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Predation and disease-related economic impacts of wild pigs on livestock producers in 13 states

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ABSTRACT

We report the results of a survey on wild pigs (*Sus scrofa*) damage to livestock producers in 13 US states (Alabama, Arkansas, California, Florida, Georgia, Louisiana, Mississippi, Missouri, North Carolina, Oklahoma, South Carolina, Tennessee, Texas). The survey was distributed by the USDA National Agricultural Statistical Service in the summer of 2017 to a sample of livestock producers in the 13-state region. Findings indicate that predation and disease-related damage can be substantial in certain states and for certain types of livestock. In particular, damage to cattle operations in Texas and Arkansas was substantially higher than damage in other states and types of livestock operations. When extrapolated to livestock producers across the entire 13-state region, we estimated that damages sum to an annual cost of about $40 million. We hope findings from this survey will help guide control efforts and research, as well as serve as a benchmark against which the effectiveness of future control efforts can be measured.

1. Introduction

Wild pigs (*Sus scrofa*) have become widespread throughout much of the United States because of their reproductive potential, adaptable biology, and relocation by humans. (Seward et al., 2004). Over the past 30 years, the range of wild pigs has increased from 17 to 38 states (Bevins et al., 2014) (Fig. 1). The recent range expansion of wild pigs has inflicted substantial costs on agricultural producers in the United States. Though estimates of damage to agricultural production range widely and are largely context specific (Bevins et al., 2014), it is clear that wild pigs have the ability to damage most crops, destroy livestock through disease and depredation, compete with native wildlife, and effectively destroy ecosystems (Barrios-Garcia and Ballari, 2012; Crooks, 2002).

With the recent range expansion of wild pigs across much of the United States, an understanding of the economic and environmental impacts caused by this non-native invasive species has continued to develop. While much work has focused on wild pig impacts specific to a local geographic region or individual resource, some aggregate estimates of damage have been published. As an example of the latter, the widely cited estimates of invasive species impacts reported by Pimentel et al. (2005) include an estimate of country-wide wild pig damage in the US of $800 million annually. More specific analyses of wild pig impacts include effects of rooting in floodplains (Arrington et al., 1999), impacts on plant species richness (Hone, 2002), and depredation of invertebrates in wetlands (Doupé et al., 2010).

Recent efforts have been made to produce more rigorous estimates of wild pig impacts at aggregated levels. Regarding crop damage to major US crops, Anderson et al. (2016) estimates annual crop loss from wild pig damage of $190 million annually to corn, soybeans, wheat, rice, peanuts, and sorghum in 11 states. Impacts to livestock production have also been highlighted due to the potential for disease spread and impacts on international trade of related products (Miller et al., 2017). While it is accepted that wild pigs impose significant impacts on domestic livestock production via depredation and disease (Bevins et al., 2014), aggregate estimates analogous to those of Anderson et al. (2016) do not exist.

This manuscript summarizes a recent survey-based effort to fill in this gap. We proceed with a discussion of the survey instrument, survey distribution, and rules related to disclosure of information. Results are then presented with a focus on two key objectives: 1) wild pigs gaining access to livestock production areas and facilities, and 2) the types and severity of damages that livestock producers experienced. We additionally examined how the findings related to these objectives varied across states and types of livestock operations. Presentation of the results is followed by a discussion of their implications. Ultimately, the

