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Food Safety Risks and Mitigation Strategies for Feral Swine (*Sus scrofa*) near Agriculture Fields

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ABSTRACT: Feral swine may harbor the causative agents of important foodborne diseases such as brucellosis, cryptosporidiosis, salmonellosis, and trichinosis. We described recently the isolation of *Escherichia coli* O157:H7 from feral swine in the central California coast during an investigation of a nationwide outbreak associated with consumption of contaminated fresh baby spinach. Additionally, the foodborne pathogen *Campylobacter* was found in tissues and feces from the same population of feral swine. Feral swine are the most abundant free-roaming ungulate in the United States, and their range in California continues to expand, with the highest numbers reported on the central coast. The expansion of feral swine in mainland California and concomitant damage to agriculture and public health underscore the need for mitigation strategies. A number of lethal and non-lethal methods for feral swine management have been described, including hunting, depredation, trapping, and exclusion such as fencing. This paper reviews current concerns relating to food safety and feral swine. The advantages and potential pitfalls of mitigation strategies to reduce the risk of contamination of raw vegetable commodities by free-roaming feral swine are discussed.

KEY WORDS: *Campylobacter*, *Escherichia coli* O157, feral swine, food safety, produce, public health, *Sus scrofa*, wild boar, wildlife damage management

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INTRODUCTION

We described recently the isolation of *E. coli* O157:H7 from feral swine and other environmental samples in the central California coast during an investigation of a nationwide outbreak associated with consumption of contaminated fresh baby spinach (Jay et al. 2007). The possibility that feral swine could be one of the risk factors for the spread of *E. coli* O157:H7 to raw vegetable crops or surrounding watersheds in California represents yet another challenge in wildlife damage management. Many potential negative impacts of feral swine, a non-native species in the United States, have been described (Frederick 1998, Seward et al. 2004, Sweitzer 1998), for example, damage to native wildlife and plant ecosystems, livestock depredation, agriculture crop or property damage, and spread of disease. Despite a long history of recognizing problems caused by expanding feral swine populations, the ability to accurately document their numbers and identify the best strategies for effective mitigation remain difficult goals, especially on the mainland. In this paper, we review potential food safety concerns posed by free-roaming feral swine and suggest an integrated approach for feral swine management to reduce the risk of foodborne pathogen contamination and damage to crop fields.

FERAL SWINE IN CALIFORNIA

Feral domestic pigs (*Sus scrofa*) were established in North America by the 1500s and around several Spanish missions in the central and north coast areas of California by the 1850s (Sweitzer 1998, Waithman et al. 1999). European wild boar were released on a private ranch in Monterey County, California in 1925, and have since interbred with the already present feral pigs (hereafter termed feral swine). Feral swine are the most abundant

free-roaming ungulate in the U.S., and their range continues to expand. Estimates of the number of feral swine in the U.S. vary widely, but the largest populations are thought to exist in California, Florida, Hawaii, and Texas.

In California, feral swine have been regulated as a big game mammal since 1957 (Updike and Waithman 1996). According to records from the California Department of Fish and Game (DFG), the total number and counties where feral swine were harvested (based on license tags from hunters) have been increasing since the 1960s (Waithman 2001). Feral swine populations have been documented in 56 of the state's 58 counties, but their highest density and widest distribution is on the central coast. Revenues generated by recreational hunting are used for feral swine management, but costs to agriculture remain high, with landowners estimating ≈\$1.7 million per year in damages in California (Frederick 1998); actual costs probably are much higher. Economic losses due to disease impacts, including the potential involvement of feral swine in the spinach outbreak in 2006, have not been quantified. In California, requests to the USDA Wildlife Services for assistance with feral swine problems are increasing (USDA 2007). The complaints are most commonly due to damages to field or row crops, vineyards, pastures, gardens, roads and fences, native wildlife, plants, and livestock.

