# A Survey to Estimate Population Distribution of and Damage Caused by Feral Swine in Tennessee

**W. Ryan Jerrolds,** University of Tennessee at Martin, Department of Agriculture, Geosciences, and Natural Resources, 256 Brehm Hall, Martin, TN 38238

**Eric C. Pelren**, University of Tennessee at Martin, Department of Agriculture, Geosciences, and Natural Resources, 256 Brehm Hall, Martin, TN 38238

**Barbara A. Darroch**, University of Tennessee at Martin, Department of Agriculture, Geosciences, and Natural Resources, 256 Brehm Hall, Martin, TN 38238

R. Gray Anderson, Tennessee Wildlife Resource Agency, P.O. Box 40747, Nashville, TN 37204

*Abstract:* Feral swine (*Sus scrofa*) cause extensive damage to commercial agriculture, wildlife, natural habitats, and personal property throughout a growing number of states. There is a need to quantify the location and type of this damage in Tennessee. We surveyed four groups of agriculture and natural resource management professionals to identify how feral swine populations have dispersed across Tennessee in the last 25 years and identify what type of damage they caused. Farm Bureau County Presidents, University of Tennessee Extension Agents, Natural Resources Conservation Service District Conservationists, and Tennessee Wildlife Resources Agency Wildlife Officers were surveyed in each of the 95 Tennessee counties to identify counties inhabited by feral swine and categorize the damage they cause. According to survey respondents, feral swine have become widespread throughout Tennessee with reported populations in 89 of 95 counties. Although 35 counties (37%) reported  $\leq$ 5 total complaints of damage caused by feral swine, 39 counties (41%) indicated that complaints first occurred within the last five years (2008–2012). Additional studies are needed to further quantify expansion of feral swine populations and develop empirical estimates of damage caused by feral swine.

Key words: feral, swine, survey, Tennessee

Feral swine (Sus scrofa) have been present in North America since 1539 when Spanish explorers released domestic pigs to roam freely (Towne and Wentworth 1950). Introduction of Eurasian boar for hunting during the 1800s and 1900s and their accidental (Kellogg 1939) and intentional release into the wild led to additional genetic variation in swine populations (Rary et al. 1968, Seward et al. 2004). Eurasian boars were introduced into Hooper Bald, North Carolina just east of the Cherokee National Forest in 1912; they later escaped their enclosure and spread to surrounding areas (Stegeman 1938). In Tennessee, swine were stocked on the Catoosa Wildlife Management Area on the Cumberland Plateau in the early 1960s (Lewis 1966), as well as the Anderson Tully Wildlife Management Area in the Mississippi River area in 1979 (Wood and Barrett 1979). It is likely that many similar unrecorded introductions occurred. These populations are a major source of the continued feral swine population growth and distribution expansion across Tennessee.

Feral swine cause a variety of environmental and agricultural damage in North America; populations in the United States are estimated to cause in excess of US \$1.5 billion in damages annually (Pimentel 2007). The behavior and diet of the species causes

Journal of the Southeastern Association of Fish and Wildlife Agencies 1:167-174

many problems, as swine tend to root and create wallows, which are damaging to agriculture and the environment. In addition, feral swine are disease reservoirs and carry approximately 30 viral and bacterial diseases, and 37 parasites that can be transmitted to people, livestock, and native wildlife (Williams and Barker 2001, Seward et al. 2004, Pimentel 2007). Feral swine are also opportunistic predators and can impact native wildlife including threatened and endangered species and species of management concern (Stancyk 1982, Tolleson et al. 1993, Lewis et al. 1996, Seward et al. 2004).

Feral swine populations have been expanding northward from the southeastern and south central United States for several decades through natural population expansion (Seward et al. 2004, Stevens 2010) and introduction to new areas for sport hunting (Gipson et al. 1998, Stevens 2010, Yoest et al. 2013a). In Tennessee, a few well-established feral swine populations have been present for many decades, but numerous recently established populations have been identified in the last decade. In response to increased swine populations, more than 20 conservation and agricultural entities signed a memorandum of understanding (MOU) to work together to address the state's feral swine issue on a scale effective for eradication (Sweaney et al. 2013, Yoest et al. 2013a, Yoest et al. 2013b). A significant and controversial part of Tennessee's eradication effort was to eliminate sport hunting of feral swine, which had been liberalized and opened statewide, based on evidence that feral swine were being surreptitiously established across the state, rather than expanding their range naturally (Yoest et al. 2013a). Once well-established, these populations are difficult to control (Campbell and Long 2009).