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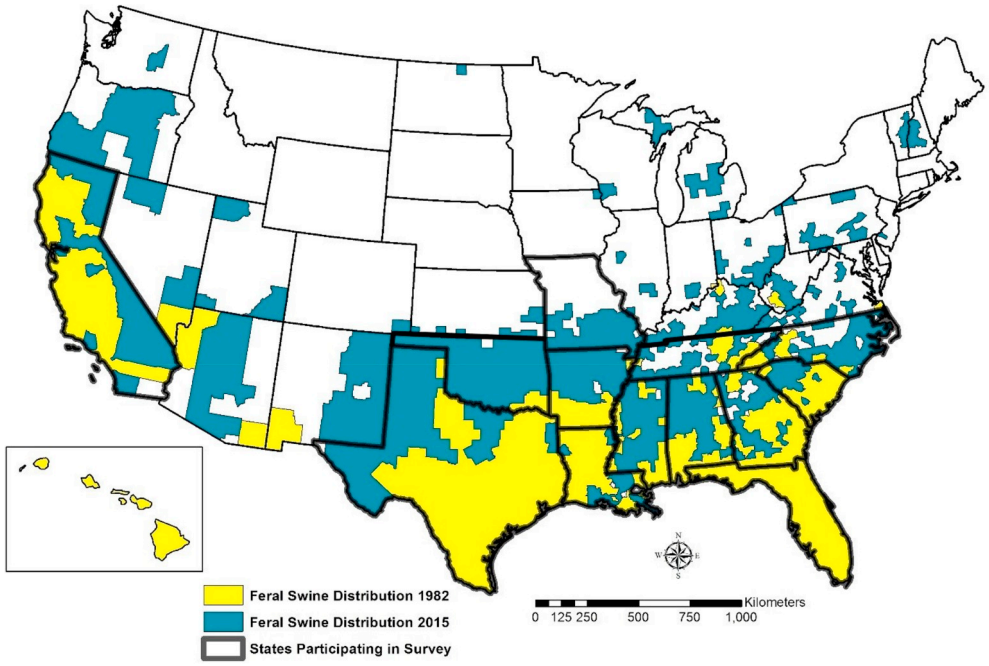

Fig. 1. Wild pig distribution in 1982 and 2015.

information we present may enhance the efficiency of producer and government led control efforts by allowing resources to be allocated to the most severe problems. Furthermore, this type of information could serve as a baseline against which the effects of future control efforts could be measured.

2. Methods

In order to obtain representative estimates of livestock impacts and costs of wild pigs at the state level, the US Department of Agriculture's (USDA) National Agricultural Statistical Service (NASS) distributed a survey designed by researchers at the USDA's National Wildlife Research Center. Targeted operations included producers of cattle (beef and dairy operations), swine, sheep, and goats. Following the 2015 survey of crop producers reported in Anderson et al. (2016), livestock producers in the same 11 states (Alabama, Arkansas, California, Florida, Georgia, Louisiana, Mississippi, Missouri, North Carolina, South Carolina, and Texas) were sampled, as well as Tennessee and Oklahoma, both of which are major producers of the targeted commodities and have wild pigs. States were ultimately selected by a subjective evaluation of economic importance (United States Department of Agriculture, 2014), vulnerability to feral swine (see Fig. 1), and political considerations.

The survey instrument was designed to elicit a range of values associated with wild pig presence. Although tailored in part to specifics of livestock production, the survey also collected information on crop impacts, property damages, control costs, and sport hunting practices. In addition to operation-wide questions regarding potential disease spread from wild pigs and related concerns, as well as pasture damages, producers were asked about livestock loss from wild pig depredation, disease, and other causes. Additionally, they were asked to report costs of medical treatments and veterinary services related to wild pig contact with their livestock. Producers that failed to respond to the initial mailing received multiple follow-up phone calls in an attempt to minimize non-response bias, and a total of 6,394 responses were obtained.

In this manuscript, we focused on two types of information collected by the survey. The first is the presence of wild pigs. Wild pig presence provides a general indication of the economic threat they pose in the area, either through direct damage or the risk of disease transmission. We solicited information on presence by asking two general questions regarding wild pig presence in the producer's county and on their operation (Fig. 2). Additionally, we asked questions about wild pigs gaining access to areas where livestock were being kept (Fig. 3). Finally, as a follow-up questions, we asked the producer to report how frequently access is occurring.

