Economic impacts of wild pigs on livestock producers in 13 states

Sophie C. McKee, U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Research Center, 4101 LaPorte Avenue, Fort Collins, CO 80521; and Colorado State University, Fort Collins, CO 80521, USA *Sophie.McKee@colostate.edu*

Ryan S. Miller, U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Center for Epidemiology and Animal Health, National Wildlife Research Center, Fort Collins, CO 80521, USA

Jeremiah L. Psiropoulos, U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, National Feral Swine Damage Management Program, National Wildlife Research Center, Fort Collins, CO 80521, USA

Stephanie A. Shwiff, U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Research Center, 4101 LaPorte Avenue, Fort Collins, CO 80521, USA

Abstract: Wild pigs (*Sus scrofa*) are an invasive species in the mainland United States, where they are responsible for a wide range of negative impacts including damage to crops, livestock depredation as well as disease transmission, destruction of property and ecosystems, and depredation of wildlife. This manuscript summarizes a recent survey-based effort to estimate wild pig damage and control costs incurred by livestock producers by state and livestock type. The survey was distributed by the U.S. Department of Agriculture National Agricultural Statistical Service in the summer of 2021 to a sample of livestock producers in the 13-state region. Findings indicated that predation and disease-related damage can be substantial in certain states and for certain types of livestock. In particular, damage to livestock operations, specifically cattle (*Bos taurus*) operations, in Texas, USA, was substantially higher than damage in other states and types of livestock operations. However, these amounts are dwarfed by the expenditure incurred by damage to property and the rooting of pasture. When aggregating across the entire 13-state region, we estimated that damage and control costs to livestock producers summed in 2020 to an annual amount of >$650 million USD, driven by damage to property ($375.5 million USD) and the rooting of pasture ($192.9 million USD). The findings from this survey provide valuable information to estimate the full scope of the economic impact of wild pigs in the United States.

Key words*:* economic impact, feral swine, invasive species, livestock damage, pasture damage, *Sus scrofa*, United States, wild pigs

Wild pigs (*Sus scrofa*: a.k.a. wild boar, wild/feral swine, wild/feral hogs [Keiter et al. 2016]) are an invasive species present in the mainland United States since the 16th century (Towne and Wentworth 1950) and are currently responsible for a wide range of negative impacts in the United States including damage to crops, livestock depredation, disease transmission, destruction of property and ecosystems, and depredation of wildlife (Barrios-Garcia and Ballari 2012, Bevins et al. 2014, Miller et al. 2017, Shwiff et al. 2017, McClure 2018). A growing body of literature seeks to describe and estimate their economic impact (Bankovich et al. 2016, Engeman et al. 2016, Didero et al. 2023, McKee et al. 2024).

Wild pigs are well documented as predators of lambs (*Ovis aries*), goats (*Capra hircus*), newborn cattle (*Bos taurus*), and exotic game (Seward et al. 2004). Animal matter typically makes up only a small percentage of their diet, but considerable economic loss can occur from livestock depredation (Taylor and Hellgren 1997). In the United States, they contribute to the transmission of at least 87% of economically important domestic animal diseases (Miller et al. 2017). With regard to the pathogens currently present in the United States, the livestock industry is most concerned with pseudorabies, leptospirosis, swine brucellosis, bovine tuberculosis, and vesicular stomatitis that could be spread by wild pigs (Seward et al. 2004, Miller et al. 2017). Pseudorabies represents a serious threat to domestic swine operations as it can cause production losses and swine brucellosis can be contracted by both humans

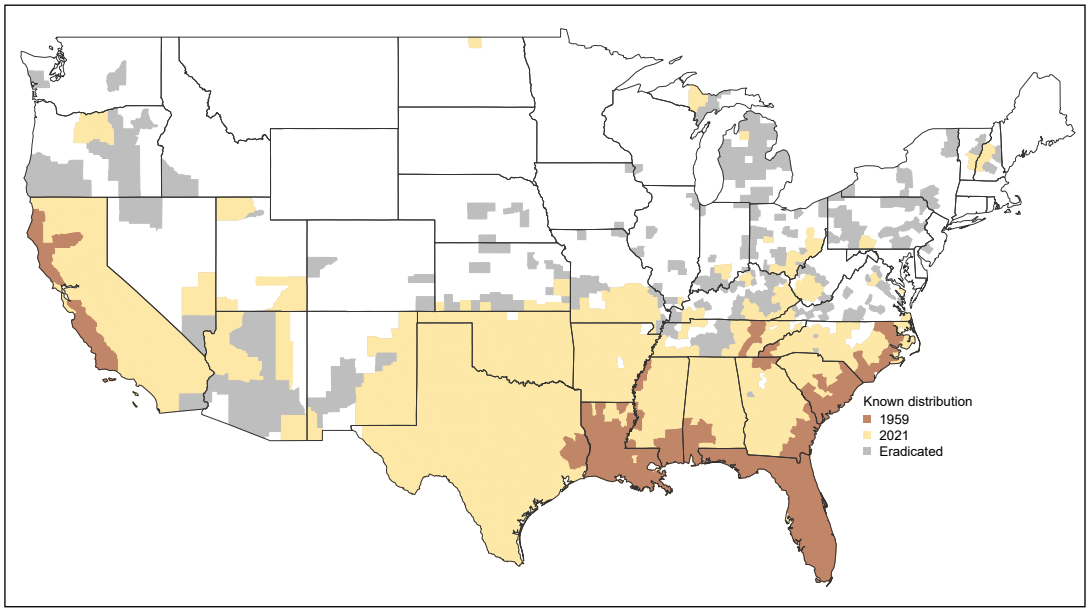

Figure 1. Change in county level distribution of wild pigs (*Sus scrofa*) in the contiguous United States from 1959 (brown) to 2021 (yellow). Gray indicates counties where pigs have previously occurred but are currently not present as a result of invasive species control activities. Data describing nationwide distribution (presence/absence) of wild pigs at the county scale are from these sources: National Feral Swine Mapping System Data (2022), Corn and Jordan (2017), Hanson and Karstad (1959), Waithman et al. (1999). Data were processed using methods described in Miller et al. (2018).

and domestic livestock (Hutton et al. 2006). With the recent discovery of African swine fever (ASF) in the Dominican Republic (World Organization for Animal Health 2022) and Haiti, along with historical detections in other Caribbean countries, ASF is a major concern for pork producers (Brown et al. 2021).

Another impact of wild pigs to livestock producers is that they commonly damage pastures and hayfields through rooting when searching for food items, potentially resulting in loss of forage, owner/employee time to repair damage, and damage to machinery such as tractor axles or disk blades while trying to repair the damage (VerCauteren et al. 2019). Tanger et al. (2015) reported damage in 2013 to pastureland at $2.3 million USD in Louisiana, USA, with loss of hay valued at $9.9 million USD, while producers spent about $2.5 million USD in re-disking ground rooted by wild pigs. Rooting by wild pigs can also influence the species richness of rangeland though the destruction of forage grasses (Sweitzer and Van Vuren 2002, Tierney and Cushman 2006, Siemann et al. 2009). This disturbance can have negative consequences for both economic productivity and biodiversity.

In the 5-county region encompassing the rangelands of central Florida, USA, Bankovich et al. (2016) estimated a regional loss of >300,000 ha of pasture area that amounted to >$2 million USD in production losses. Additionally, producers interviewed in Carlisle et al. (2021) noted that weeds emerged in areas disturbed by wild pigs, requiring additional herbicide application to manage the weeds. Other farm-related damage caused by wild pigs includes damage to fencing and other farm structures such as livestock feeders, watering systems, streams and ponds, roads, top-soil erosion, storage for feed, grain, and hay, or damage to yards or gardens (VerCauteren et al. 2019, Carlisle et al. 2021).

Most economic estimates for damage caused by wild pigs have been limited by geographic, temporal, and resource specificity and inconsistent metrics for valuation. Given the logistical challenges of collecting on-the-ground observations of wild pig damage as well as changes in wild pig populations (Engeman et al. 2005, 2018), many studies are limited geographically and temporally, making it difficult to translate findings to separate situations or infer data from 1 region to a similar region. Also, various stud-

ies have examined the economic impact of wild pigs to region-specific resources like loggerhead sea turtles (*Caretta caretta*) or seepage slope wetlands (Engeman et al. 2016, 2019), which are highly valued resources but less common in the scope of wild pig damage. Although agricultural damage has been the most often valued area of wild pig damage, only around 25 commodity crops and common domestic livestock (beef and dairy, swine [*S. domesticus*], sheep, goats, poultry) have been the focus of damage estimation (Anderson et al. 2016; Engeman et al. 2018; Anderson et al. 2019; McKee et al. 2020, 2024). Also, inconsistent metrics for valuation of damage are a substantial limiting factor in that some damage metrics for a particular resource may be in land acres in production while others are measured in realized production (e.g., bushels or tons of yield). Often it is impossible to compare results because the relationship between area in production and realized production is inconsistent. Finally, studies reporting wild pig damage have not provided damage estimates in context of wild pig density or abundance in regions experiencing damage. This has limited application of damage studies to provide estimates of the potential damage associated with wild pigs in regions without damage surveys.