Various methods have been used to quantify feral swine populations across the United States. Gipson et al. (1998) surveyed state wildlife and agricultural agencies in Kansas to determine the status of wild hogs. In California, Waithman et al. (1999) used hunter surveys and hunt tags received from hunters to evaluate changes in the distribution of wild hogs. Adams et al. (2005) surveyed landowners and managers using a self-administered, mailout questionnaire. This method was based on purposive sampling used by Schuett and Selin (2002) to select landowner respondents based on their involvement in five forest management initiatives. In Oklahoma, Stevens (2010) surveyed representatives from four state agencies to estimate population density of feral swine in each county. Survey respondents also estimated the year that feral hogs were first observed. These studies and others have demonstrated that feral swine populations are expanding across many states including Kansas (Gipson et al. 1998), California (Waithman et al. 1999), Texas (Adams et al. 2005), Oklahoma (Stevens 2010), Georgia (Mengak 2012), and Florida (Engeman et al. 2003).

A significant impediment to feral swine control efforts in Tennessee is lack of knowledge regarding population distribution, timing of population establishment, and types of damage. This knowledge is sought by MOU partners and other decision-makers working to eradicate feral swine in Tennessee. In response to growth in distribution and population, we administered a survey to determine feral swine population distributions and damage in Tennessee. Our goals were to estimate (1) when feral swine were first identified in each county and when damages were first reported; (2) number of swinerelated landowner complaints in each county and cause of these complaints; and (3) frequency and nature of damage.

### Methods

During fall 2012, we conducted a survey of Tennessee Wildlife Resources Agency (TWRA) wildlife officers, University of Tennessee (UT) Extension Service county agents, Natural Resources Conservation Service (NRCS) district conservationists, and Farm Bureau county presidents. These groups were selected based on their involvement with landowners throughout the state. The highest ranking TWRA Wildlife Officer was chosen from each of the 95 Tennessee counties. We used only one officer per county based on the assumption that information would be shared; this avoided repetition in the results. From each county, one UT Extension agent who had the most natural resources experience and responsibility (based on their assigned duties) in their county was also selected. Jurisdictions of several NRCS district conservationists spanned multiple counties, so only 54 were surveyed collectively to represent every county. Farm Bureau was represented by each of the 95 county presidents. The survey was reviewed by five professionals to ensure validity of the survey questions and was approved by IRB Docket #13-187-E05-4005.

The questionnaire began by asking if the respondents had knowledge or evidence of the presence of feral swine in their county. Respondents who answered yes were asked: how long have you lived or worked in this county, when did you first notice swine, and when did you first notice damage? The questionnaire then asked for an estimated total number of landowner complaints in the past year, and to categorize these complaints by type of damage.

The survey was administered via SurveyMonkey (www.survey monkey.com) for TWRA, NRCS, and UT Extension employees over a three-week period beginning on 26 October 2012. At the end of the first and second week, follow up e-mails were sent to all selected participants who had not responded. Farm Bureau Presidents responded to a written survey that was administered during their annual meeting in December 2012. To minimize bias caused by using two modes of survey delivery, we used a unified mode of questionnaire construction (Dillman et al. 2009) for both the web-based and paper surveys. Non-response bias was assumed to be minimal because of the specific, targeted groups that were surveyed.

Results were compiled into a single Excel (Microsoft Office 2013) file combining the information from each group. This information was organized so that it could be transferred to ArcGIS (v10.1, ESRI). Excel was used to provide tables, statistical calculations, and figures for all of the combined results. ArcGIS was used to create maps detailing results. The frequency procedure in SAS 9.3 was used to calculate chi-square values based on count data to determine if type of damage was independent of TWRA region. Regions included West Tennessee (Region I), Middle Tennessee (Region II), Cumberland Plateau (Region III), and East Tennessee (Region IV, Figure 1). Damage was grouped into categories as listed in Table 1.