In addition to our interest in the presence and the frequency of gaining access to livestock areas, our other focus was on the perceived damages by wild pigs. We used a series of questions to solicit information regarding damages from producers in 2016 (Fig. 4). Specifically we asked about losses due to predation, disease, and unknown causes (e.g. undetermined, stress), as well as costs related to veterinary services (e.g. paying a veterinarian) and medical treatments (e.g. drugs costs).

Despite the potential inaccuracies associated with relying on self-reported damages, we chose this design for several reasons. First, self-reporting of wildlife damages to agriculture is common and has been

4. During the last three years, have wild pigs been present in the county reported in item 3? **For the purposes of this study, wild pigs refers to all species of feral swine, feral hogs, and wild boar.**			
106	1☐ Yes	3☐ No	2☐ Don't Know
5. During the last three years, have wild pigs been present on your operation?			
107	1☐ Yes	3☐ No	2☐ Don't Know

Fig. 2. Survey questions related to wild pig presence in the area.

d. In 2016, to the best of your knowledge, were wild pigs ever present in areas where these livestock are kept? (If **Yes**, continue. If **No** or **Don't Know**, SKIP to Item 4.)	136	1☐ Yes 2☐ Don't Know 3☐ No	137	1☐ Yes 2☐ Don't Know 3☐ No
(i) In 2016, to the best of your knowledge, how often were wild pigs present in areas where these livestock are kept?	138	1☐ Daily 2☐ Weekly 3☐ About once a month 4☐ Less than once a month	139	1☐ Daily 2☐ Weekly 3☐ About once a month 4☐ Less than once a month

Fig. 3. Survey questions related to wild pig presence on the operation and their impact on the two highest-valued livestock types that were on the operation.

h. In 2016, could you attribute deaths of these livestock on your operation to **predation** by wild pigs? (If **Yes**, continue. If **No**, SKIP to item i.)	292	1☐ Yes 3☐ No	293	1☐ Yes 3☐ No
(i) In 2016, how many head of these livestock were lost to wild pig predation?	144	___ head	145	___ head
(ii) What was the total market value of these livestock that were lost to wild pig predation?	146 $		147 $	
i. In 2016, could you attribute deaths of these livestock on your operation to **disease** from wild pigs? (If **Yes**. Continue. If **No**, SKIP to item j.)	294	1☐ Yes 3☐ No	295	1☐ Yes 3☐ No
(i) In 2016, how many head of these livestock were lost to disease from wild pigs?	296	___ head	297	___ head
(ii) What was the total market value these livestock that were lost to disease from wild pigs?	298 $		299 $	
j. In 2016, did you seek veterinary services for these livestock due to the presence of or contact with wild pigs? (If **Yes**, continue. If **No**, SKIP to item k.)	300	1☐ Yes 3☐ No	301	1☐ Yes 3☐ No
(i) What was the total cost of veterinary services used for these livestock due to the presence of or contact with wild pigs?	305 $		306 $	
k. In 2016, did you use any medical treatments on these livestock due to the presence of or contact with wild pigs? (If **Yes**, continue. If **No**, SKIP to item l.)	307	1☐ Yes 3☐ No	308	1☐ Yes 3☐ No
(i) What was the total cost of the medical treatments used for these livestock due to the presence of or contact with wild pigs?	309 $		310 $	
l. In 2016, could you attribute any deaths of these livestock on your operation to **other/unknown causes** of wild pigs? (If **Yes**, continue. If **No**, SKIP to item 4.)	311	1☐ Yes 3☐ No	312	1☐ Yes 3☐ No
(i) In 2016, how many head of these livestock were lost to wild pigs due to other/unknown causes?	313	___ head	314	___ head
(ii) What was the total market value of these livestock that were lost to other/unknown causes of wild pigs??	315 $		316 $	

Fig. 4. Questions related to wild pig damages to the two highest-valued livestock types that were on the operation.

shown to be quite accurate (Conover, 2002; Johnson-Nistler et al., 2005; Tzilkowski, 2002; Wywialowski, 1994). Second, livestock values can vary substantially according to region and type of livestock (even within specific categories). We believed it preferable to rely on producers that have first-hand knowledge of values and prices rather than making an assumption based on potentially crude pricing statistics. Finally, even if

Table 1
Wild pig presence in the last three years by state.