The distribution and abundance of wild pigs in North America and the United States has increased significantly since the 2000s (Snow et al. 2017, Aschim et Brook 2019). In addition to range expansion (Figure 1), the predicted abundance of wild pigs in the United States has increased 185% from an estimated 2.5 million animals in 1982 to 6.9 million animals in 2016 (Lewis et al. 2019). This has resulted in at least 56.5% of the U.S. animal production industry being co-located in areas with wild pig populations and thus being subject to damage from wild pigs (Miller et al. 2017). In response to the wild pig range expansion, the U.S. Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) established the National Feral Swine Damage Management Program (NFSDMP) in 2014 (NFSDMP 2022) to coordinate wild pig control. Since the NFSDMP began tracking this information, there has been a 29% reduction in the range of wild pigs.

Our objective in this study was to further investigate potential damage to animal agriculture that has thus far not been investigated at the national scale. Additionally, we wanted to conduct a follow-up survey to the Anderson et al. (2019) survey conducted in 2017 to determine any potential changes in damages incurred by wild pigs. We surveyed livestock producers in the same 13 states (Alabama, Arkansas, California, Florida, Georgia, Louisiana, Mississippi, Missouri, North Carolina, Oklahoma, South Carolina, Tennessee, and Texas, USA) that were sampled in Anderson et al. (2019) and focused our survey on producers of cattle (beef, calving, and dairy operations), swine, sheep, and goats, although producers of other commodities were expected (e.g., poultry and equine).

The survey instrument was designed to elicit a range of values associated with wild pig presence. The instrument was modified from the version administered in 2017 to estimate perceived changes in wild pig populations and to account for specific categories identified in Carlisle et al. (2021). These categories have not been included in previously published large scale economic estimates of wild pig impacts on livestock producers such as comprehensive wild pig rooting impacts of damages to pasture, or additional time and expenses incurred for wild pig management and damage repairs (including damage to a wide range of property and equipment items). Lastly, previous studies have not reported wild pig damage estimates within the context of wild pig abundance, which we provide (Appendix A, Table A.1), reporting the 2020 abundance and density estimates with 95% confidence intervals for the predicted wild pig populations in the state surveyed estimates using methods described in Lewis et al. (2019). We proceed with a discussion of the survey distribution, the rules related to disclosure of information, and the survey instrument. Results are then presented, followed by a discussion of the implications of the findings and how they relate to the previous study.

Methods

All surveys were designed by researchers at USDA's National Wildlife Research Center and Center for Epidemiology and Animal Health, and distributed by the USDA National Agricultural Statistical Service (NASS) to targeted producers of the specific commodity of interest in states with known wild pig populations. Representative samples were obtained by state and com-

modity, therefore avoiding geographic specificity and repetition of these surveys, which allows for an examination of temporal variation (see survey sampling methodology in Appendix B).

Our focus here is on 5 types of information collected by the survey. The first is the presence of wild pigs as it provides a general indication of the economic threat they pose in the area, either through direct damage or the risk of disease transmission. We asked general questions regarding wild pig presence and perceived change in wild pig populations in the producer's county and on their operation (Appendix C, Figure C.1). We used a series of questions to solicit information regarding damages from producers (Appendix C, Figure C.2). 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., drug costs). We dedicated a whole section to costs related to pasture damage (Appendix C, Figure C.3). This included questions on area damaged, time and cost of repair, and money spent on supplemental feed as a result of pasture damage. We also asked a detailed set of questions on 14 different property items to estimate their level of damage and the associated hours and money spent on repair (Appendix C, Figure C.4). Finally, we inquired about the entities performing control on the landowner's property and the cost and effectiveness of the methods used (Appendix C, Figure C.5).

Wild pig damage was estimated at the state level, accounting for differences in commodity production and producer response rates. To account for differences across commodities, NASS calculated a weighting score for each producer that accounts for statewide production of each commodity, as the inverse of a producer's probability of selection (π_i), adjusted to account for non-response by other producers. These producer-level weights were then adjusted for non-response to specific questions, allowing estimation of wild pig damage at the state level. NASS employs disclosure limitation methodology to protect the private information of producers. The first criterion is a threshold rule, where each summarized estimate must be computed from at least 3 weighted farms. This means anytime there are only 1 or 2 weighted operations, the value of that cell is categorically suppressed. The second criterion is a dominance rule; NASS uses different dominance rules in different circumstances. The (n,k) rule invokes a suppression when the top n producers account for k percent or more of the estimated total. In other words, a (2,80) rule will suppress a cell when the top 2 producers represent 80 percent or more of that cell total. The p-percent rule requires sufficient protection so that the largest producer value cannot be approximated to within a range of p-percent. For example, a 20-percent rule will suppress a cell if revealing that total allows someone to estimate the top producer value to within ±20%. Federal statistical agencies do not publicly disclose the actual values of n, k, or p, as revealing them compromises the protection. For these reasons, some categories of damages cannot be reported and are denoted with a "D." In these cases, there may be positive loss in this category, and these values should not be interpreted as a zero or missing. For categories where the value of >1 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.

To perform an analysis by species, we restricted our sample to respondents reporting wild pig presence on their property in 2020 and raising only 1 group of livestock species: cattle (beef and dairy), swine, or sheep and goat (treated as 1 species). For each category, we estimated the average share of producers reporting having pasture, average time and cost of repairing pasture and property, average spending on supplemental feed, and loss to predation, disease, and other, as well as veterinary costs and cost of medical treatment. We also estimated the average time and cost of control for the same producers. Both a damage and a control index were created by aggregating costs and labor assuming a $15 USD hourly rate (U.S. Department of Labor 2022).

Results

A total of 18,074 surveys in 13 states were mailed by NASS, with a follow-up with non-respondents by phone. The final response rate was 44.5%, for a total of 8,035 responses. All the results presented are estimated at the population level.

Population

Texas had the highest percentage of producers reporting wild pigs in their county (88%) and on their operation (70%; Table 1). Oklahoma had the second highest number of producers reporting wild pigs in their county (75%), while Arkansas reported the second highest percentage with wild pigs on their operation (52%). Missouri had the lowest number of producers reporting wild pig presence in their county (22%), while North Carolina and Tennessee had the fewest reporting wild pig presence on their operation (4% each). Appendix D, Table D.1, provides the percentage of livestock producers reporting wild pig presence in their county or on their operation in the previous 3 years, by livestock type.

Table 1. Percentage of producers who reported having wild pigs (*Sus scrofa*) present in their county or on their operation in the previous 3 years. Standard errors in parentheses.

State	Presence in county			Presence on operation		
	Yes	No	Don't know	Yes	No	Don't know
Alabama	0.43	0.20	0.37	0.18	0.80	0.02
	(0.09)	(0.07)	(0.11)	(0.06)	(0.06)	(0.01)
Arkansas	0.65	0.07	0.28	0.52	0.44	0.04
	(0.09)	(0.03)	(0.10)	(0.09)	(0.09)	(0.02)
California	0.37	0.40	0.23	0.19	0.75	0.07
	(0.05)	(0.06)	(0.08)	(0.03)	(0.05)	(0.04)
Florida	0.61	0.24	0.16	0.35	0.60	0.04
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.02)
Georgia	0.57	0.23	0.20	0.27	0.71	0.03
	(0.05)	(0.03)	(0.04)	(0.04)	(0.04)	(0.01)
Louisiana	0.74	0.17	0.09	0.50	0.48	0.01
	(0.06)	(0.06)	(0.04)	(0.06)	(0.06)	(0.01)
Mississippi	0.68	0.16	0.17	0.33	0.64	0.02
	(0.04)	(0.03)	(0.04)	(0.04)	(0.04)	(0.01)
Missouri	0.22	0.58	0.20	0.06	0.92	0.02
	(0.05)	(0.07)	(0.06)	(0.03)	(0.03)	(0.01)
North Carolina	0.26	0.57	0.17	0.04	0.94	0.02
	(0.05)	(0.07)	(0.05)	(0.02)	(0.02)	(0.01)
Oklahoma	0.75	0.18	0.08	0.46	0.50	0.04
	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)	(0.01)
South Carolina	0.51	0.28	0.21	0.22	0.75	0.03
	(0.08)	(0.10)	(0.05)	(0.05)	(0.06)	(0.02)
Tennessee	0.30	0.35	0.35	0.04	0.89	0.07
	(0.07)	(0.07)	(0.08)	(0.01)	(0.05)	(0.05)
Texas	0.88	0.07	0.04	0.70	0.27	0.02
	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.01)
Total	0.63	0.22	0.15	0.41	0.56	0.03
	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)