FOOD SAFETY ISSUES AND FERAL SWINE

Feral swine are highly mobile disease reservoirs and of increasing concern, due to their potential role in the spread of zoonotic and livestock pathogens such as avian influenza, brucellosis, classical swine fever, foot and mouth disease, pseudorabies, and trichinosis (Hutton et al. 2006, Seward et al. 2004). Reports of zoonotic disease

transmission between feral swine and humans are relatively uncommon, but large outbreaks of trichinosis have been attributed to consumption of contaminated feral swine or wild boar meat (Barrett-Connor et al. 1976, Greenbloom et al. 1997, Serrano et al. 1989). An epidemiologic study of brucellosis trends in Florida revealed 6 human cases among feral swine hunters (Bigler et al. 1977). A recent survey of feral swine carcasses processed in Australia identified low levels of *Salmonella* contamination (Eglezos et al. 2008). These findings underscore the importance of following proper handling and cooking procedures when field dressing or preparing wild game meat.

Domestic animals and wildlife may shed zoonotic enteric bacteria or parasites in their feces and contribute to the contamination of watersheds, soil, and plants, including vegetable crops. Atwill et al. (1997) showed that *Cryptosporidium* and *Giardia*, two protozoan species that may cause gastroenteritis in humans, are present in feral swine populations in California, which may be a source of contamination for surface water. Entry of free-roaming wildlife into fresh-produce growing areas such as vegetable-crop fields or orchards could result in direct contamination by fecal deposition. For example, deer were suspected as a possible source of contamination of dropped apples used in unpasteurized juice, linked to a large, multistate outbreak of *E. coli* O157:H7 (Cody et al. 1999).

In addition to the isolation of *E. coli* O157:H7 from feral swine during the spinach outbreak investigation, *Campylobacter* was cultured from colonic feces and tonsil samples (M. T. Jay, unpubl. data). *Campylobacter* is the leading cause of bacterial gastroenteritis in humans worldwide; infections are most often associated with consumption of contaminated chicken, but these bacteria are commonly found as commensal organisms in the intestines of many mammalian and avian hosts (Miller and Mandrell 2005).

***ESCHERICHIA COLI* O157:H7 IN SWINE**

E. coli O157:H7 infections are usually foodborne and may result in bloody diarrhea and other gastrointestinal symptoms; in susceptible persons, especially children under 5 years of age, the infection can lead to severe kidney disease and sometimes death. Historically, most outbreaks have been associated with ground beef consumption, but raw or minimally processed fresh produce (e.g., lettuce, spinach, unpasteurized juices, raw sprouts) has emerged as another important food vehicle. The FDA and the California Department of Public Health have documented 22 leafy green-associated *E. coli* O157:H7 outbreaks since 1995, and almost half were traced to production regions in California (Cooley et al. 2007). Results from these recent investigations suggest that initial contamination may be occurring at the farm level. The exact mechanism of in-field contamination of the plants is unknown, but potential environmental sources include contaminated fecal material (domestic livestock, wildlife, human), water, soil amendments (compost), or bioaerosols.

Evidence is mounting that domestic pigs sometimes serve as reservoirs of *E. coli* O157:H7 (Booher et al.

2002, Doane et al. 2007, Feder et al. 2003). Cornick and Helgerson (2004) determined experimentally that *E. coli* O157:H7 is transmitted from donor to naïve pigs, and infected pigs shed the bacteria in their feces for 2 months. In a subsequent study, *E. coli* O157:H7 was transmitted swine-to-swine, but not sheep-to-sheep, by contaminated aerosols (Cornick and VuKhaç 2008). In 2006, the strain of *E. coli* O157:H7 associated with a nationwide outbreak traced to consumption of fresh spinach was cultured from cattle feces, feral swine feces or colonic feces, soil, sediment, and surface water at a ranch in San Benito County, California (Jay et al. 2007). The relatively high percentage of positive specimens among feral swine (~15%) and the ease of recovery of *E. coli* O157:H7 from feces during that investigation suggested that feral swine could be a carrier.

