker (2001).

Table 1. A partial list of viral and bacterial diseases to which feral swine are susceptible.
* Indicates zoonotic disease

Viral Diseases	**Bacterial Diseases**
Bovine herpesvirus*	Anthrax*
Classic swine fever (hog cholera)	Brucellosis*
Coronaviral infections*	Erysipelothrix infections*
Encephalomyocarditis*	Helicobacter spp.*
Foot-and-mouth disease*	Leptospirosis*
Influenza*	Bovine tuberculosis*
Louping-ill virus*	Pasteurellosis*
Malignant catarrhal fever	Plague*
Menangle virus*	Salmonellosis*
Papillomavirus infections*	Yersiniosis*
Parainfluenza virus*	
Pestivirus infections	
Pseudorabies (Aujeszky's disease)	
Rabbit hermorrhagic disease	
Rinderpest	
San Miguel sea lion virus	
Swinepox virus	
Vesicular stomatitis*	

Zoonoses

Feral swine carry several diseases that can infect humans including brucellosis, balantidiasis, leptospirosis, salmonellosis, toxoplasmosis, trichinosis, trichostrongylosis, sarcoptic mange (Seward et al 2004), tuberculosis, tularemia (Hubalek 2002, Stevens 1996), anthrax, rabies (Luangtongkum et al. 1986, Helmers and Van Essen 2002) and plague (Burns and Loven 1998).

Some authors (Amass 1998) report that human infection with swine diseases is rare based on the lack of reported human cases. There are also undoubtedly illnesses contracted from swine that people perceive as the common flu that are untreated, unreported, or misdiagnosed. A recent swine brucellosis incident in Iowa was discovered only when a pork producer was diagnosed with Undulant fever (brucellosis) when he went to a hospital for treatment. He had contracted the disease from his swine, which had been suffering abortions for six months and had been infected by a feral boar (Kevin Petersburg, APHIS, pers. com.). Although human infection directly from feral swine may be rare, secondary infections through a third host can occur. Feral swine may transmit many diseases to other wild mammals, birds, and reptiles, which in turn may transmit them to either domestic livestock or humans.

While serious diseases that pass from swine to humans may be rare in the United States due to modern livestock production, disease control, medical technology and limited feral swine distribution, diseases like brucellosis, anthrax, rabies, plague, tuberculosis and tularemia can be fatal for the infected individual.

Livestock & Wildlife Diseases

The US livestock industry is currently most concerned with pseudorabies, leptospirosis, swine brucellosis, bovine tuberculosis, and vesicular stomatitis that could be spread by feral pigs (Seward et al, 2004). Pseudorabies represents a serious threat to domestic swine operations as it can cause massive production losses and swine brucellosis can be contracted by both humans and domestic livestock. Several other diseases can cause loss of production in domestic livestock operations, death to commercial pigs, and large-scale economic loss to the producers. Wildlife can be affected by brucellosis, pseudorabies, leptospirosis, plague, anthrax (Davidson et al. 1997), tuberculosis, vesicular stomatitis, and tularemia (Dudley and Woodford 2002, Hubalek 2002). Wild swine could also play a role in the spread and subsequent eradication of foreign animal diseases like classical swine fever, African swine fever, Foot-and-Mouth Disease, Rinderpest, Rift Valley fever and Nipah virus (Dudley and Woodford 2002), if they emerged in the United States. The emergence of any of these diseases in the United States would cause the closure of export markets, be expensive or impossible to eradicate, and cause substantial damage to America’s economy and social system in the process. Additionally, the passage of various disease agents from feral swine to native wildlife species could devastate the local population of infected species.

Swine as Virus Reassortment Vessels

As described above, feral swine currently play a role in the spread of many diseases, some with significant implications. Feral swine could also play a role in the emergence of new Type A Influenza varieties since a variety of avian-like, human-like and swine influenza viruses/virus gene segments have been isolated from swine. Several researchers have identified the presence of such material in domestic swine in Canada, Italy, Great Britain, and the United States (Wright et al. 1992, Webby et al. 2000, Zhou et al. 1999 and Hatchette 2004). Brown (2004) reviewed current evidence of the transmission of influenza viruses between pigs and other species. He concludes:

> Pigs serve as a(sic) major reservoirs of H1N1 and H3N2 influenza viruses which are endemic in pig populations worldwide and are responsible for one of the most prevalent respiratory diseases in pigs. The maintenance of these viruses in pigs and the frequent exchange of viruses between pigs and other species is facilitated directly by swine husbandry practices which provide for a continual supply of susceptible pigs which have regular contact with other species particularly humans. The pig has been a contender for the role of intermediate host for reassortment of influenza A viruses of avian and human origin since they are the only mammalian species which are domesticated, reared in abundance and are susceptible to, and allow productive replication of,