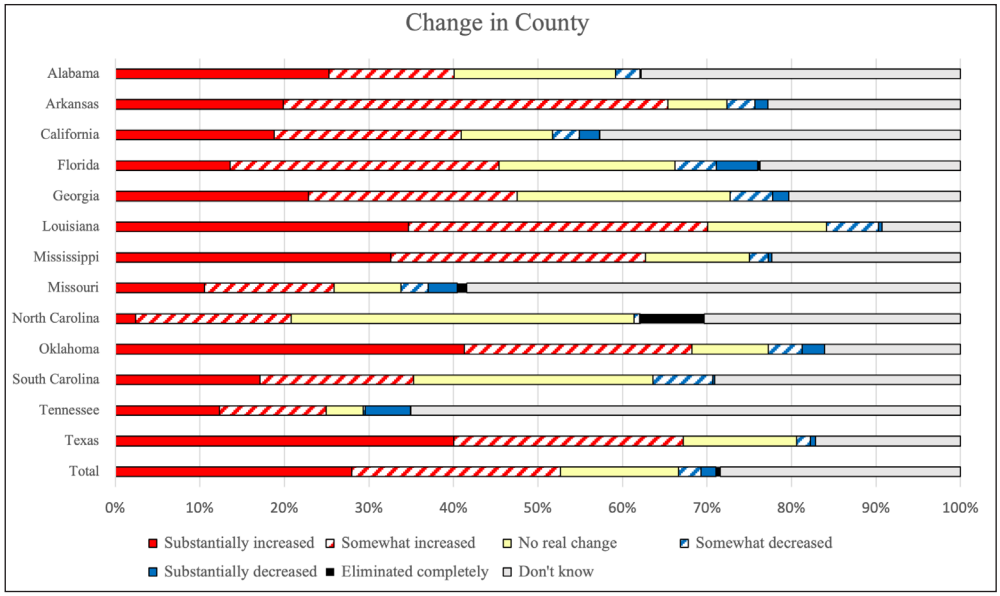

Figure 2. Perceived change in wild pig (*Sus scrofa*) presence in county in the last 3 years by state (among producers who reported wild pig presence).

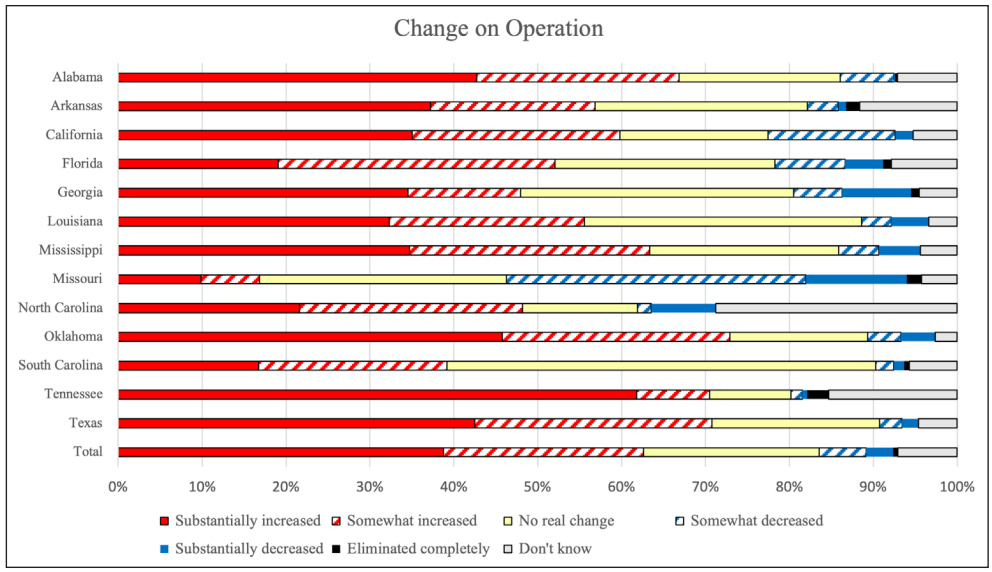

Figure 3. Perceived change in wild pig (*Sus scrofa*) presence on producers' livestock operation properties in the last 3 years by state (among producers who reported wild pig presence).

Among producers who reported wild pig presence in their county in the previous 3 years, Arkansas, Louisiana, Mississippi, Oklahoma, and Texas had >50% of producers reported wild pig populations had somewhat or substantially increased during this period, with Louisiana the highest (70%) and Texas the second highest (67%; Figure 2). The remaining states surveyed all reported <50% of producers reporting wild pigs had increased in their county, with North Carolina reporting the fewest (17%) and Tennessee the second fewest (25%). Florida reported the greatest percentage of producers reporting wild pigs decreased in population in their county (10%), while the remaining states all reported <10% of producers saying populations had decreased in their county.

Among producers who reported wild pig presence on their operation in the previous 3 years, 9 states (Alabama, Arkansas, California, Florida,

Louisiana, Mississippi, Oklahoma, Tennessee, and Texas) had >50% of producers reporting that wild pig presence somewhat or substantially increased on their operation, with Oklahoma reporting the highest increase (73%; Figure 3). The remaining 4 states surveyed had <50% of producers reporting wild pig presence had increased on their operation, with Missouri reporting the lowest (17%). Missouri also had the highest percentage of producers reporting a decrease or elimination of wild pigs on their operation (50%).

Overall, the share of producers who reported not knowing if wild pigs are present in their county (37% in Alabama) or if their presence has

Table 2. Cost (USD) of livestock deaths and medical expenditures attributed to wild pig (*Sus scrofa*) predation or disease by state. Standard errors in parentheses.

State	Total market value			Total cost	
	Predation deaths	Disease deaths	Other deaths	Veterinary services	Medical treatments
Alabama	146,062	-	-	-	2,107,529
	(145,171)	-	-	-	(2,094,236)
Arkansas	9,278,938	5,160,040	-	5,775	13,961
	(6,470,426)	(5,143,705)	-	(4,927)	(9,857)
California	720,194	5,630	123,049	180,585	511,425
	(403,593)	(5,510)	(81,228)	(128,971)	(387,204)
Florida	304,712	105,995	101,776	282,599	243,072
	(137,342)	(64,505)	(59,757)	(228,980)	(165,084)
Georgia	181,691	49,577	25,857	6,315	121,558
	(110,652)	(44,202)	(20,618)	(3,656)	(74,347)
Louisiana	447,467	-	739,217	3,124	1,141,918
	(273,488)	-	(732,608)	(3,096)	(1,131,708)
Mississippi	152,887	230,465	731,804	30,217	53,987
	(151,673)	(228,634)	(725,993)	(22,966)	(37,229)
Missouri	-	-	4,648	-	-
	-	-	(4,602)	-	-
North Carolina	2,702	-	-	-	-
	(2,665)	-	-	-	-
Oklahoma	3,779,019	363,710	328,469	47,475	259,605
	(2,061,312)	(264,477)	(185,475)	(25,833)	(128,530)
South Carolina	22,144	-	413,292	8,960	16,572
	(21,902)	-	(408,336)	(8,862)	(10,475)
Tennessee	25,435	-	-	5,247	36,421
	(25,220)	-	-	(4,555)	(35,509)
Texas	38,611,664	4,065,963	9,828,952	1,657,122	2,540,420
	(11,802,009)	(1,411,189)	(5,509,748)	(707,375)	(1,172,234)
Total	53,672,916	9,981,380	12,297,063	2,227,419	7,046,467
	(13,627,797)	(5,345,794)	(5,624,309)	(755,504)	(2,691,245)

Table 3. Cost (USD) of livestock deaths and medical expenditures attributed to wild pig (*Sus scrofa*) predation or disease by commodity. Standard errors in parentheses.

