1-1-2003

FERAL SWINE---ARE THEY A DISEASE THREAT TO LIVESTOCK IN THE UNITED STATES?

Gary W. Witmer
USDA, APHIS,Wildlife Services, National Wildlife Research Center, 4101 LaPorte Avenue, Fort Collins, CO 80521, USA

Robert B. Sanders
USDA, FSIS Training and Education Center, 200 Discovery Drive, TAMU Research Park, College Station, TX 77845, USA

Arnold C. Taft
USDA, APHIS, VS, 4700 River Road, Unit 43, Riverdale, MD 20737, USA

FERAL SWINE---ARE THEY A DISEASE THREAT TO LIVESTOCK IN THE UNITED STATES?

GARY W. WITMER, USDA, APHIS,Wildlife Services, National Wildlife Research Center, 4101 LaPorte Avenue, Fort Collins, CO 80521, USA
ROBERT B. SANDERS, USDA, FSIS Training and Education Center, 200 Discovery Drive, TAMU Research Park, College Station, TX 77845, USA
ARNOLD C. TAFT (deceased), USDA, APHIS, VS, 4700 River Road, Unit 43, Riverdale, MD 20737, USA

Abstract: Feral swine populations provide both benefits and liabilities to citizens of the United States. Their expanding range and increasing densities, however, have raised concern over the adverse environmental and agricultural effects and the increased risk of disease transmission between feral swine and livestock. We discuss the role of feral swine in the transmission of wildlife diseases and, in particular, in diseases of national significance to the livestock industry. We also discuss available management tools and strategies for reducing feral swine populations, minimizing damage or disease occurrences and eradicating populations when deemed appropriate. Finally, we note areas of research that may provide valuable management tools in the future.

Key words: bovine tuberculosis, brucellosis, exotics, feral swine, invasive species, livestock, pseudorabies, *Sus scrofa*, trichinosis, vesicular stomatitis

Proceedings of the 10th Wildlife Damage Management Conference. (K.A. Fagerstone, G.W. Witmer, Eds). 2003

INTRODUCTION

Feral swine (*Sus scrofa*) were introduced into the United States as a source of meat as early as the 1400s when Europeans were exploring and settling the North American continent (Mayer and Brisbin 1991). There have been many subsequent introductions, using domestic stock and, in some cases, Eurasian wild boar which freely hybridize. Swine introductions can occur through a variety of means, including: 1) translocation to establish populations for hunting, 2) escapees from shooting preserves or confinement operations, 3) dispersal from established populations, 4) avoidance of capture by domestic pigs in free-range commercial operations, and 5) abandonment of pigs by their owners (Gipson et al. 1997). Mayer and Brisbin (1991) used the term "wild-living pigs" to encompass all varieties and discussed the history of introductions in the United States, the comparative morphology of feral swine populations, the expansion of populations into adjacent states, and the status of populations as of 1989.

The management of feral swine is contentious because there are diverse and strongly held views and attitudes by governmental personnel as well as private individuals and groups (Miller 1993). One of the challenges faced by resource managers and agency personnel is that feral swine are considered a valuable resource to many segments of the public, and, in

particular, to the hunting public and ethnic meat producers. For example, the Texas Parks and Wildlife Department generated over $1 million in 1998 through the sale of 30,512 five-day-hog-hunting permits to non-residents (Chambers 1999). A game rancher in Texas estimated that he made over $500 for every hog that left his ranch. The management of feral swine for hunting and food production varies widely from state to state, as does their legal status. It is common for individuals to release feral swine into new areas in an effort to establish new populations for personal objectives (Miller 1993). This practice occurs even though illegal in many states. Additionally, feral swine populations are difficult to manage from a technical standpoint (i.e., using traditional wildlife management techniques) and are even more difficult to eradicate once established (Miller 1993).