	In County			On Operation		
	Yes	No	Don't Know	Yes	No	Don't Know
Alabama	49%	32%	19%	17%	79%	4%
Arkansas	64%	21%	15%	33%	63%	4%
California	44%	38%	18%	21%	77%	2%
Florida	65%	23%	11%	34%	62%	4%
Georgia	54%	33%	14%	26%	70%	4%
Louisiana	73%	17%	11%	37%	60%	3%
Mississippi	66%	24%	11%	24%	71%	6%
Missouri	19%	58%	24%	5%	92%	3%
North Carolina	28%	49%	23%	7%	88%	5%
Oklahoma	75%	14%	11%	46%	50%	5%
South Carolina	61%	26%	13%	27%	68%	5%
Tennessee	30%	51%	19%	7%	89%	4%
Texas	88%	7%	4%	68%	31%	2%
Total	61%	26%	13%	37%	60%	3%

Table 2
Wild pig presence on operations in the last three years by type.

	Yes	No	Don't Know
Beef Cows	41%	56%	3%
Milk Cows	40%	59%	1%
Other Cattle	43%	54%	3%
Domestic Pigs	39%	58%	3%
Sheep and Lambs	28%	69%	4%
Goats and Kids	29%	68%	3%
Poultry	36%	62%	2%
Equine	42%	55%	3%
Other	44%	52%	4%
Total	40%	57%	3%

producer perceptions are not entirely accurate, the perception themselves are important to consider given that production and control decisions are based on these perceptions.

3. Results

A total of 12,000 surveys were administered by NASS, with a response rate of 53%, for a total of 6,394 responses. In order to produce estimates of wild pig impacts at the state level, NASS calculates weights that account for state-wide production of each commodity. Additionally, individual level responses are weighted to account for non-response by other producers. These producer-level weights were used and adjusted accordingly for non-response of specific questions, leaving estimates of wild pig damages representative at the state level. In cases where either a single producer made up a large portion of responses to a specific question or only a few producers responded to it, values are not disclosed in order to protect the private information of producers. At the state level, these disclosure requirements are largely unrestrictive in terms of limiting presentable results. Analysis of survey responses at the more disaggregated level of livestock types within states is not as immune to disclosure concerns and is therefore unreported here.

A majority (61%) of counties in most of the surveyed states are believed to have had wild pigs in the last three years (Table 1). Additionally, over a third (37%) of the targeted livestock producers in these states reported wild pigs on their operation during this period. The reported belief that wild pigs are present in the county or on the operation are highest in Texas (88%/68%) and Oklahoma (75%/46%) and lowest in Missouri (19%/5%) and North Carolina (28%/7%). In addition to summarizing presence at the state level, we also calculated the percent of responses that reported presence on their operation by livestock type (Table 2). Note that producers may report on more than one livestock type for their operation. Thus, total values do not necessarily align when comparing state-level and type-level calculations. The results indicate that operations with cattle were most likely to report the presence of wild pigs, while sheep and goat operations were the least likely.

Table 3
Producers reporting wild pigs had gained access to areas where livestock are kept.

	FS Had Gained Access	Frequency Seen (if present)			
		Daily	Weekly	About once a month	Less than once a month
Alabama	8%	29%	32%	19%	20%
Arkansas	23%	23%	30%	21%	22%
California	18%	27%	27%	22%	20%
Florida	25%	25%	22%	29%	23%
Georgia	14%	22%	31%	24%	24%
Louisiana	27%	18%	37%	22%	19%
Mississippi	15%	11%	28%	40%	16%
Missouri	3%	0%	40%	1%	59%
North Carolina	2%	22%	22%	0%	57%
Oklahoma	38%	32%	29%	20%	17%
South Carolina	15%	24%	20%	25%	26%
Tennessee	4%	0%	0%	40%	60%
Texas	60%	34%	26%	24%	14%
Total	30%	31%	27%	24%	17%

Table 4
Producers reporting wild pigs had gained access to where livestock are kept.