	Total market value			Total cost	
Species	Predation deaths	Disease deaths	Other deaths	Veterinary services	Medical treatments
Beef cows	20,786,652	8,445,350	7,993,163	681,147	3,254,829
	(9,265,197)	(5,313,381)	(5,325,970)	(234,034)	(1,248,336)
Milk cows	-	-	20,167	248,155	121,117
	-	-	(20,152)	(232,786)	(77,721)
Other cattle	14,145,398	1,139,661	1,549,949	412,317	2,340,500
	(8,112,949)	(576,300)	(1,044,514)	(229,079)	(2,107,412)
Swine	1,623,619	5,245	69,260	10,047	40,567
	(1,601,083)	(5,236)	(63,589)	(6,006)	(35,987)
Sheep	7,293,706	32,645	-	25,259	65,052
	(4,234,340)	(19,905)	-	(19,098)	(54,978)
Goats	8,816,725	329,597	772,383	5,956	57,672
	(3,470,790)	(329,320)	(698,611)	(5,951)	(49,981)
Poultry	-	16,203	655	917	2,322
	-	(16,197)	(655)	(915)	(2,322)
Equine	981,382	-	-	233,383	19,219
	(926,116)	-	-	(232,449)	(17,501)
Other	25,435	12,679	1,891,486	610,239	1,145,189
	(25,434)	(12,677)	(1,368,760)	(604,172)	(1,141,474)

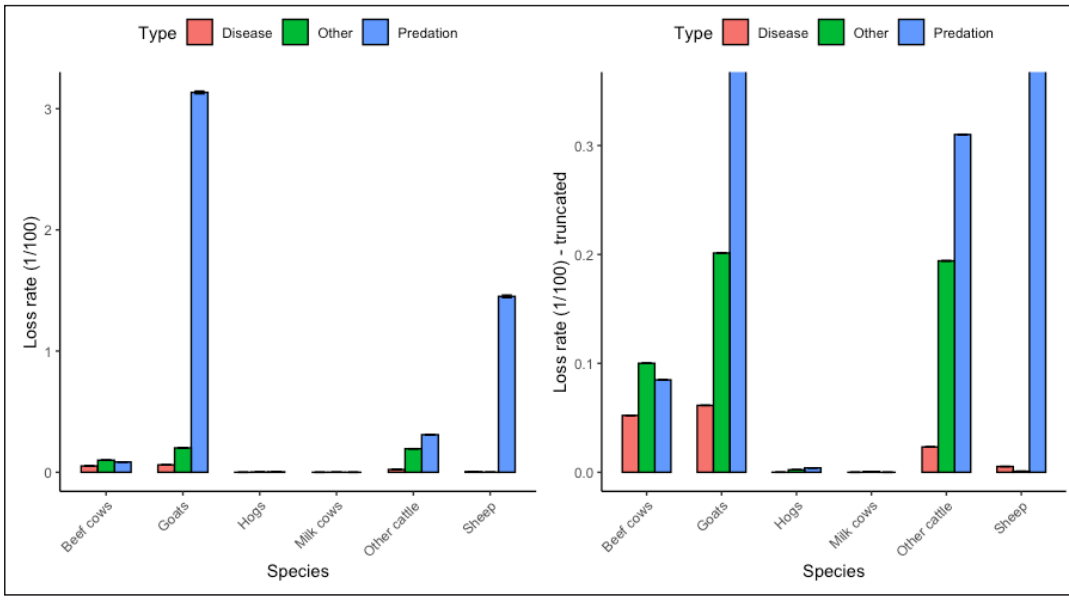

Figure 4. Loss rates attributed to wild pigs (*Sus scrofa*; in 1/100) by cause and species across the 13 states. The figure to the right is a truncated version of the figure to the left to better display the loss rates for cattle and hogs.

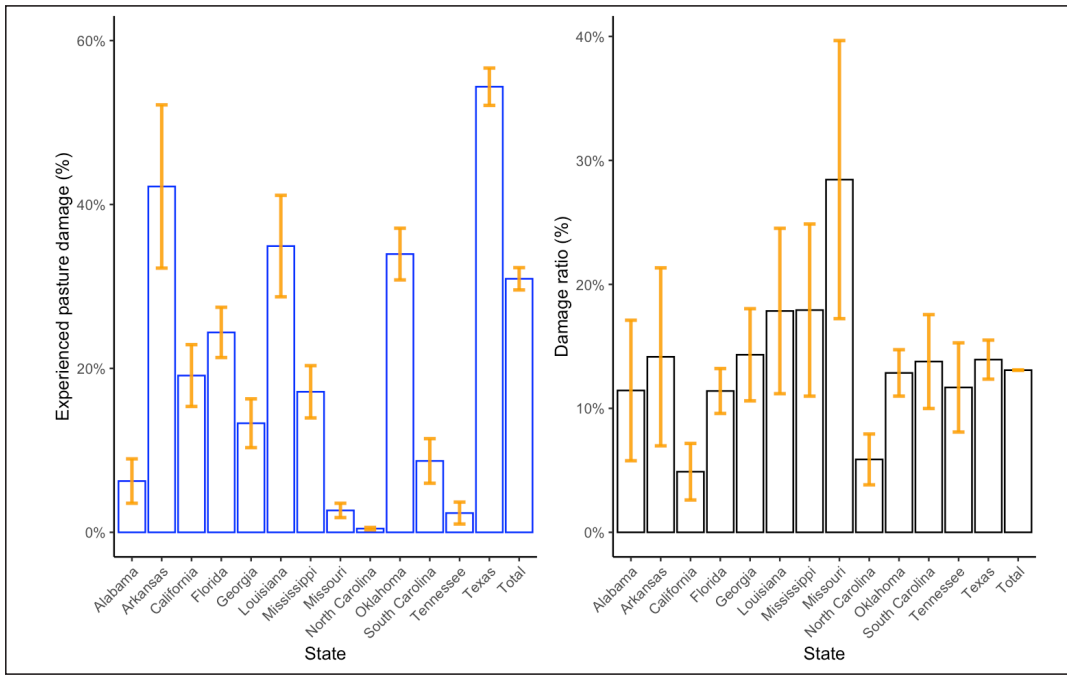

Figure 5. Fraction of respondents attributing damage on their pasture to wild pigs (*Sus scrofa*) (left), and the percent of pasture lost (damage ratio; right) by state.

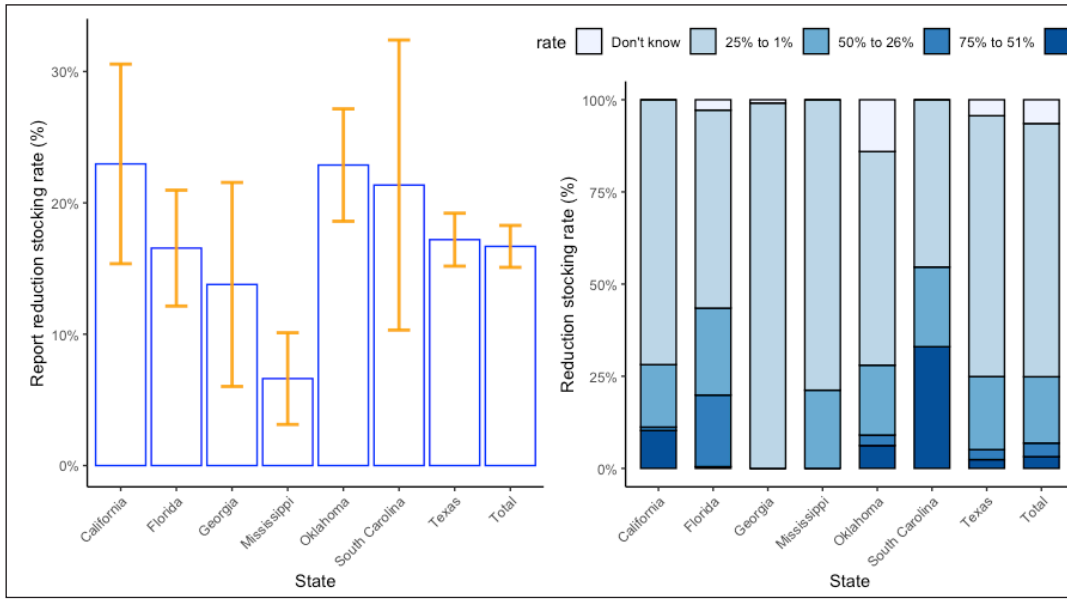

Figure 6. Percent of producers reporting a reduction in the stocking rate by state (left) and reduction in stocking rate (right) attributed to wild pigs (*Sus scrofa*). Only a subset of states are shown, as the remaining states did not meet the disclosure standards.

changed (65% in Tennessee) is high, which highlights a need for education and/or outreach in targeted states. The tables used to create Figures 2 and 3 are available in Appendix D, as well as similar tables by livestock type (Tables D.2, D.3, D.4, and D.5, respectively).