The susceptibility of domestic and feral swine to colonization by *E. coli* O157:H7 should be the same; however, additional studies are needed to determine the prevalence of *E. coli* O157:H7 in feral swine populations across different geographic regions. Likewise, research is needed to determine the importance of proximity to cattle populations in maintaining or spreading *E. coli* O157:H7, especially in produce-growing regions in the central California coast where high numbers of feral swine exist and may co-mingle with grazing cattle.

RECOMMENDATIONS FOR PREVENTION OF FERAL SWINE INTRUSION IN CROP FIELDS

The International Fresh Cut Produce Association published commodity-specific food-safety guidelines for the lettuce and leafy greens supply chain in 2006 (Gorny et al. 2006). Identification of the specific risk factors and best practices for on-farm risk management to prevent contamination of leafy green vegetables are areas of active research by groups in government, academia, and industry. Feral swine and other wildlife represent one of many potential sources of foodborne pathogens at the farm level. Most of the published guidelines that address wildlife control are general in nature, and recommend monitoring and minimizing wildlife intrusion into crop production areas.

In California, approximately 99% of leafy-green handlers are members of the Leafy Green Handler Marketing Agreement, which mandates government audits to ensure that farmers follow accepted food-safety practices for lettuce, spinach and other leafy greens. Additionally, many growers, handlers, and retailers utilize third-party audits to monitor their food safety and quality programs at the farm and processing levels. A series of detailed metrics are used as guidelines for good agricultural practices (GAP) that must be followed by marketing agreement signatories. Assessing and mitigating potential risks due to wildlife near crop fields are important components of the GAP program. Some of these guidelines also have led to potential conflicts with conservation and water quality programs, especially recommendations to restrict wildlife movement using fencing and removal of wildlife habitat near crop fields (Beretti and Stuart 2008, Stuart 2006).

Extensive information is available on feral swine management in the context of ecosystem damage and

livestock depredation. Many of these principles are applicable to mitigation of disease risks including food-safety concerns from free-roaming feral swine. Below, we outline specific mitigation strategies that could be used to assess and manage feral-swine populations near leafy-green vegetable fields.

Defining the Risks

The central California coast supports a highly diverse wildlife population including large numbers of feral swine (Sweitzer et al. 2000, Waithman et al. 1999). The species and densities of wildlife populations vary widely between farms, depending on the surrounding habitat and time of the year. Before embarking on a major effort to control wildlife, growers should consider consulting with professional wildlife biologists or others with expertise in wildlife identification to define the specific risks from local wildlife and options for mitigation. For example, although feral swine are large mammals with distinct signs (e.g., droppings, tracks, trails, tree rubs, wallows, etc.), we found during the spinach outbreak investigation that most feral swine activity occurred from dusk to dawn (Jay et al. 2007). Thus, an auditor or inspector may not fully appreciate the presence of feral swine or other nocturnal wildlife near fields during a daytime visit to the farm.

Digital remote-sensing surveillance cameras, mark-capture-release, and passive tracking have been used to estimate swine population densities (Atwill et al. 1997, Jay et al. 2007, Seward et al. 2004, Sweitzer et al. 2000). Information on population density and behavior near crop fields is important when assessing the potential risk and control strategies. For example, we speculated that the high population density of feral swine (4.6 swine/km²) in close proximity to cattle could have been contributing factors to the contamination of spinach plants or surface water (Jay et al. 2007). Growers could consider using trail cameras or other surveillance methods to supplement routine visual observations in and around their fields. The added costs associated with conducting a more formal population assessment may be justifiable if the information can be used to develop effective and specific wildlife management programs. Strategies being used in the central California coast currently to control wildlife include fencing and habitat removal, both of which may be expensive, non-specific, and cause undesirable impacts on the environment and water quality (Beretti and Stuart 2008).