#### Results

Of the 244 people surveyed online, 152 (62%) responded; 89 (94%) of the 95 Farm Bureau presidents responded to the written survey. The final sample size of respondents included 241 of 339 individuals (71%). On average, respondents had 17 years of experience working or living in their county. Feral swine were identified

**Table 1.** Total number of landowner complaints and chi-square statistics, by category, reported to natural resource professionals in each Tennessee Wildlife Resources Agency Region during 2012. Total  $\chi^2$  statistic has 27 degrees of freedom, a value of 823.5, and a *P* < 0.0001.

	Region 1		Region 2		Region 3		Region 4	
Damage <sup>b</sup>	Number <sup>a</sup>	Cell $\chi^2$						
Commercial row crops	42	111.0	62	1.4	183	17.1	172	14.0
Personal crops	5	12.2	233	34.1	583	21.7	194	29.7
Specialty crops	16	0.0	16	19.2	129	4.9	139	40.1
Equipment	5	2.9	16	50.5	293	1.3	192	17.3
Livestock	16	2.0	2	81.6	386	28.4	141	1.0
Pasture	10	2.8	159	7.6	418	1.1	227	0.0
Forest/timber	7	0.0	126	96.7	122	21.7	88	0.8
Loss of lease value	15	4.8	76	1.8	206	1.5	118	0.0
Owner and/or employee time	5	3.5	19	51.6	314	1.4	206	18.1
Other	0	8.9	132	63.0	262	4.2	33	63.4

a. Number = number of complaints per region

b. Commercial crops include corn, wheat, soybean, etc.; personal crops include gardens, ornamental plants, etc.; specialty crops include sod, orchards, etc.; equipment includes

fences, water troughs, or other improvements; loss of lease value includes damage to food plots and habitat improvements.



Figure 1. Map of statewide feral swine distribution, divided into Tennessee Wildlife Resources Agency regions, indicating absence or presence of swine, or no response from reports to natural resource professionals in each Tennessee county, as reported in 2012.

in 89 counties (94%) by the survey group (Figure 1). Knowledge of feral swine in their respective counties was reported by 152 of the 241 participants (63%). Participants from 26 counties (27%) indicated first identifying feral swine in or prior to 2007 (Figure 2) and damage was first identified within this period in 25 counties (26%, Figure 3). However, within the five-year period from 2008–2012, participants from an additional 31 counties (33%) noted the presence of feral swine (Figure 2) and 39 counties (41%) first identified damage (Figure 3). This represents a 60% increase in counties that identified feral swine and a 62% increase in counties that first identified damage. Four counties reported no feral swine and two counties had no response (Figure 1).

Although respondents from 35 counties estimated  $\leq$ 5 complaints, 15 counties reported  $\geq$ 21 complaints in the last year (Fig-

ure 4). Complaints related to personal crops (n = 1019) and pastures (n = 824) were the most common complaints received statewide in 2012 (Figure 5). On average, 12 (SE = 3.4) personal crop complaints and 9 (SE = 2.8) pasture complaints were reported per county (Figure 6).

A chi-square analysis comparing damage in the four TWRA regions verified (*P* <0.0001) that category of damage was related to region (Figure 7). Region I (West Tennessee) had more than the expected number of complaints regarding row crop damage (cell  $\chi^2$ =110.9, Table 1). Region II (Middle Tennessee) varied the most from the other regions with notably greater timber/forest damage (cell  $\chi^2$ =96.7) and complaints in the "other" category (cell  $\chi^2$ =62.9). Region II also had significantly fewer than expected complaints regarding livestock (cell  $\chi^2$ =81.6), equipment (cell  $\chi^2$ =50.5) and



Figure 2. Estimated first indication of feral swine reported to natural resource professionals categorized by how long swine have been present in each Tennessee county, as reported in 2012.



Figure 3. Estimated first indication of damage from feral swine reported to natural resource professionals categorized by how long swine have been causing damage in each Tennessee county, as reported in 2012.



**Figure 4.** Estimated greatest number of landowner complaints regarding feral swine reported to natural resource professionals in each Tennessee county during 2012. When more than one response was provided, the greatest number was chosen.