Economic impacts of predation and disease

Similar to the 2017 survey conducted by Anderson et al. (2019), we calculated the annual U.S. 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 2) and livestock type (Table 3). Loss rates by species are also presented (Figure 4). These results indicate that predation is the most severe impact to livestock producers and is driven by predation of sheep and goats. The majority of damages related to predation and disease occur in Texas, Arkansas, and Oklahoma, while producers in many other states suffer more limited livestock loss. Likewise, cattle producers suffer more damage than other livestock producers in dollar amounts,

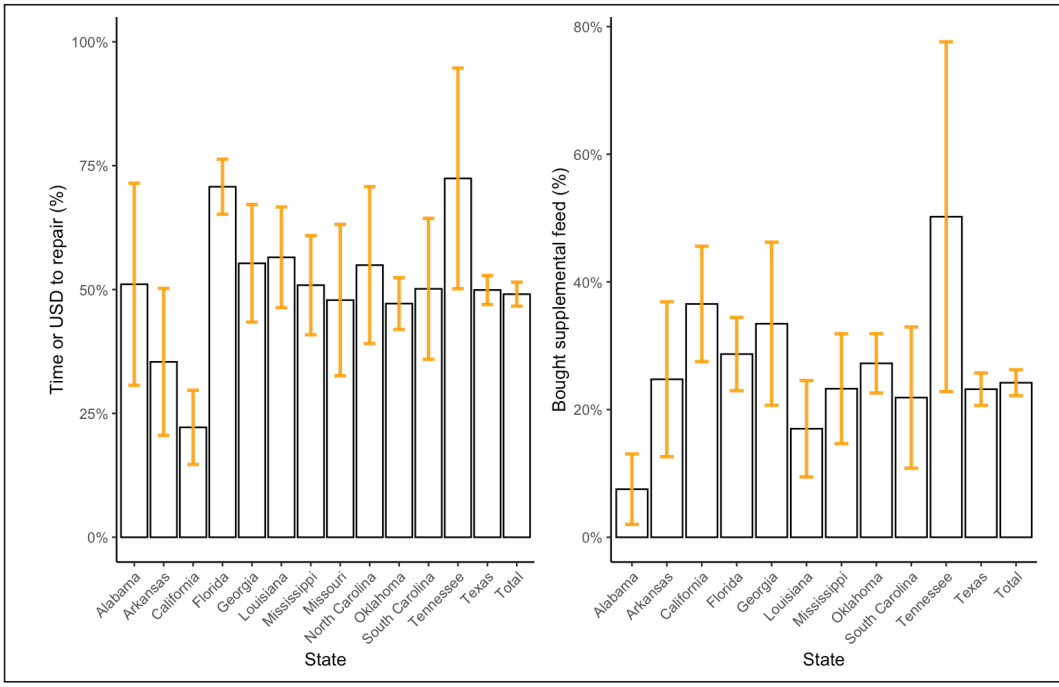

Figure 7. Fraction of producers with pasture damage who incurred costs or labor to repair pasture damage by state (left) and fraction of respondents with wild pig (*Sus scrofa*) damage reporting having bought supplemental feed state (right).

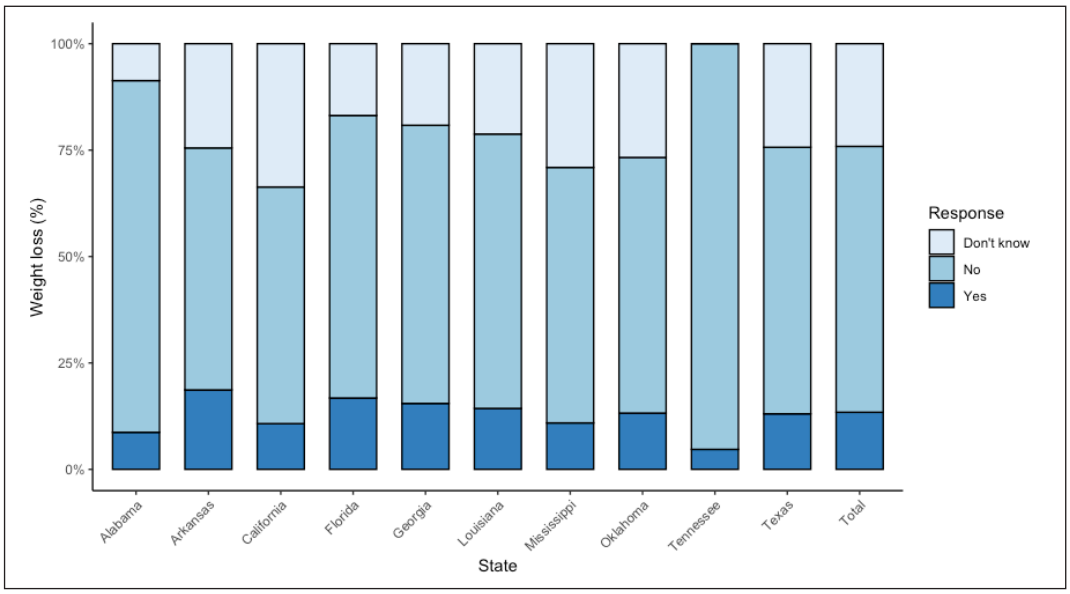

Figure 8. Share of producers by state with wild pig (*Sus scrofa*) damages to pasture reporting that their livestock weights were impacted.

resulting from the much higher production value of cattle. Loss rates by state and livestock type are provided in (Appendix D, Tables D.6 and D.7, respectively). Comparing these results to the Anderson et al. (2019) 2017 survey reveals that the inflation corrected total for these costs increased by 98% between 2016 and 2020, driven by an increase of 188% of the total market value of predation deaths. The Anderson et al. (2019) survey did not report standard errors; hence, we were not able to perform a formal *t*-test.

Table 4. Amount of time and money (USD) spent repairing pasture and amount (USD) spent on supplemental feed, by state, in 2020 because of wild pig (*Sus scrofa*) damage. Standard errors in parentheses.

State	Hours repair	Costs repair ($)	Costs supp. feed ($)
Alabama	36,675	1,679,368	561,487
	(19,106)	(1,002,139)	(507,986)
Arkansas	25,962	965,403	1,710,126
	(13,258)	(466,138)	(861,942)
California	10,355	685,839	5,274,491
	(5,582)	(320,815)	(2,809,558)
Florida	103,790	4,437,218	3,095,570
	(18,222)	(663,524)	(828,990)
Georgia	43,922	934,934	702,114
	(19,668)	(319,334)	(411,808)
Louisiana	82,368	1,404,377	694,625
	(38,371)	(539,354)	(350,283)
Mississippi	23,054	1,281,149	1,038,307
	(8,538)	(382,623)	(451,619)
Missouri	38,536	4,638,344	1,091,959
	(31,467)	(3,270,986)	(733,419)
North Carolina	408	48,492	17,368
	(184)	(27,424)	(12,534)
Oklahoma	278,046	14,369,288	11,144,180
	(65,538)	(5,590,425)	(3,190,394)
South Carolina	10,442	641,178	405,180
	(4,333)	(248,625)	(266,766)
Tennessee	8,386	84,905	221,983
	(5,399)	(41,872)	(155,970)
Texas	1,836,975	55,310,341	43,007,223
	(487,428)	(10,380,734)	(11,391,063)
Total	2,498,921	86,480,835	68,964,613
	(495,738)	(12,332,080)	(12,273,816)

Pasture

Except for California (84%), at least 95% of producers responded having pasture on their operation in each of the states surveyed. The mean pasture area by state for producers having pasture varied widely from 57 acres in North Carolina to 1,206 acres in California. Descriptive statistics of all responses by state related to pasture damage can be found in Appendix D (Table D.8).

The fraction of producers attributing damage on their pasture to wild pigs ranged from 0.5% in North Carolina to 54.4% in Texas (Figure 5). The damage ratio (i.e., percent of pasture lost due to wild pig damage) also varied across states. On average, producers in California reported the lowest percentage, at 5%, and producers in Missouri reported the highest, at 28%.

Producers with pasture damage were asked if they had to reduce their stocking levels as a result of pasture acreage lost and, if so, by how much (Figure 6). For most producers reporting a reduction in the stocking rate, this reduction was <25%.

Half (49%) of producers with pasture damage reported incurring costs or labor to repair pasture damage, with the highest average in Tennessee (72%) and the lowest in California (35%; Figure 7). About a fourth of respondents with pasture damage reported having bought supplemental feed, with the highest share in Tennessee (50%; Figure 7).

Across all states, most landowners with pasture damage did not mention any livestock weight loss (62%) or did not know (24%); 13% did answer positively (Figure 8).