Mitigation Strategies for Feral Swine

If a grower determines that feral swine are a potential risk for microbial contamination of crop fields or nearby watersheds, especially if their population density is high, a combination of management strategies is recommended. Because of the adaptability and exceptionally high reproductive rate (mature females can produce about 10 offspring per year), feral swine control efforts are difficult, and complete eradication is unlikely in mainland settings (Frederick 1998, McCann et al. 2004, Updike and Waithman 1996). According to DFG, the feral swine population can withstand an annual combined mortality rate of 70% without affecting

existing populations (Waithman et al. 1999). In areas of high hunting pressures, feral swine have been known to adapt their behaviors to avoid humans. The relatively large home range and mobility of feral swine represent additional challenges in assessing and mitigating problems near crop fields.

A strategic plan for dealing with feral swine depredation in California has been proposed (Updike and Waithman 1996). Legal sport hunting is a major mechanism used to control feral swine populations in the state; however, feral swine populations are concentrated primarily on private land, which restricts access by most hunters. There is no initial cost to the landowner for sport hunting, and the results can be effective at reducing feral swine numbers to a manageable level. A possible disadvantage to sport hunting is the liability that landowners take by allowing hunting on their property. Depredation permits are an alternative to sport hunting. Permits in California are issued to private landowners by DFG, which allow the landowner or their agent to use legal methods (e.g., shooting and trapping) to remove feral swine known to damage, or threatening to damage, crops and personal property.

Fences can be an effective method to control feral swine movements onto sensitive agriculture crops. Fencing should be combined with feral swine population control by hunting or trapping to protect the perimeter of the fence. Studies suggest that feral swine-proof fences need to be constructed with heavy mesh wire secured to the ground to prevent digging, 2-3 strands of barbed wire above, and electrified stand-off wires (Hone and Atkinson 1983, McCann et al. 2004). In areas with high feral swine density, especially if hunting or trapping is limited (for example, if a neighboring landowner is opposed to hunting feral swine), a double fence may be needed (McCann et al. 2004). In a discrete area, such as a crop field, this method could be very effective, especially if the integrity of one fence is compromised.

There are disadvantages to fencing. For example, if both feral swine and deer are entering the crop field, the fencing requirements for these species are quite different. Fencing requires a substantial initial investment and also demands constant monitoring and upkeep to make repairs when needed (Hone and Atkinson 1983, McCann et al. 2004). Habitat removal is not likely to be an effective control strategy for feral swine, due to their mobility and large home range, but vegetation removal along the base of the fence is necessary to allow regular inspection of the integrity of the barrier. From an ecological standpoint, the use of some fences also can restrict movement of other wildlife to and from critical habitat. Additionally, landowners and residents may complain that the fences are unattractive.

Regardless of the methods chosen for feral swine management, it is critical that the landowner remains in compliance with local, state, and federal laws. Regional wardens and USDA Wildlife Services specialists are available to assist landowners with permits and interpretation of the regulations relating to wildlife control. Finally, feral swine can be dangerous, and precautions should be taken to ensure the safety of persons involved in the control program.

CONCLUSIONS

Feral swine populations are entrenched in the central California coast, where prime riparian and oak woodland habitat, water, and food sources are abundant. This region also supplies much of the country with leafy-green vegetables during the summer and fall months. In some locations, feral swine may damage these crop fields and possibly contribute to food safety concerns. Recent findings of foodborne pathogens such as *E. coli* O157:H7 and *Campylobacter* in feral swine feces suggest that they may contribute to microbial contamination of plants or the surrounding environment under the right conditions. Additional research is needed to better define the specific risks and best management approaches for feral swine and other local wildlife near crop fields. Success in mitigating food safety concerns related to feral swine ultimately depends on a coordinated effort between agriculture, conservation groups, industry, public health, researchers, wildlife agencies, and landowners.

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