Figure 5. Estimated greatest number of landowner complaints regarding feral swine, by category, reported to natural resource professionals in each Tennessee county during 2012. When more than one response was provided, the greatest number was chosen. Specialty crops include sod, orchards, etc.; personal crops include gardens, ornamental plants, etc.; loss of lease value includes damage to food plots and habitat improvements; equipment includes fences, water troughs, or other improvements; commercial crops include corn, wheat, soybean, etc.



Figure 6. Mean and 95% confidence interval of landowner complaints regarding feral swine, by category, reported to natural resource professionals in each Tennessee county during 2012. Specialty crops include sod, orchards, etc.; personal crops include gardens, ornamental plants, etc.; loss of lease value includes damage to food plots and habitat improvements; equipment includes fences, water troughs, or other improvements; commercial crops include corn, wheat, soybean, etc.

owner and/or employee time (cell  $\chi^2$ =51.6). Region III (Cumberland Plateau) had more than expected complaints regarding livestock (cell  $\chi^2$ =28.4) and personal crop damage (cell  $\chi^2$ =21.7), but fewer than expected complaints related to timber/forest resources (cell  $\chi^2$ =21.7). Region IV (East Tennessee) had more than expected complaints concerning personal crop loss (cell  $\chi^2$ =29.7) and specialty crop loss but fewer than expected complaints in the other category (cell  $\chi^2$ =63.4, Figure 7, Table 1).

During 2012, counties within West Tennessee reported the most complaints in row crop damage, with 42 reported complaints (= 2/ county, SE = 0.6, Figure 8). Counties in Middle Tennessee reported a high number of complaints (n = 233, = 9/county, SE = 0.9) regarding personal crop losses, 159 (=7/county, SE = 3.9) complaints regarding pasture damages, and 126 (=5/county, SE = 3.9) complaints regarding forest/timber damages. Counties in Cumberland Plateau reported 583 (= 25/county, SE = 9.9) complaints regarding

personal crop losses, 418 (=18/county, SE=8.7) complaints regarding pasture damages, and 386 (=17/county, SE=13.1) complaints regarding livestock damages. Counties in East Tennessee reported 227 (=12/county, SE=5.5) complaints regarding pasture damages, 206 (=11/county, SE=5.2) complaints regarding owner and/or employee time, and 194 (=10/county, SE=5.4) complaints regarding personal crop losses (Figure 8).

Thirty counties had reports of households raising heritage breed pigs, 26 of which reported less than three households in their county. Four counties reported 10 or more resident households that kept heritage pigs: 15 in Cocke County, 12 in Cumberland County, 30 in Monroe County, and 10 in Sevier County. Eightyfive percent of survey participants were unaware of heritage pigs in their respective counties or believed there to be none present.



Figure 7. Estimated percentage of each category of damage caused by feral swine as reported by land owners to natural resource professionals in each Tennessee Wildlife Resources Agency region during 2012. Specialty crops include sod, orchards, etc.; personal crops include gardens, ornamental plants, etc.; loss of lease value includes damage to food plots and habitat improvements; equipment includes fences, water troughs, or other improvements; commercial crops include corn, wheat, soybean, etc.





## Discussion

Feral swine populations expanded widely in Tennessee over the past 30 years, from approximately 15 counties in 1982 (TWRA unpublished data) to 89 counties in 2013. A majority (60%) of counties reported first observing feral swine populations in the five-year period from 2008 through 2012, and respondents from 41 counties reported damages within this same time frame. This rapid increase in feral swine distribution and damage follows the pattern of growth that is evident nationally (Mengak 2012, Stevens 2010, Gipson et al. 1998) and confirms perceptions of wildlife professionals in Tennessee that recent increases in swine populations have been significant statewide.

Approximately 85% of counties reported feral swine in the last 15 years, which roughly corresponds with liberalization in feral swine hunting regulations in Tennessee. In an effort to reduce feral swine populations, TWRA opened a statewide sport hunting season in 1999. However, this study shows that hunting has not controlled population growth; counties with feral swine present approximately quadrupled from 1999 to present. Other studies have also shown that sport hunting alone has been ineffective at controlling feral swine populations and damage (Zivin et al. 2000, Campbell and Long 2009). Sport hunting may exacerbate the spread of feral swine rather than reducing their numbers because there is some evidence to indicate that hunters have released feral swine in new areas (Gipson et al. 1998, Cavendish et al. 2008, Yoest 2013a). Acknowledging that sport hunting regulations designed to reduce feral swine populations have been unsuccessful in Tennessee should be a consideration when other states attempt to control the species.