Unfortunately, feral swine populations have many negative impacts. There has been considerable interest in feral swine as an "invasive" species on both island and mainland settings. Where they occur in sizeable densities, feral swine have been implicated in losses to native flora and fauna (including threatened and endangered species), soil erosion and declines in water quality, reduced bio-diversity, crop and reforestation damage, structural damage, and livestock depredations (Stone and Scott 1985, Sweitzer 1998, Wood and Barrett 1979). They can also harbor many diseases and parasites which can infect humans and livestock. Several national symposia in recent years have documented these problems and searched for solutions (e.g., Hanselka and Cadenhead 1993, Schmitz 1997, Texas Animal Health Commission 1999, Wood 1977). Feral swine cause an estimated $800 million in damage to agriculture and the environment each year (Pimentel et al. 2000).

Feral swine populations can grow and disperse relatively rapidly because of their ability to use diverse foods and habitats, their intelligence and wariness, and their adaptability to control efforts. Additionally, feral swine have the greatest reproductive potential of all free-ranging, large mammals in the United States (Wood and Barrett 1979). The biology and ecology of feral swine have been reviewed by Barrett and Birmingham (1994), Choquenot et al. (1996), and Sweeney and Sweeney (1982).

STATUS OF FERAL SWINE IN THE UNITED STATES

Feral swine are widespread and increasing their distribution in the United States. The number of states with populations of feral swine has increased dramatically in recent decades. Mayer and Brisbin (1991) conducted a survey in 1988 and listed 23 states (Alabama, Arizona, Arkansas, California, Florida, Georgia, Hawaii, Iowa, Kentucky, Louisiana, Mississippi, Missouri, New Hampshire, New Mexico, North Carolina, Oklahoma, Oregon, South Carolina, Tennessee, Texas, Virginia, Washington, and West Virginia) with populations, but noted that the populations in Iowa, Missouri, Oregon, and Washington were believed to have been extirpated. Extirpation of free-ranging populations is very difficult, however, and Witmer and Lewis (2001) noted that small populations may still occur in Oregon and Washington. Free-ranging feral swine populations have been present for many decades in many of the southern states and Hawaii, but their distribution is expanding northward. In many states, populations are confined in large fenced areas, mostly for hunting purposes. For example, a Southeastern Cooperative Wildlife Disease Study (SCWDS, 1994) survey reported that feral swine enclosures occurred in at least 26 states and that 34 were in 14 states without free-ranging populations. The SCDWS

survey and other reports (e.g., Nettles 1997)

Table 1. A partial list of viral and bacterial diseases to which feral swine are susceptible[a]

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

[a]Compiled from Williams and Barker (2001).

suggest that many states, in addition to those listed above, have feral swine populations: Alaska, Colorado, Idaho, Illinois, Indiana, Kansas, Michigan, Minnesota, Nebraska, Nevada, New York, North Dakota, Ohio, Pennsylvania, South Dakota and Vermont. An estimated 4 million feral swine occur in the United States, with the largest populations in California, Florida, Hawaii, and Texas (Pimentel et al. 2000).

ROLE OF FERAL SWINE IN LIVESTOCK DISEASES

Feral swine as well as domestic swine are susceptible to many diseases and parasites. The feral swine sections and index listings of several texts on wildlife diseases and parasites, read like a "Who's Who" of the disease world (e.g., Davidson and Nettles 1997, Samuel et al. 2001, Williams and Barker 2001). Feral swine can harbor a number significant viral and bacterial diseases (Table 1). Additionally, swine are susceptible to many parasitic nematodes, roundworms, and flukes as well as lice and ticks. Most notably, swine can be infected with the nematode which causes the serious illness trichinosis (Samuel et al. 2001). Better animal husbandry coupled with proper food handling, processing, and cooking have largely eliminated the threat of this pathogen to humans in the United States; despite these practices, surveillance of commercial swine herds continues (Gamble undated).

Many diseases that feral swine can

harbor are transmissible to humans and livestock as well as wildlife. Pseudorabies, swine brucellosis, bovine tuberculosis, leptospirosis, and vesicular stomatitis are of particular concern. For recent reviews of these diseases see Williams and Barker (2001). There is also a concern regarding the role feral swine might play in an outbreak of a foreign animal disease, such as foot-and-mouth disease or hog cholera (classic swine fever). There have been efforts to model the role that feral swine might play in an outbreak of hog cholera (Hone et al. 1992) or of foot-and-mouth disease (Pech et al. 1992). On the other hand, they may serve as a surveillance tool for the early detection of exotic diseases (Mason and Fleming 1999). Feral swine can also be used as an indicator or sentinel species to monitor the distribution and prevalence of established diseases (Lorigan 2002).