The total state-level hours of their own time, the amount spent by producers repairing damage to pasture, and the dollars spent on supplemental feed as a result of pasture damage by wild pigs across the states surveyed reached respectively 2.5 million hours, $86.5 million USD, and $69.0 million USD, with Texas shouldering the highest amounts (at 1.8 million hours, $55.3 million USD, and $43.0 million USD; Table 4).

Table 5. Property damage by type of property caused by wild pigs (*Sus scrofa*). This table pertains to livestock producers reporting wild pigs on their property the previous year and focuses on the property items damaged. For each item, producers were asked if this type of damage occurred in 2020 on their operation. The first 3 columns show the share of producers responding respectively "Yes," "I don't know," and "No." The next 2 columns display the average numbers of hours and cost spent in dollars repairing the damage if damage was reported. The last 4 columns describe the intensity of damage observed for the producers who reported damage to each property item. Standard errors in parentheses.

Item	Damage			Times (hours)	Cost ($)	Damage intensity			
	Yes	Don't know	No			Mild	Moderate	Severe	Unsure
Buildings	0.04	0.02	0.93	25	1,759	0.27	0.26	0.38	0.10
	(0.01)	(0.00)	(0.01)	(4)	(619)	(0.08)	(0.07)	(0.11)	(0.05)
Fencing	0.54	0.05	0.42	26	969	0.40	0.45	0.13	0.02
	(0.02)	(0.01)	(0.02)	(3)	(129)	(0.03)	(0.03)	(0.02)	(0.01)
Waterers	0.10	0.03	0.87	15	914	0.34	0.41	0.20	0.05
	(0.01)	(0.01)	(0.01)	(3)	(163)	(0.05)	(0.05)	(0.04)	(0.02)
Vehicles	0.09	0.02	0.90	15	1,961	0.31	0.47	0.20	0.02
	(0.01)	(0.00)	(0.02)	(3)	(453)	(0.09)	(0.09)	(0.07)	(0.01)
Residential	0.17	0.03	0.80	12	1,253	0.30	0.48	0.20	0.02
	(0.02)	(0.01)	(0.02)	(2)	(379)	(0.05)	(0.06)	(0.04)	(0.01)
Roads	0.17	0.04	0.79	11	1,063	0.50	0.33	0.17	0.01
	(0.01)	(0.01)	(0.01)	(2)	(329)	(0.04)	(0.04)	(0.04)	(0.00)
Feed	0.22	0.03	0.75	43	1,379	0.35	0.37	0.25	0.03
	(0.02)	(0.01)	(0.02)	(31)	(277)	(0.04)	(0.04)	(0.04)	(0.01)
Fecal water	0.17	0.32	0.51	2	194	0.34	0.37	0.14	0.15
	(0.01)	(0.02)	(0.02)	(0)	(44)	(0.04)	(0.04)	(0.02)	(0.03)
Water wallow	0.29	0.17	0.55	9	442	0.44	0.37	0.15	0.04
	(0.02)	(0.02)	(0.02)	(3)	(88)	(0.03)	(0.03)	(0.02)	(0.01)
Terraces	0.33	0.11	0.57	16	594	0.34	0.45	0.18	0.02
	(0.02)	(0.01)	(0.02)	(8)	(132)	(0.03)	(0.04)	(0.03)	(0.01)
Wildlife habitat	0.21	0.20	0.59	3	569	0.35	0.41	0.19	0.06
	(0.02)	(0.02)	(0.02)	(1)	(354)	(0.04)	(0.04)	(0.04)	(0.02)
Topsoil erosion	0.55	0.09	0.36	16	1,119	0.31	0.42	0.22	0.05
	(0.02)	(0.01)	(0.02)	(2)	(228)	(0.03)	(0.03)	(0.02)	(0.03)
Trees	0.09	0.14	0.77	3	371	0.46	0.39	0.12	0.03
	(0.01)	(0.02)	(0.02)	(1)	(126)	(0.06)	(0.05)	(0.04)	(0.01)
Fecal crops	0.10	0.16	0.74	21	1,971	0.33	0.35	0.29	0.03
	(0.01)	(0.02)	(0.02)	(13)	(930)	(0.06)	(0.06)	(0.06)	(0.01)
Other	0.02	0.18	0.80	8	95	0.25	0.53	0.19	(D)
	(0.01)	(0.02)	(0.02)	(8)	(60)	(0.13)	(0.18)	(0.10)	-

Property

Overall, field topsoil erosion and fencing appear to be the most impacted by wild pigs with 55% and 54% of producers with wild pigs on their property in the previous year reporting damages, respectively (Table 5).

The total hours of their own time and the amount spent by producers repairing damage to property across all the states surveyed to respectively 7.1 million hours and $268.4 million USD, with Texas incurring the highest amounts at 4.7 million hours and $169.7 million USD (Table 6).

Table 6. Time and cost (USD) spent by livestock producers repairing property damage caused by wild pigs (*Sus scrofa*), by state, in 2020. Standard errors in parentheses.

State	Times (hours)	Cost ($)
Alabama	167,924	12,113,206
	(117,649)	(7,374,273)
Arkansas	649,814	13,618,511
	(532,316)	(8,107,638)
California	107,493	6,906,862
	(25,854)	(2,038,904)
Florida	532,179	13,805,391
	(220,264)	(6,598,990)
Georgia	113,012	3,273,854
	(40,744)	(765,203)
Louisiana	106,553	3,206,378
	(25,436)	(936,287)
Mississippi	134,412	6,182,724
	(68,226)	(3,601,084)
Missouri	34,567	442,672
	(24,693)	(236,278)
North Carolina	5,548	6,965,874
	(2,579)	(6,487,110)
Oklahoma	568,953	30,703,294
	(103,173)	(8,750,974)
South Carolina	31,033	933,399
	(12,531)	(266,995)
Tennessee	12,355	475,191
	(6,752)	(388,591)
Texas	4,676,734	169,739,980
	(1,031,187)	(46,669,304)
Total	7,140,579	268,367,336
	(1,195,055)	(49,791,683)

Control

Landowners were asked if someone had come to their operation in 2020 to assist with reducing or preventing damage by wild pigs. Across all states, producers report that most of the control is performed by themselves or someone living on their property (51%), and only 4% benefit from the support of a federal, state, or county agency (Table 7).

Across all states, shooting on sight is the most widely used method (28%) to reduce or prevent damage from wild pigs, followed by hunting without dogs (*Canis familiaris*; 17%), and trapping (14%; Figure 9). The full results are presented in Appendix D, Table D.9.

More than 12.4 million hours (Table 8) and $80.8 million USD (Table 9) were spent controlling wild pigs in 2020 across the states surveyed, with Texas totaling close to 8.2 million hours and >$48.9 million USD.

Fencing

The survey asked questions about the use of fencing (electric and non-electric) for the primary purpose of reducing damage by wild pigs. Across all states, 15% of producers with wild pigs on their property in 2020 reported using electric fencing and 7% non-electric fencing (Figure 10).

Species analysis

When limiting damage analysis to these relevant impacts, the cattle producers in areas where wild pigs are present appear to suffer on average more damage than other producers (Table 10). This can be partly explained by a higher share of cattle ranchers having pasture (99%) compared to 83% for sheep and goats and 41% for swine. Cattle ranchers also incur higher property costs ($2,083 USD), followed by sheep and goat ($1,014 USD), and swine producers ($237 USD). The ranking in the damage indices is paralleled by the investment in control as measured by the control indices, indicating that cattle ranchers invest more in control than other producers. However, the cost-benefit ratio between the damage and control indices is still higher for cattle ranchers, possibly indicating an underinvestment in control.

Discussion

Our results suggest that in the 13 states included in the study, wild pigs are believed to be present in a large fraction of the sampled counties and on a majority of the operations sampled. Additionally, among producers reporting wild pig presence on their operation, 9 of the 13 states had most producers reporting wild pig presence increased on their operation in the last 3 years, with Oklahoma reporting the highest share (73%). Missouri had the highest percentage of producers reporting a decrease or elimination of wild pigs on their operation (50%). This could be attributed to the task force formed by landowners in 1998 to address the growing wild pig problem in Missouri (Hartin and Hutton 2007).

Table 7. Proportion of producers using **e**ntities to perform wild pig (*Sus scrofa*) control by state for landowners reporting wild pig presence in 2020. Standard errors in parentheses. Landowners could report >1 entity. (D) Withheld to avoid disclosing data for individual farms.