	FS Had Gained Access	Frequency Seen (if present)			
		Daily	Weekly	About once a month	Less than once a month
Beef Cows	35%	35%	26%	24%	13%
Milk Cows	33%	10%	36%	11%	43%
Other Cattle	27%	25%	32%	20%	22%
Domestic Pigs	29%	4%	1%	7%	77%
Sheep and Lambs	4%	34%	29%	0%	39%
Goats and Kids	20%	18%	16%	49%	18%
Poultry	7%	21%	42%	1%	37%
Equine	13%	0%	6%	59%	34%
Other	15%	15%	52%	33%	0%
Total	30%	31%	27%	24%	17%

A primary concern stemming from the close proximity of wild pigs and domestic livestock production is the potential for wild pigs to spread disease to both animals and humans (Miller et al., 2017). Although wild pigs may be present on many operations, the question of contact with domestic animals is more specific. To this end, producers were asked if wild pigs had gained access to areas where livestock were kept during 2016, and if so, how frequently wild pigs had been seen in these areas (Table 3, Table 4). As these responses are specific to each (of up to two) livestock types reported on, the state and type totals are the same. Regarding a comparison across states, the results largely mirror the results presented in Table 1. Nearly 34% of Texas responses indicated that wild pigs gain daily access to areas where livestock are kept. Significantly, in nine (82%) of the states, responses indicate that wild pigs are gaining daily access to areas where livestock are kept on over 20% of operations.

Beef cattle operations are the most likely to report wild pigs gaining access to areas where livestock are kept, while poultry and sheep and lambs are the least likely to report access gained (Table 4). We suspect that the differences observed in Table 4 are driven by several different factors. First, there may be geographic effects. Certain types of operations may be more prevalent in areas with high wild pig density. Additionally, biosecurity and the prevalence of large commercial operations probably plays a role. For example, large commercial cattle operations may find it difficult to prevent wild pig access, but hobby farms that raise small numbers of sheep, goats, or chickens may not have the

Table 5
Value of livestock deaths and medical expenditures due to wild pigs by state.

	Predation	Disease	Other Deaths	Veterinary Services	Medical Treatments
Alabama	$349,950	(D)	(D)	$55,538	$24,196
Arkansas	$3,160,753	$0	$2,810,725	(D)	$1,428,871
California	$19,193	(D)	$0	(D)	$5,803
Florida	$349,903	$0	$823,390	(D)	(D)
Georgia	$154,919	$59,872	$27,421	$46,717	$46,492
Louisiana	$204,053	(D)	$151,646	(D)	$81,588
Mississippi	(D)	(D)	(D)	(D)	$0
Missouri	(D)	$0	$0	$0	(D)
North Carolina	$0	$0	$0	(D)	(D)
Oklahoma	$107,586	$2,313,105	(D)	$301,242	$1,288,340
South Carolina	$126,089	$27,437	$11,212	$4,209	$10,308
Tennessee	$0	$0	$0	$0	$0
Texas	$12,794,578	$6,711,569	$2,946,801	$2,050,828	$543,673
Total	$17,303,516	$9,518,034	$7,003,548	$2,641,853	$3,481,148

Table 6
Value of livestock deaths and medical expenditures due to wild pigs by livestock type.