Because of the disease threat posed by feral swine, disease surveillance has been conducted in populations in several states. Muller et al. (2000) reviewed the results of pseudorabies surveillance in the United States and other countries and reported a wide range of prevalence rates: 43-46% (Hawaii), 36% (Texas), 35% (Florida), 19-22% (southeastern states), 7-10% (Georgia), 3% (California), and 0% (Tennessee). Gipson et al. (1999) found no evidence of pseudorabies in feral swine sampled in Kansas. Muller et al. (2000) also reported high prevalence rates (29-63%) in several European and African countries. Variable prevalence rates for brucellosis in feral swine have also been reported: 53% (Florida, Becker et al. 1978), 18% (South Carolina, Wood et al. 1976), 4% (California, Drew et al. 1992), 3% (Texas, Corn et al. 1986), and 0% (Tennessee, New et al. 1994; Kansas, Gipson et al. 1999). Surveillance for leptospirosis in feral swine found prevalence rates of 44% (Tennessee, New et al. 1994) and 8-21% (Texas, Corn et al. 1986). Mason et al. (1998) reported a leptospirosis prevalence rate of 20% in feral swine collected in southeastern Australia. Surveillance for vesicular stomatitis (Stallknecht et al. 1986) found infected feral swine in four states: Arkansas (100%), Louisiana (70%), Georgia (28%), and Florida (4%). States where evidence of vesicular stomatitis was not found (although sample sizes were often very small) included Alabama, Arizona, California, Hawaii, Mississippi, North Carolina, South Carolina, Tennessee, Texas, Virginia, and West Virginia.

Pseudorabies (USDA 2000), swine brucellosis (USDA 1998), and bovine tuberculosis (USDA 1999) are among several livestock diseases for which the USDA Animal and Plant Health Inspection Service (APHIS) has established national eradication programs with a goal of elimination of the diseases from all livestock in the United States. Unfortunately, one of the most serious setbacks to achieving this goal is the widespread and growing occurrence of feral swine populations across the country. Feral swine can harbor and transmit these diseases, and in some areas may serve as the most important wildlife host. The diseases are transmitted in various ways, including close contact, inhalation, consumption of contaminated materials, or by venereal contact (e.g., Romero et al. 2001). The most significant route of transmission varies by disease and these routes are often poorly understood, especially in free-ranging wildlife. As such, diseases can be transmitted from feral swine to fenced domestic swine when close contact or contamination occurs at fence lines, when fences are breached, or when infected feral or “backyard” swine are shipped and processed at markets (e.g., Gipson et al. 1999).

THE COMMERCIAL PORK INDUSTRY IN THE UNITED STATES

Although feral swine pose a disease risk to humans, livestock and wildlife, the main concern has been the potential impact to the commercial pork industry. The commercial pork industry is a large and well organized entity in the United States, with both domestic and export markets. The National Pork Producers Council is among the largest commodity organizations in the United States with 44 affiliated state pork producer associations. Over 99 billion pounds of pork were processed from about 99 million hogs in 1999 (National Pork Producers Council 2000). Annual farm sales usually exceed $11 billion, while the retail value of pork sold to consumers exceeds $34 billion. There are about 100,000 swine operations in the United States. While all 50 states have some swine operations, the states with the highest production include Illinois, Indiana, Iowa, Ohio, Oklahoma, Minnesota, Missouri, Nebraska, North Carolina, and South Dakota. It is interesting to note that all of these states now have free-ranging or fenced populations of feral swine. Most of the commercial facilities are large, "high-tech", confined operations with bio-safety procedures. On the other hand, many swine growers are "backyard" operators with few, if any, bio-safety procedures.