The greatest number of complaints of damage caused by feral swine dealt with personal crops, pastures, and owner and/or employee time. Damage to personal crops and pasture land is relatively difficult to quantify but the prevalence of gardens and pastures throughout Tennessee is the likely explanation for the high number of complaints. In some counties, it is possible that estimates of swine populations were tied directly to damage caused by feral swine. However, in counties with large areas of public lands or large forested tracts, populations of swine were identified even though the number of damage complaints was relatively low.

West Tennessee had fewer complaints than other regions likely due to feral swine just starting to establish there. The Cumberland Plateau had more complaints regarding livestock than other regions, reflecting the prevalence of livestock in this region of the state. East Tennessee and the Cumberland Plateau had a high level of complaints regarding employee time spent dealing with swine. Several counties in East Tennessee include portions of the Great Smoky Mountains National Park and the Cherokee National Forests, and are generally known to harbor high densities of feral swine (Stegeman 1938, Cavendish et al. 2008). The number of complaints in some of these counties was relatively low, perhaps due to the relatively low amount of private land. Blount County, in particular, includes a significant amount of public land and, perhaps as a result, exhibited fewer complaints and damage than surrounding counties. Additionally, landowners in these regions, where swine have long been present (Stegeman 1938, Cavendish et al. 2008), may be more experienced and adept at dealing with the damage.

Types of swine damage varied by region; however, damage to personal crops, pastures, commercial crops, and timber were high in all regions of the state. Less row crop damage was reported in East Tennessee than in the Cumberland Plateau counties, likely due to a lower presence of row crops. The introduction of swine is more recent in West Tennessee; therefore, damage in this region has been relatively low, but the extensive row crops in this region are vulnerable to the growing feral swine population.

In summary, according to survey respondents, feral swine are no longer isolated to the northern Cumberland Plateau and Appalachian region and the two areas of Tennessee where they have been historically present; they are widespread, and their abundance is increasing. The rapidity of recent expansion also stresses the need for urgency in management actions. Many small disjunct pockets of feral swine may be at small enough levels for local eradication to be possible, but allowing these pockets to grow will result in increased cost and decreased feasibility of eradication. Finally, this distribution and damage information can be used to better educate landowners and decision makers in all areas about the negative impact of feral swine and ultimately the need to eradicate them from the landscape.

### Acknowledgments

We would like to thank the cooperators of the Tennessee Wild Hog MOU, particularly the TWRA Officers, UT Extension Agents, NRCS District Conservationists, and Farm Bureau County Presidents who participated in the survey. We would also like to thank Dr. Ben West, Chuck Yoest, and Joy Sweaney for editorial comments.

#### **Literature Cited**

- Adams, C. E., B. J. Higginbotham, D. Rollins, R. B. Taylor, R. Skiles, M. Mapston, and S. Turman. 2005. Regional perspectives and opportunities for feral hog management in Texas. The Wildlife Society Bulletin 33:1312–1320.
- Campbell, T. A. and D. B. Long. 2009. Feral swine damage and damage management in forested ecosystems. Forest Ecology and Management 257:2319–2326.
- Cavendish, T., W. Stiver, and E. K. Delozier. 2008. Disease surveillance of wild hogs in Great Smoky Mountains national park - A focus on Pseudorabies.

Paper 7 in 2008 National Conference on Feral Hogs, 13–15 April 2008, St. Louis, Missouri.