> avian and human influenza viruses. This could lead to the generation of new strains of influenza some of which may be able to transmit to other species including humans. This concept is supported by the detection of human-avian reassortant viruses in European pigs with some evidence for subsequent transmission to the human population. Following interspecies transmission to pigs some influenza viruses may be extremely unstable genetically, giving rise to many virus variants, which could be conducive to the species barrier being breached a second time. Eventually a stable lineage derived from the dominant variant may become established in pigs. Genetic drift occurs in the genes of these viruses; particularly those encoding the external glycoproteins, but does not usually result in the same antigenic variability that occurs in the prevailing strains in the human population. Finally, it would appear that adaptation of a 'newly' transmitted influenza virus to pigs can take many years. Both human H3N2 and avian H1N1 were detected in pigs many years before they acquired the ability to spread rapidly and become associated with disease epidemics in pigs.

While research on virus reassortment has not been conducted on feral swine, they are the same species with the same physiology and similar proclivities for disease as domestic swine, though without as much intimate contact with humans. At the same time, since they are free-roaming, feral swine have behaviors and habitat preferences that bring them into contact with native quail, turkey, wild waterfowl, domestic swine, poultry, and humans and make them possible vectors for influenza virus transfer between and among species. The current strain of highly pathogenic H5N1 influenza virus circulating in Asia, Europe, Africa, and the Middle East is known to infect domestic swine, which act as reassortment vessels for the virus. It is feared by many that the swine will be the location of reassortment of the H5N1 virus into one that is easily transmitted from human to human.

POTENTIAL ECONOMIC IMPACT OF DISEASES CARRIED BY FERAL SWINE

Agricultural Economy

The United States Department of Agriculture's Economic Research Service forecasts cash receipts from the sale of U.S. hogs and cattle at $14.2 and $49.6 billion respectively (2005). Obviously, the potential economic impact of disease outbreaks caused by feral swine depends on the disease and its variant involved, its rate of spread, the animal species affected and population size, the geographic area involved, the ease of eradication, and disposal and cleanup costs. For mild infections of one or two people or livestock the economic cost might be minimal with slightly lower job productivity with a day or two of sick leave for people, or decreased weight gain or reproductive output for livestock. In the Iowa brucellosis situation described above, depopulation and indemnification costs amounted to approximately $60,000 not counting state or federal employee time, lost productivity of the swine operation, or the infected operator's medical costs. For the more serious foreign animal diseases, the ultimate cost would undoubtedly be considerably more and would include human health costs, lost productivity in the workplace, in addition to agricultural losses.

Large populations of widely distributed feral swine also jeopardize ongoing efforts to control a number of livestock diseases and the considerable investments that support those efforts. For example, the United States' domestic swine recently achieved pseudorabies-free status after a 17-year effort and the expenditure of approximately $200-250 million dollars (John Korslund, APHIS, pers. comm.). A similar multi-year, multi-million dollar effort is underway for brucellosis in swine and cattle and the presence of infected feral swine may complicate and delay the final success of that program. Witmer et al. (2003) summarized surveillance studies of feral swine populations in the United States and reported infection rates of 0-46 and 0-53% for pseudorabies and swine brucellosis respectively. With these rates of infection feral swine serve as a reservoir for disease reintroduction and pose a constant threat to the progress of disease eradication programs in domestic livestock. The most serious, potential disease situation would be the reemergence of Foot-and-Mouth Disease (FMD) in portions of the United States inhabited by feral hogs. In such an eventuality the costs would be greatly magnified and affects on society and the economy would be disastrous and many faceted. The economic losses attributed to the FMD outbreak in the United Kingdom in 2001 is estimated at over $12 billion. An earlier outbreak in Taiwan in 1997 cost $25 billion, almost wiping out Taiwan's entire hog industry (Pearson et al. 2005). Paarlberg et al. (2002) estimated that a FMD outbreak in the U.S., like that in the U.K., would decrease U.S. farm income by $14 billion assuming a 10% decrease in consumption. If a 20% decrease in consumption occurred, farm income is estimated to decrease by $20.8 billion dollars. Although the likelihood of the reemergence of FMD in the U. S. is impossible to quantify, FMD is widely distributed in Asia, Africa, and South America (Pearson et al. 2005) and could be introduced into the United States accidentally or intentionally by terrorists. Current livestock marketing and production systems would quickly spread it over wide areas where feral swine would likely contract it. Although the role of feral swine in the spread of FMD or other foreign animal diseases is poorly understood, their presence poses a definite risk when they interact with domestic livestock and wildlife. Additional impacts would be felt in the social sector of our country as livestock producers, health care workers, and animal health professionals would be overworked and stressed in round-the-clock attempts to stamp out the disease.