The highly infectious diseases pseudorabies and swine brucellosis are considered threats to the well-being of the commercial pork industry. Large economic costs are incurred by a state and the livestock industry when the state loses its disease-free status because of testing requirements, and shipping and marketing restrictions. Pseudorabies is a viral disease that can affect sow fertility and result in high mortality rates in young pigs. Swine brucellosis is a bacterial disease that can cause weight loss, infertility, death of young animals, lameness and reduced milk production. Millions of dollars are spent each year to detect and prevent pseudorabies and swine brucellosis outbreaks in domestic swine. APHIS has made major progress in eliminating these diseases in domestic livestock herds in the United States over the past decades. This reduction in prevalence largely involved nationwide surveillance of swine at slaughter plants. When an infected animal is found, "trace-back" and "trace-forward" systems are used to locate infected herds which are quarantined and tested for the disease. Infected animals, or the entire herd, may be destroyed (i.e., depopulated) with an indemnity paid. In recent years, with relatively few known infected herds remaining, it looked as if the eradication of these diseases in livestock was within sight. However, the final instances of a disease are often the most difficult to find and eliminate. The levels of surveillance conducted by USDA have been expanded in the national effort to eradicate these diseases of the commercial pork industry.

While bovine tuberculosis is not considered a serious threat to the swine industry, it is to the cattle and captive cervid industries. Bovine tuberculosis is a chronic, bacterial disease that causes loss of condition, emaciation, behavioral changes, and respiratory problems. Feral swine are susceptible and may be playing a role in the reoccurrence of infection in cattle on the Hawaiian Island of Molokai (Robert Meyer, USDA APHIS, personal communication).

ISSUES AND CHALLENGES OF FERAL SWINE MANAGEMENT

A goal of USDA is to reduce the risk of disease transmission from free-ranging wildlife, and in particular, feral swine, to livestock so that national plans to eradicate several diseases from livestock in the United States can be accomplished. Additionally, eliminating these diseases from feral swine

populations would reduce losses of highly-valued wildlife resources and lessen the risk to humans of some diseases. In large part, this will involve efforts to maintain or re-establish healthy wildlife populations. In some situations, this will require a substantial feral swine population reduction or even eradication of local populations. Eliminating diseases or reducing prevalence in feral swine populations will require the establishment of both operational and research-based programs, on a federal level and in conjunction with other governmental agencies and the private sector, for the monitoring and management of disease occurrence and transmission by wildlife. National eradication goals will not be verified until several consecutive years have passed with no reported infection of livestock herds by wildlife and the diseases in wildlife have been eliminated or prevalence rates have fallen to very low levels (<1%). In most situations, this is not easily achieved in free-ranging populations, and a sustained, well-coordinated effort with adequate funds, equipment, trained personnel, diagnostic laboratory access, and emergency response-capabilities are required (e.g., Wobeser 1994).

Many governmental agencies, universities, other institutions, non-governmental organizations, and landowners would play important roles in achieving disease eradication goals. While the basic framework and infrastructure for federal and state involvement in livestock disease eradication programs are in place (e.g., Diez et al. 2002), it and associated operating funds are woefully inadequate for an aggressive and effective effort to achieve the goal. Because of the inherently complex and difficult nature of disease management and eradication when free-ranging wildlife are involved (Wobeser 1994), specific long-term management and research programs must be launched and sustained to achieve eradication goals. Attainment of the goals may require one or more decades even with concerted efforts.