State	Federal, state, or county agency	University outreach services	Private company	Hunters	Yourself
Alabama	(D)	(D)	(D)	0.14	0.27
	-	(0.05)	-	(0.08)	(0.15)
Arkansas	0.19	(D)	-	0.33	0.38
	(0.10)	(0.02)	-	(0.14)	(0.15)
California	0.07	(D)	-	0.43	0.46
	(0.04)	(0.00)	-	(0.08)	(0.08)
Florida	0.01	(D)	0.02	0.34	0.53
	(0.00)	(0.00)	(0.01)	(0.05)	(0.06)
Georgia	-	-	(D)	0.52	0.61
	-	-	-	(0.09)	(0.08)
Louisiana	(D)	(D)	(D)	0.32	0.68
	-	(0.00)	-	(0.08)	(0.08)
Mississippi	0.03	(D)	-	0.31	0.48
	(0.02)	(0.02)	-	(0.08)	(0.08)
Missouri	0.20	-	-	(D)	0.18
	(0.15)	-	-	-	(0.13)
North Carolina	(D)	-	(D)	0.23	0.36
	-	-	-	(0.17)	(0.23)
Oklahoma	0.05	(D)	(D)	0.40	0.59
	(0.01)	(0.00)	-	(0.05)	(0.05)
South Carolina	(D)	(D)	-	0.21	0.46
	-	(0.01)	-	(0.08)	(0.14)
Tennessee	0.11	-	-	(D)	0.32
	(0.09)	-	-	-	(0.22)
Texas	0.03	(D)	0.02	0.37	0.52
	(0.01)	(0.00)	(0.01)	(0.02)	(0.03)
Total	0.04	-	0.02	0.36	0.51
	(0.01)	(0.00)	(0.00)	(0.02)	(0.02)

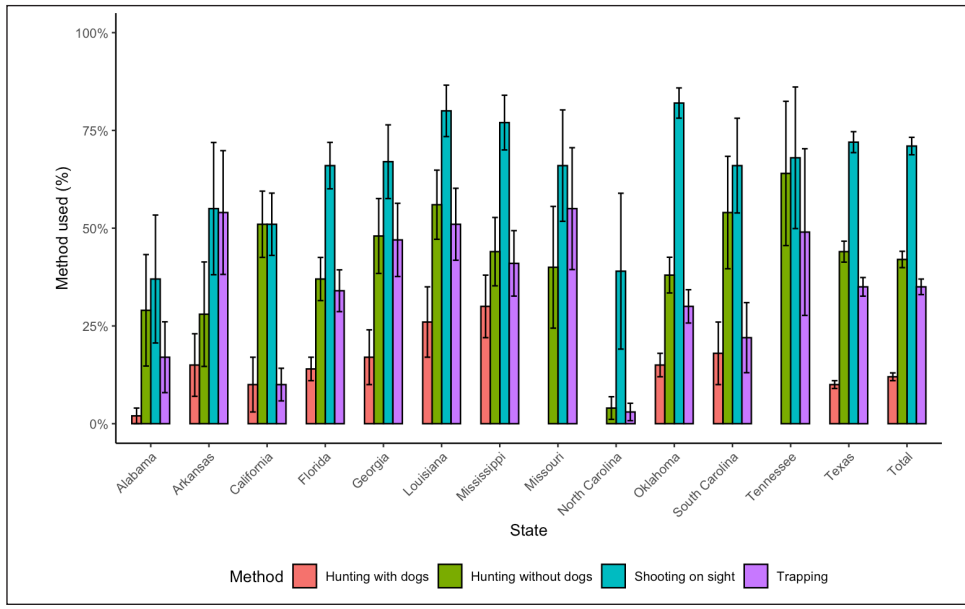

Figure 9. Control methods used by state to mitigate wild pig (*Sus scrofa*) damage.

Table 8. Total hours spent in 2020 by control method and state to mitigate damage caused by wild pigs (*Sus scrofa*). Standard errors in parentheses. (D) Withheld to avoid disclosing data for individual farms.

State	Shooting on sight	Hunting with dogs	Hunting without dogs	Aerial hunting	Trapping
Alabama	39,419	(D)	31,246	-	29,279
	(16,912)	-	(14,823)	-	(23,238)
Arkansas	90,266	17,080	25,139	-	106,524
	(38,602)	(13,705)	(17,709)	-	(63,550)
California	78,527	(D)	54,409	-	5,995
	(45,760)	-	(29,175)	-	(4,756)
Florida	172,618	24,521	54,821	(D)	121,800
	(38,342)	(6,786)	(19,226)	-	(41,429)
Georgia	106,303	20,537	88,097	-	43,102
	(56,748)	(19,442)	(52,863)	-	(16,892)
Louisiana	142,263	7,347	84,470	-	59,596
	(54,392)	(6,081)	(44,084)	-	(16,233)
Mississippi	108,141	9,839	65,619	-	82,366
	(42,651)	(5,335)	(24,702)	-	(48,834)
Missouri	76,271	-	(D)	-	(D)
	(47,552)	-	-	-	-
North Carolina	2,550	(D)	(D)	-	-
	(1,253)	-	-	-	-
Oklahoma	1,255,896	136,922	455,814	(D)	205,500
	(399,199)	(53,746)	(199,815)	(D)	(69,537)
South Carolina	41,370	(D)	33,439	-	4,879
	(24,484)	-	(22,507)	-	(2,352)

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Tennessee	16,882	(D)	(D)	-	5,443
	(15,665)	-	-	-	(3,110)
Texas	3,639,204	475,342	2,020,425	196,514	1,855,186
	(583,616)	(283,150)	(469,590)	(153,434)	(518,186)
Total	5,769,709	719,560	3,158,976	199,607	2,528,331
	(718,619)	(290,044)	(556,920)	(153,437)	(531,658)

Table 9. Amount (USD) spent in 2020 by control method and state to mitigate wild pig (*Sus scrofa*) damage. Standard errors in parentheses. (D) Withheld to avoid disclosing data for individual farms.

State	Shooting on sight	Hunting with dogs	Hunting without dogs	Aerial hunting	Trapping
Alabama	1,084,039	(D)	333,890	-	288,787
	(576,180)	-	-	-	(249,310)
Arkansas	1,136,695	(D)	862,412	-	231,793
	(957,112)	-	-	-	(128,735)
California	710,350	(D)	111,398	-	(D)
	(539,580)	-	-	-	-
Florida	1,881,142	93,014	574,088	(D)	919,199
	(645,043)	(29,672)	-	-	(259,280)
Georgia	536,446	52,941	452,212	-	631,809
	(202,482)	(32,217)	-	-	(297,769)
Louisiana	3,145,916	(D)	252,644	(D)	712,619
	(2,868,153)	-	-	-	(291,550)
Mississippi	128,333	(D)	137,151	-	273,031
	(44,909)	-	-	-	(80,340)
Missouri	1,473,801	-	(D)	-	(D)
	(1,435,354)	-	-	-	-
North Carolina	33,104	(D)	(D)	-	(D)
	(15,110)	-	-	-	-
Oklahoma	5,478,637	2,081,695	2,160,254	59,034	1,771,465
	(1,459,743)	(1,331,905)	-	(45,012)	(486,535)
South Carolina	158,090	(D)	217,542	-	235,520
	(75,837)	-	-	-	(112,754)
Tennessee	14,995	-	-	-	(D)
	(9,904)	-	-	-	-
Texas	18,279,984	1,804,575	9,400,318	7,235,045	12,168,324
	(2,803,810)	(526,322)	-	(1,937,662)	(1,937,472)
Total	34,061,533	4,177,513	14,515,624	7,330,489	20,658,571
	(4,720,499)	(1,434,157)	(2,672,311)	(1,938,366)	(3,899,650)

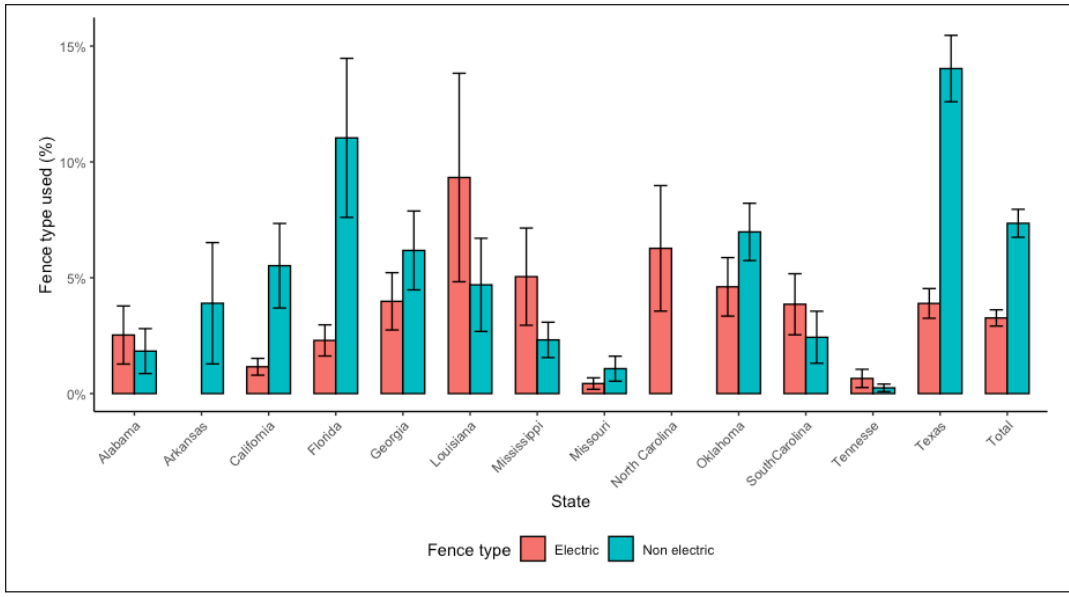

Figure 10. Fence use by producers reporting wild pig (*Sus scrofa*) presence to mitigate the damage.