Swine as Amplifiers of FMD

Pigs usually become infected by eating FMDV contaminated products, by direct contact with another infected animal, or by being placed in a heavily infected environment (Kitching and Alexandersen 2002). Once FMD is established in the herd, transmission via oral, mucosal and through damaged epithelium can be very rapid (Kitching and Alexandersen 2002). Feral swine would not only spread FMD mechanically and through these routes, they would also excrete large quantities of aerosol virus--up to $10^{8.6}$ $TCID_{50}$/24 hours (Donaldson 1999), 30-100 more times than do cattle and sheep (Andrews 2001), 100 times more than sheep for the 2001 UK FMD outbreak (Donaldson et al. 2001), and up to 3,500 times more than ruminant species (Donaldson 1999) depending on the FMD strain. This output greatly increases the risk of airborne transmission of the disease (Sellers and Parker 1969), and would exacerbate its eradication and all of the resulting impacts. Fortunately, pigs are relatively resistant to infection with airborne FMDV compared to sheep and cattle (Alexandersen and Donaldson 2002).

ECONOMIC COSTS TO TOURISM/OUTDOOR RECREATION

As with agricultural losses, the disease impact on tourism will depend on the disease variant involved, its infectivity to humans, its rate of spread, the geographic area involved, the size of the quarantine area(s), if any, and the time required for eradication. The most serious impacts would again be from an outbreak of Foot-and-Mouth Disease.

While such an outbreak would affect U.S. tourism in general, the greatest impact undoubtedly would fall on outdoor recreation, including fishing, hunting, and wildlife watching because of the strict quarantine(s) necessary to control the disease. The cessation of hunting, fishing, and/or outdoor recreation activities would economically impact private business that relies on these activities for all or a portion of their income as well as decreasing revenue to state natural resource agencies. This outcome would have serious economic impact since non-residential, wildlife-related recreation is enjoyed by 59.6 million people who spend over $105 billion per year (U. S. Fish & Wildlife Service 2001). Non-wildlife related outdoor recreation would also be affected. The Outdoor Industry Foundation reports an additional 64 million Americans, 32 million identified as enthusiasts, participated at least once in outdoor activities like bicycling, hiking, car camping, canoeing, backpacking, climbing, or skiing in 2004 (Outdoor Industry Association 2005).

UNQUANTIFIABLE BUT REAL SOCIAL COSTS

The Productivity Commission of the Australian Government (2002) has identified the social impacts of severe disease outbreaks and they include the following from lower livestock prices and FMD control measures**.**

-Financial losses cause attendant social and mental stresses for farmers, their families, neighbors, suppliers, and communities.

-Elimination of livestock as part of disease control would prove traumatic for farmers and their families who’s whole lives are invested in the animals.

-Quarantine and buffer control areas would result in the loss of control for livestock owners in the operation of their farms and their daily lives. This would add to feelings of anxiety, grief, hopelessness, anger, and frustration.

-Emergency service personnel may face extraordinary pressures because of the long hours and shared trauma from implementing eradication activities and enforcing quarantines.

-Disruption a family routines and school and cancellation of recreational activities would increase travel times and reduction in normal social interactions.

-Stress would increase health and mental disorders, suicide and alcohol and drug abuse.

SUMMARY

Feral Swine in the United States are expanding their range, both on their own and with human assistance. They are a destructive invasive species that affects many human, agricultural, and natural resources but adequate funding for addressing this serious threat has not been available. While the physical damage they cause is substantial in itself, the most compelling justification for aggressive control of feral swine populations comes from their associated disease risks and the role they may play in emergence of new viruses that can potentially affect human and animal health and the world's economy. In consideration of these substantial risks, prudence requires that the United States mount a coordinated, comprehensive feral swine control program. Such a program will require at minimum legislation/regulation changes; a sustained, multi-dimensional public education effort; overt and covert law enforcement, and an aggressive, adequately funded, control effort to succeed. The Midwest Association of Fish and Wildlife Agencies, Wildlife and Fish Health Committee recommends an aggressive effort, conducted by both state and federal agencies, to attempt to halt the spread of feral swine populations and, where possible, reduce or eliminate existing populations. This effort can only be undertaken by the infusion of additional funds from state and federal levels and the establishment of a national, coordinated effort with all entities cooperating.

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