Achievement of these disease goals with feral swine may greatly lessen the many other impacts of feral swine, as an invasive species, to agricultural and natural resources. This will be achieved by the control or elimination of feral swine populations and the development of better "tools" for the management of feral swine. Specific activities required to achieve disease eradication goals include wildlife population and disease surveillance, wildlife and habitat management (both pro-active and retroactive), public education and technology transfer, and research (Table 2). The management of feral swine populations poses many challenges to resource managers. In states where feral swine are unprotected or classified as a pest species, they can be taken at almost any time by a variety of methods. States in which feral swine are classified as game animals rely heavily on hunter harvest to maintain populations at appropriate densities, although depredation permits are also issued as needed (e.g., Frederick 1998, Updike 1998). Unfortunately, there are many areas (e.g., parks, posted private land) where hunting is not allowed. Changes in state game laws, in some cases, may help improve the harvest of feral swine by hunters and landowners suffering damage (Updike 1998). Aerial shooting or night shooting at bait stations by professional shooters is also allowed in some states to reduce populations (e.g., Brown 1985). Other methods to reduce populations or damage by feral swine include exclusion with wire mesh or electric fences and trapping or snaring followed by relocation or euthanasia (Barrett and Birmingham 1994, Choquenot et al. 1996). Choquenot et al. (1996) provided detailed guidance on all these approaches, along with the use of

Table 2. Potential management and research activities to better manage feral swine, to reduce the occurrence of disease in feral swine, and to reduce the risk of disease transmission between feral swine and livestock.

A. Wildlife Monitoring and Disease Surveillance
1. Determine the status and demographics of feral swine and other wildlife populations in all states
2. Determine the host species and transmission routes in feral swine and other wildlife and between wildlife and livestock
3. Determine the extent and area of infection in feral swine and other wildlife
4. Provide samples and animals for testing and research
B. Management of Wildlife Populations and Disease in Wildlife
1. Develop management and emergency response plans with state agencies
2. Conduct feral swine population reduction and depopulation activities
3. Construct barriers and conduct other activities to restrict feral swine and other wildlife movement and to reduce risk of disease transmission to livestock
4. Apply modeling and GIS applications for feral swine movements, disease occurrence and disease transmission
5. Develop and evaluate population and disease control and risk reduction strategies
6. Design and conduct biohazard management strategies
C. Public Education and Information Transfer
1. Construct searchable literature databases on feral swine and swine diseases
2. Compile and maintain diagnostic test result databases for feral swine and other wildlife and evaluate within the context of free-ranging populations and potential interaction with livestock
3. Organize and participate in public and scientific meetings and workshops
4. Create liaison and information sources for regulatory agencies
5. Prepare public and agency information products (pamphlets, videos, guidelines, etc.)
6. Provide training in wildlife monitoring, capture, and management techniques and in wildlife disease methodologies.
7. Promote effective law enforcement with regard to feral swine
8. Conduct site assessments for landowners
D. Research
1. Improve feral swine population monitoring and capture methods
2. Develop effective and economical barriers to feral swine movement and to reduce interactions between feral swine and livestock
3. Develop vaccine and delivery systems for feral swine and other wildlife
4. Develop fertility control and delivery systems for feral swine and other wildlife
5. Investigate the potential for lethal baiting strategies for feral swine control
6. Determine species susceptibility, transmission routes, and interactions between wildlife and livestock
7. Model the ecology of diseases in feral swine and the potential risk to livestock
8. Assist in development of diagnostic tests for feral swine and other wildlife
9. Obtain federal and state registrations for new products

toxicants, and discuss the advantages and disadvantages of each method. The need for a large-scale community effort to successfully manage feral swine has been noted (Choquenot et al. 1996, Dorrington and Mitchell 2000). VanVuren (1992)

discussed the damage caused by feral ungulates on islands and the many methods available to eradicate feral populations. He also presented examples of successful island eradications (see also Katahira et al. 1993). The use of toxicants for feral swine control, although not currently legal in the United States, can provide an effective and economical means of feral swine control or eradication (e.g., Hone 1983, Hone and Stone 1989).

Aerial baiting can be an effective way of delivering toxicants, fertility control materials, or vaccines to feral swine populations. Research continues on the development of baits that will be highly attractive to, and effective on, feral swine (e.g., Fletcher et al. 1990, Fleming et al. 2000, Kavanaugh and Linhart 2000). Research also continues on a contraceptive vaccine for feral swine (Killian et al. 2003).