The stated mission of the task force is to eradicate wild pigs in Missouri. The Missouri Department of Conservation has implemented several measures to combat wild pigs in the state, including banning public hunting in favor of systematic control operations in the Mark Twain National Forest, and the adoption of new legislation in House Bill 369, Feral Hogs (sections 270.170, 270.180, 270.270, and 270.400), which penalizes people who "recklessly or knowingly release any swine to live in a wild or feral state."

Contact between wild pigs and domestic livestock imposes a wide range of costs on producers. These naturally include losses of livestock to predation and disease, and expenditures on veterinary services and medical treatments, which amounted in 2020 to an estimated $85 million USD for the 13 states surveyed. Some of these impacts may be underestimated because wild pig predation and subsequent consumption of carrion could easily be mistaken as low productivity in herds and flocks rather than predation. In contrast, wild pig predation may be confused with coyote (*Canis latrans*) predation, as signs of predation from both species appear similar, so severity of wild pig predation on livestock is difficult to discern and measure (Seward et al. 2004). Nonetheless, these amounts are dwarfed by the expenditure incurred by damage to property ($375.5 million USD) and the rooting of pasture ($192.9 million USD), when accounting for a $15 USD hourly wage (U.S. Department of Labor 2022). In particular, producers dedicated many hours of their own time in 2020 repairing damage to their property (7.1 million hours) and pasture (2.5 million hours) from wild pigs. A deeper analysis of property damages by wild pigs should be undertaken to better understand the complexity of this issue. Sheep and goat producers incur the highest loss ratio due to predation, but on average, cattle producers suffer higher overall damage because of higher destruction to pasture and property.

This study contributes to the growing body of literature surrounding wild pig damage by attempting to understand temporal changes in producer perceptions of wild pig impacts to livestock, property, and wild pig population trends. The trends between the 2 surveys indicate that all states other than Alabama and Florida indicated larger losses in this survey than the previous survey; this change was driven by losses related to cattle.

There are numerous factors that explain the trends between the 2 studies. First, efforts to manage wild pigs, even at the national level, are still extremely limited in scope, and the wild pig problem is extensive. The impacts associated with wild pigs have been growing unchecked for decades, and changes in wild pig-related

Table 10. Damage and control indices for cattle (*Bos taurus*), swine (*Sus domesticus*), sheep (*Ovis aries*), and goats (*Capra hircus*) relative to wild pig (*Sus scrofa*) damage. Damage and a control indices were created by aggregating costs and labor assuming a $15 USD hourly rate (U.S. Department of Labor 2022). Standard errors in parentheses.

Species		Pasture			Property		Predation and disease					Control		Damage index ($)	Control index ($)	Cost-benefit ratio
	Has pasture (%)	Time (hours)	Cost ($)	Suppl. feed ($)	Time (hours)	Cost ($)	Predation ($)	Disease ($)	Other ($)	Vet. costs ($)	Med. treatment ($)	Time (hours)	Cost ($)			
Cattle only	0.99	20	508	301	56	2,083	223	99	93	4	13	72	525	4467	1605	2.8
	(0.01)	(6)	(91)	(56)	(14)	(527)	(119)	(71)	(71)	(3)	(4)	(13)	(99)			
Swine only	0.41	2	191	20	3	237	-	-	155	11	-	25	182	701	557	1.3
	(0.16)	(1)	(117)	(19)	(2)	(199)	-	-	(161)	(12)	-	(6)	(79)			
Sheep and goats only	0.83	7	128	108	14	1,014	55	-	-	2	5	39	284	1627	869	1.9
	(0.09)	(4)	(59)	(63)	(7)	(447)	(31)	-	-	(2)	(3)	(20)				

impacts because of management will likely take significant time to manifest. Across all states, producers report that most of the control is performed by themselves or someone living on their property (51%), and only 4% benefit from the support of a federal, state, or county agency. Second, these increases could be partly explained by the restrictions to human activities implemented to mitigate the spread of the novel coronavirus SARS-CoV-2. In many parts of the world, different species of animals have been frequently observed in urban or suburban areas where previously they were not common to see, as a result of less human activity (Rutz et al. 2020). Lastly, during the time among these 2 surveys there has been a significant amount of research and education programs related to the damaging effects of wild pigs and the development of methods to detect this damage. These types of education campaigns can increase the amount of reported damage solely because producers are now better able to classify damage as related to wild pigs as opposed to classifying it as another species or just ubiquitous "wildlife damage." Efforts should be made to continue educating and training farm and ranch owners and workers so that they can measure and record swine damage in a uniform, systematic manner that is comparable between establishments and comparable year after year in each state.

Management implications

In the present analysis, we have focused on 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. One result to highlight from this study is that contact between wild pigs and domestic animals is common and emphasizes the potential danger wild pigs pose in terms of disease transmission. In fact, from the previous survey, higher losses were reported from disease impacts than were reported in 2017. With the risk of an ASF introduction to the United States increasing from neighboring countries and international travel, potential containment becomes drastically more difficult if introduced into the wild pig population. Quantification of the channels of disease transmission at the wild pig–domestic livestock interface could help identify the facilities at risk.

This study provides a glimpse into the immense costs of wild pigs to the U.S. economy and further justifies aggressive wild pig management. Lethal control programs focusing on whole sounder removal for wild pigs in the United States need to be implemented to reduce future threats to agriculture, property, and human health and safety. Results from this study can help inform legislators, producers, and members of the public to these costs and provide the impetus to prevent the spread of wild pigs in the United States. Further research is needed to fully quantify the full scope of economic losses from wild pigs.

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Supplemental material

Supplemental material can be viewed at https://digitalcommons.usu.edu/hwi/vol17/iss3/4.

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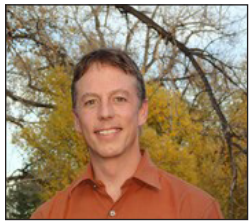
Associate Editor: Jessica Tegt

Sophie C. McKee is a research economist at the National Wildlife Research Center's *Economics, Operations Research, and Social Dimensions of Wildlife Management* project. Her main research interests and publications involve the estimation of the economic impacts of wild pig damage and wildlife transmitted diseases, and the valuation of wildlife damage management actions on agriculture and natural resources. She received her Ph.D. degree in economics from Colorado State University and her M.S. degree in computer science from Supelec in France.

Ryan S. Miller is a senior ecologist with U.S. Department of Agriculture Center for Epidemiology and Animal Health and received a Ph.D. degree in zoology from Colorado State University. He is broadly interested in quantitative landscape and population ecology, with special interests in disease ecology. Specifically, he is interested in the mechanisms that drive contact and transmission of pathogens at the wildlife-livestock interface. Further, he is interested in how quantitative tools can be used to inform policy decisions to mitigate disease transmission. Specific systems he has studied include the cervid-cattle interface, feral swine-livestock interface, and wild bird-domestic fowl interface.



Jeremiah L. Psiropoulos is a district wildlife biologist with the U.S. Forest Service on the Medicine Bow and Routt National Forests in Colorado. Originally from Southern Oregon, he earned B.S. degrees in fisheries and wildlife sciences from Oregon State University and environmental studies from the University of Oregon. He has worked with birds, mammals, and fish in Oregon, California, Iceland, and presently in Colorado. His professional interests include forest health and vertebrate ecology.

Stephanie A. Shwiff is a supervisory research economist and project leader at the U.S. Department of Agriculture's National Wildlife Research Center (NWRC) and affiliate faculty at the University of Colorado – Boulder and Colorado State University. At NWRC, she leads the research project entitled, *Economics, Operations Research, and Social Dimensions of Wildlife Management.* Her research is aimed at better understanding the economic impact of wildlife diseases and damage, and developing, assessing, and improving wildlife management techniques.