	Predation	Disease	Other Deaths	Veterinary Services	Medical Treatments
Beef Cows	$8,111,869	$8,594,582	$6,069,188	$2,034,733	$3,004,286
Milk Cows	(D)	$0	(D)	$0	$0
Other Cattle	$9,124,638	(D)	$887,602	(D)	$447,317
Hogs	(D)	$0	$0	(D)	(D)
Sheep	$0	$0	(D)	$0	(D)
Goats	$8,937	(D)	(D)	$0	(D)
Poultry	$0	$0	$0	$0	$0
Equine	(D)	(D)	$0	$0	$0
Other	$0	$0	$0	$0	$0
Total	$17,303,516	$9,518,034	$7,003,548	$2,641,853	$3,481,148

same difficulty if production occurs in small, easily enclosed areas.

Our primary objective was to collect information about economic impacts and damages. To address this objective we calculated the annual dollar value of livestock losses to predation, disease, and other deaths, as well as veterinary and medical expenditures, as a result of wild pigs. These values were calculated by state (Table 5) and livestock type (Table 6). For reasons of disclosure described above, some categories of damages cannot be reported. Such observations are given a "(D)", which means there may be positive loss in this category, but it cannot be reported. These values should not be interpreted as a zero. For columns where the value of more than one state or livestock type cannot be disclosed, the total may still contain the undisclosed values, and therefore be different from the sum of the reported values in that column. This also implies that the state-level estimates should be interpreted as lower bounds on the true damages.

It is apparent from these results that predation is the most severe impact to livestock producers. It is also clear that the majority of damages occur in Texas and Arkansas, while producers in many other states suffer relatively little damage. Likewise, cattle producers suffer far more damage that other livestock producers, largely as a result of the much higher production value of cattle.

4. Discussion

Contact between wild pigs and domestic livestock imposes a potentially wide range of costs on producers. These include losses of livestock to predation and disease, expenditures on veterinary services and medical treatments as a result of such contact, and costs of control efforts to reduce contact. Additionally, damages to property, loss of crops, rooting of pasture land, and damage to other farm resources (e.g. livestock waterers) may be significant (Bevins et al., 2014). In the present analysis we have focused on only a few of the relevant impacts. Thus, the total damages implied by our findings should be interpreted as a lower bound on the true impacts of wild pigs on livestock producers. This is reinforced by the fact accurate assessment of feral swine predation is hindered by pig's habit of consuming entire carcasses (Seward et al., 2004). Finally, additional caution is warranted because our results are based on self-reported damages.

Our results suggest that in the 13 states included in the study, wild pigs are believed to be present in most of the sampled counties, and on many of the operations sampled. Contact between wild pigs and domestic animals is also common and highlights the potential danger wild pigs pose in terms of disease transmission and other impacts. While the costs of control efforts and other damages may be substantial, this report summarizes only the direct costs in terms of deaths and medical expenditures resulting from wild pig presence. For the group of targeted producers in these 13 states, these damages sum to an estimated annual cost of $39,948,099.[1] Although the total estimated annual cost is not large relative to the size of the industry in the surveyed states, our findings have important implications. Damages appear to be heavily concentrated in several states and among several types of livestock producers. In fact, producers of most livestock types in most of the states with wild pigs populations appear to be relatively unaffected by the presence of wild pigs. This may result from relatively low swine density in many areas, differences biosecurity and control efforts, or geographic heterogeneity in the true nature of the threat posed by wild pigs.

We believe the results of our survey can serve two key purposes. First, an understanding of which areas and livestock types experience the most damage can help improve management efficiency. Producers and government agencies expend considerable time and effort managing wild pig damage, and knowing where the problem is most severe will help these entities allocate their resources more appropriately. Second, USDA/APHIS Wildlife Services has initiated a widespread feral swine control campaign. In addition to guiding the implementation of this program, the findings we present can serve as a benchmark for evaluating this control program. Thus, our hope is that this survey can be repeated at regular intervals to ensure that the objectives of the control

[1] This is the sum of the totaled values in Table 5.

program are being met and progress is being made against the threat that wild pigs represent to US agricultural producers.

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Appendix A. Supplementary data

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