CONCLUSIONS

We conclude that feral swine pose a serious disease threat to livestock and hinder our ability to eradicate several important diseases of livestock in the United States. Disease outbreaks, involving risk to livestock, humans and other wildlife, are high profile, high priority situations that typically receive substantial attention and funding at both the state and federal levels. Emergency funds are often made available for several years, but may quickly disappear when another disease suddenly shows up and takes priority. Because of the wide occurrence of feral swine populations in the United States and the technical challenges posed by feral swine management, it is important for federal agencies to establish priorities on which states to address first in this effort and how to divide the limited resources available to conduct activities. Meetings between federal and state agencies, commodity groups, wildlife associations, and other pertinent groups might be required to help resolve this situation. It is important to convey---and to reach agreement on---certain themes, including: 1) the importance of protecting the health of people, livestock, and wildlife, 2) the strong economic incentive to protect the livestock industry, both domestic and export, as well as highly-valued wildlife resources, 3) the serious threats to humans, livestock, and natural resources posed by expanding feral swine populations, and 4) the importance of insuring that, ultimately, agricultural lands are safe and accessible to both livestock and wildlife.

It would also be very valuable to conduct surveys within all states to help assess the feral swine situation, its legal status, important issues, and agency and public attitudes. This information would provide an essential data base upon which to design an approach to feral swine management in each state or region. Finally, continued research is needed to provide better ways to manage feral swine populations and habitat.

LITERATURE CITED

BARRETT, R.H., AND G.H. BIRMINGHAM. 1994. Wild pigs. Pages D65 – D70 *in* S. Hygnstrom, R. Timm, and G. Larsen, editors. Prevention and Control of Wildlife Damage. Cooperative Extension Service, University of Nebraska, Lincoln, NE, USA.

BECKER, H.N., R.C. BELDEN, T. BREAULT, M.J. BURRIDGE, W.B. FRANKENBERGER, AND P. NICOLETTI. 1978. Brucellosis in feral swine in Florida. Journal of American Veterinary Medical Association 173:1181-1182.

BROWN, L.N. 1985. Elimination of a small feral swine population in an urbanizing section of central Florida. Florida Scientist 48:120-123.

CHAMBERS, M. 1999. Conserving a resource. Pages 115-116 *in* Proceedings of the Feral Swine Symposium. Texas Animal Health Commission. Austin, TX, USA.

CHOQUENOT, D., J. MCILROY, AND T. CORN. 1996. Managing vertebrate pests: feral pigs. Bureau of Resource Sciences. Australian

Government Publishing Service, Canberra, Australia.

CORN, J.L., P.K. SWIDEREK, B.O. BLACKBURN, G.A. ERICKSON, A.B. THIERMANN, AND V.F. NETTLES. 1986. Survey of selected diseases in wild swine in Texas. Journal of American Veterinary Medical Association 189:1029-1032.

DAVIDSON, W.R., AND V.F. NETTLES. 1997. Field manual of wildlife diseases in the southeastern United States. Southeastern Cooperative Wildlife Disease Study. University of Georgia, Athens, GA, USA

DIEZ, J.R., M. GILSDORF, AND R. WERGE. 2002. The federal role in regulating alternative livestock operations. Transaction of the North American Wildlife and Natural Resources Conference 67:289-296.

DORRINGTON, B., AND J. MITCHELL. 2000. Community based feral pig management in northern Australia's wet tropics. Proceedings of the Vertebrate Pest Conference 19:180-182.

DREW, M.L., D.A. JESSUP, A.A. BURR, AND C.E. FRANTI. 1992. Serologic survey for brucellosis in feral swine, wild ruminants, and black bear of California, 1977 to 1989. Journal of Wildlife Diseases 28:355-363.

FLEMING, P.J., D. CHOQUENOT, AND R.J. MASON. 2000. Aerial baiting of feral pigs for the control of exotic disease in the semi-arid rangelands of New South Wales. Wildlife Research 27:531-537.

FLETCHER, W.O., T.E. CREEKMORE, M.S. SMITH, AND V.F. NETTLES. 1990. A field trial to determine the feasibility of delivering oral vaccines to wild swine. Journal of Wildlife Diseases 26:502-510.

FREDERICK, J. M. 1998. Overview of wild pig damage in California. Proceedings of the Vertebrate Pest Conference 18:82-86.