- Dillman, D. A., J. D. Smyth, and L. M. Christian. 2009. Internet, mail, and mixed-mode surveys: The tailored design method, 3rd edition. John Wiley and Sons, Inc. Hoboken, New Jersey.
- Engeman, R. M., H. T. Smith, S. A. Shwiff, B.U. Constantin, M. Nelson, D. Griffin, and J. Woolard. 2003. Prevalence and economic value of feral swine damage to native habitat in three Florida state parks. Environmental Conservation 30:319–324.
- Gipson, P. S., B. Hlavachick, and T. Berger. 1998. Range expansion by wild hogs across the central United States. Wildlife Society Bulletin 26:279– 286.
- Kellogg, R. 1939. Annotated list of Tennessee mammals. Proceedings of the United States National Museum 86(3051):245–303.
- Lewis, J. C. 1966. Observations of pen-reared European hogs released for stocking. Journal of Wildlife Management 30:832–835.
- Lewis, T. E., D. Atencio, R. Butgereit, S. M. Shea, and K. Watson. 1996. Sea turtle nesting and management in northwest Florida. Pages 162–164 in Proceedings of the Fifteenth Annual Workshop on Sea Turtle Biology and Conservation. J. A. Keinath, D. E. Bernard, J. A. Musick, and B. A. Bell, editors. NOAA Technical Memorandum NMFS-SEFSC-387, Springfield, Virginia.
- Mengak, M. 2012. 2012 Georgia Pig Survey Final Report. Warnell School of Forestry and Natural Resources, University of Georgia, Athens.
- Pimentel, D. 2007. Environmental and economic costs of nonindigenous species in the United States. Proceedings of an International Symposium USDA/APHIS/WS, National Wildlife Research Center, Fort Collins, Colorado.
- Rary, J. M, V. G. Henry, G. H. Matschke, and R. L. Murphree. 1968. The cytogenetics of swine in the Tellico Wildlife Management Area, Tennessee. Journal of Heredity 59: 201–204.
- Schuett, M.A. and S. Selin. 2002. Profiling collaborative natural resource initiatives and active participants. Northern Journal of Applied Forestry 19:155–160.

Seward, N. W., K. C. VerCauteren, G. W. Aitmer, and R. M. Engeman. 2004.

Feral swine impacts on agriculture and the environment. Sheep and Goat Research Journal 19:34–40.

- Stancyk, S. E. 1982. Non-human predators of sea turtles and their control. Pages 139–152 in Biology and Conservation of Sea Turtles. K. A. Bjorndal, editor. Smithsonian Institution Press, Washington, D.C.
- Stegeman, L. C. 1938. The European wild boar in the Cherokee National Forest, Tennessee. The Journal of Mammalogy 19:279–290
- Stevens, R. 2010. The feral hog in Oklahoma, second edition. The Samuel Roberts Noble Foundation, Ardmore, Oklahoma.
- Sweaney, J., C. Yoest, D. Ratajczak, and G. Anderson. 2013. Tennessee Wild Hog Annual Report. TWRA Wildlife Technical Report 13-09. Tennessee Wildlife Resources Agency, Nashville.
- Tolleson, D., D. Rollins, W. Pinchak, M.Ivy, and A. Hierman. 1993. Impact of feral hogs on ground-nesting gamebirds. Pages 76–83 in C. W. Hanselka and J. F. Cadenhead, editors. Feral swine: A compendium for resource managers. Texas Agricultural Extension Service, Kerrville.
- Towne, C. W. and E. N. Wentworth.1950. Pigs from cave to cornbelt. University of Oklahoma Press, Norman.
- Waithman, J. D., R. A. Sweither, D. V. Vuren, J. D. Drew, A. J. Brinkhaus, I. A. Gardner, and W. M. Boyce. 1999. Range expansion, population sizes, and management of wild pigs in California. Journal of Wildlife Management 63:298–308.
- Williams, E. S. and I. K. Barker. 2001. Infectious Diseases of Wild Mammals. Iowa State University Press, Ames.
- Wood, G. W. and R. H. Barrett. 1979. Status of wild pigs in the United States. Wildlife Society Bulletin 7:237–246.
- Yoest, C., J. Sweaney, D. Ratajczak, and G. Anderson. 2013a. Tennessee Wild Hog Management Plan. TWRA Wildlife Technical Report 13–08. Tennessee Wildlife Resources Agency, Nashville.
- \_\_\_\_\_, G. Anderson, J. Sweaney, and D. Gibbs. 2013b. Tennessee Wild Hog Operational Plan. TWRA Wildlife Technical Report 13–10. Tennessee Wildlife Resources Agency, Nashville.
- Zivin, J., B. Hueth, and D. Zilberman. 2000. Managing a multiple-use resource: The case of feral pig management in California rangeland. Journal of Environmental Economics and Management 39:189–204.