GAMBLE, H.R. Undated. Trichinae: pork facts – food quality and safety. Unpublished Report. USDA Agricultural Research Service. Beltsville, MD, USA.

GIPSON, P.S., B. HLAVACHICK, T. BERGER, AND C.D. LEE. 1997. Proceedings of the Great Plains Wildlife Damage Control Workshop 13:148-150.

_____, J.K. VEATCH, R.S. MATLACK, AND D.P. JONES. 1999. Health status of a recently discovered population of feral swine in Kansas. Journal of Wildlife Diseases 35:624-627.

HANSELKA, C.W., AND J.F. CADENHEAD, editors. 1993. Feral swine: a compendium for resource managers. Texas Agricultural Extension Service, Corpus Christi, TX, USA.

HONE, J. 1983. A short-term evaluation of feral pig eradication at Willandra in western New South Wales. Australian Wildlife Research 10:269-275.

_____, R. PECH, AND P. YIP. 1992. Estimation of the dynamics and rate of transmission of classical swine fever (hog cholera) in wild pigs. Epidemiology and Infection 108:377-386.

_____, AND C.P. STONE. 1989. A comparison and evaluation of feral pig management in two national parks. Wildlife Society Bulletin 17:419-425.

KATAHIRA, L.K., P. FINNEGAN, AND C.P. STONE. 1993. Eradicating feral pigs in montane mesic habitat at Hawaii Volcanoes National Park. Wildlife Society Bulletin 21:269-274.

KAVANAUGH, D.M., AND S.B. LINHART. 2000. A modified bait for oral delivery of biological agents to raccoons and feral swine. Journal of Wildlife Disease 36:86-91.

KILLIAN, G., L. MILLER, J. RHYAN, T. DEES, D. PERRY, AND H. DOTEN. 2003. Evaluation of GnRH contraceptive vaccine in captive feral swine in Florida. Proceedings of the Wildlife Damage Management Conference 10: *in press*.

LORIGAN, R.D. 2002. The use of deer, pigs, and ferrets as indicator species for detecting Tb. Proceedings of the Vertebrate Pest Conference 20:249-252.

MASON, R.J., AND P.J. FLEMING. 1999. Australian hunters and the surveillance of feral pigs for exotic disease. Wildlife Society Bulletin 27:395-402.

_____, J.S. FLEMING, L.D. SMYTHE, M.F. DOHNT, M.A. NORRIS, AND M.L. SYMONDS. 1998. *Leptospirosis interrogans* antibodies in feral pigs from New South Wales. Journal of Wildlife Disease 34:738-743.

MAYER, J.J., AND I.L. BRISBIN. 1991. Wild pigs in the United States. University of Georgia Press, Athens, GA, USA.

MILLER, J.E. 1993. A national perspective on feral swine. Pages 9-16 *in* C.W. Hanselka and J.F. Cadenhead, editors. Feral swine: a compendium for resource managers. Texas Agricultural Extension Service, Corpus Christi, TX, USA.

MULLER, T., F.J. CONRATHS, AND E.C. HAHN. 2000. Pseudorabies virus infection (Aujeszky's disease) in wild swine. Infectious Disease Review 2:27-34.

NATIONAL PORK PRODUCERS COUNCIL. 2000. Pork facts 2000/2001. National Pork Producers Council. Des Moines, IA, USA.

NETTLES, V.F. 1997. Feral swine: where we've been, where we're going. Pages 1-4 *in* K.L. Schmitz, editor. Proceedings of the National Feral Swine Symposium. USDA, APHIS Veterinary Services, Riverdale, MD, USA.

NEW, J.C., K. DELOZIER, C.E. BARTON, P.J. MORRIS, AND L. POTGIETER. 1994. A serologic survey of selected viral and bacterial diseases of European wild hogs, Great Smoky Mountains National Park, USA. Journal of Wildlife Diseases 30:103-106.

PECH, R.P., J.C. MCILROY, AND M.F. CLOUGH. 1992. A microcomputer model for predicting the spread and control of foot and mouth disease in feral pigs. Proceedings of the Vertebrate Pest Conference 15:360-364.

PIMENTEL, D., L. LACH, R. ZUNIGA, AND D. MORRISON. 2000. Environmental and economic costs of nonindigenous species in the United States. BioScience 50:53-65.

ROMERO, C.H., P.N. MEADE, J.E. SHULTZ, H.Y. CHUNG, E.P. GIBBS, E.C. HAHN, AND G. LOLLIS. 2001. Venereal transmission of pseudorabies viruses indigenous to feral swine. Journal of Wildlife Diseases 37:289-296.

SAMUEL, W.M., M.J. PYBUS, AND A.A. KOCAN, editors. 2001. Parasitic diseases of wild mammals. Iowa State University Press, Ames, USA.

SCHMITZ, K.L. 1997. Proceedings: national feral swine symposium. USDA, APHIS Veterinary Services, Riverdale, MD, USA.

SOUTHEASTERN COOPERATIVE WILDLIFE DISEASE STUDY. 1994. Wild swine behind fence. SCWDS Briefs 10:2. University of Georgia, Athens, GA, USA.

STALLKNECHT, D.E., V.F. NETTLES, G.A. ERICKSON, AND D.A. JESSUP. 1986. Antibodies to vesicular stomatitis virus in populations of feral swine in the United States. Journal of Wildlife Diseases 22:320-325.

STONE, C.P., AND J.M. SCOTT, editors. 1985. Hawaii's terrestrial ecosystems: preservation and management. University of Hawaii Press, Honolulu, HI, USA.

SWEENEY, J.M., AND J.R. SWEENEY. 1982. Feral hog. Pages 1099-1113 *in* J.A. Chapman and G.A. Feldhamer, editors. Wild mammals of North America. John Hopkins University Press, Baltimore, MD, USA.

SWEITZER, R.A. 1998. Conservation implications of feral pigs in island and mainland ecosystems, and a case study of feral pig expansion in California. Proceedings of the Vertebrate Pest Conference 18:26-34.

TEXAS ANIMAL HEALTH COMMISSION. 1999. Proceedings of the feral swine symposium. Texas Animal Health Commission. Austin, TX, USA.

UPDIKE, D. 1998. Changes in wild pig depredation in California: a new law. Proceedings of the Vertebrate Pest Conference 18:87-89.

USDA. 1998. Swine brucellosis control/eradication: state-federal-industry uniform methods and rules. APHIS 91-55-042. USDA, APHIS, Riverdale, MD, USA.

_____. 1999. Bovine tuberculosis eradication: uniform methods and rules, effective January 22, 1999. APHIS 91-45-011. USDA, APHIS, Riverdale, MD, USA.

_____. 2000. Pseudorabies eradication: state-federal-industry program standards, effective January 1, 2000. APHIS 91-55-051. USDA, APHIS, Riverdale, MD, USA.

VAN VUREN, D. 1992. Eradication of feral goats and sheep from island ecosystems. Proceedings of the Vertebrate Pest Conference 15:377-381.

WILLIAMS, E.S., AND I.K. BARKER, editors. 2001. Infectious diseases of wild mammals. Iowa State University Press, Ames, USA.

WITMER, G.W., AND J.C. LEWIS. 2001. Introduced wildlife of Oregon and Washington. Pages 423-443 *in* D. Johnson and T. O'Neil, editors. Wildlife-habitat relationships in Oregon and Washington. Oregon State University Press, Corvallis, OR, USA.

WOBESER, G.A. 1994. Investigation and management of disease in wild animals. Plenum Press, New York, NY, USA.

WOOD, G.W., editor. 1977. Research and management of wild hog populations: proceedings of a symposium. Belle W. Baruch Forest Science Institute, Clemson University, Georgetown, SC, USA.

_____, AND R.H. BARRETT. 1979. Status of wild pigs in the United States. Wildlife Society Bulletin 7:237-246.

_____, J.B. HENDRICKS, AND D.E. GOODMAN. 1976. Brucellosis in feral swine. Journal of Wildlife Diseases 12:579-582.