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Texas hunters' attitudes toward wild pigs (*Sus scrofa*) and their management: an applied approach for wildlife managers

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Abstract

Choosing and executing a wild pig management strategy is often a considerable challenge for wildlife managers due to the wide variety of potential strategies and stakeholder preferences. Our research aims to understand management preferences for and tolerance of wild pigs among Texas resident hunters within 8 managerial districts of Texas. We applied the Potential for Conflict Index (PCI_2) to estimate potential management preference conflicts within each district. From 24,201 questionnaires completed in 2019, we found that, on average, 74% of respondents across all management actions in each district were found to be acceptable. Resident respondents were overall intolerant of wild pigs and were least tolerant in the San Angelo district. Study findings are useful in informing socially acceptable and contextually appropriate wild pig management plans. Our research serves as an approach that matches the units of analysis with the units of management for decision-making.

KEYWORDS

Acceptability, attitudes, human dimensions, hunters, PCI_2, tolerance, wild hogs, wildlife management

Wild pigs (*Sus scrofa*), also known as wild boar, feral swine, wild hog, and Russian or Eurasian boar, are a destructive nonnative species in the western hemisphere. Wild pigs were first introduced to continental North America in the mid-1500s by Spanish explorers as a food source (Belden and Frankenberger 1977). In the 1990s, the wild pig population began to increase in both numbers and geographic spread due to the species' adaptability to a wide variety of habitats (Bevins et al. 2014), high fecundity (Bevins et al. 2014), reforestation, and climate change (Vetter et al. 2020). Human-mediated movement of wild pigs for sport hunting also contributes to the species' population expansion (Grady et al. 2019). Wild pigs are currently estimated at 6.9 million individuals (Lewis et al. 2019, Boyce et al. 2020) and are present in at least 31 states. However, within some of those states, wild pig distribution is restricted (U.S. Department of Agriculture [USDA] 2019). Referred to as one of the world's 100 worst invasive species by the International Union for Conservation and Nature (Lowe et al. 2000), wild pigs cause extensive economic and environmental impacts, including alteration of ecosystems and damage to agriculture at large and small scales, disease transmission (McLean et al. 2021*a*), and vehicle collisions (Thurfjell et al. 2015). In terms of damage to agriculture at large scales, in a study conducted by McKee et al. (2020) there was an estimated crop loss due to wild pigs of US$272 million for the surveyed set of crops (i.e., hay, pecans, melons, honeydew, watermelon, sugarcane, sweet potatoes, and cotton) in 12 U.S. states. In addition, researchers recently estimated that wild pigs contribute to approximately 4.9 million metric tons of CO_2 emissions per year from soil disturbance alone (O'Bryan et al. 2021).

Despite the many risks, damages, and ecological impacts associated with wild pigs, there are segments of the public that have neutral-to-positive attitudes toward them and value them for utilitarian or cultural purposes. Hunters, for example, value wild pigs as a source of food or recreation, while other individuals (e.g., landowners who lease their land to hunters and hunting guides) earn income from wild pig hunting (Connally et al. 2021). In areas where wild pig hunting and meat consumption are popular, the species may also gain cultural importance. In Texas, for example, several small towns hold annual wild pig festivals that include pageants, parades, and cookoffs (Historic Ben Wheeler Texas 2021). Pejchar and Mooney (2009) describe the cultural importance of wild pigs in Hawaiian communities, noting that wild pigs serve not only as an important food source, but that they also hold religious and cultural significance for Hawaiians who hunt them. Given the cultural importance associated with wild pigs, hunters have expressed concern over the management and removal of them on the landscape. For example, Texas hunters, animal welfare, and environmental interest groups were a part of a lawsuit against a toxicant manufacturer in 2017 that prompted the registration withdrawal of a wild pig toxicant in the state (Carlisle et al. 2020). Moreover, studies have shown that efforts made by government agencies to control wild pigs have encountered criticism from hunters who did not agree with total eradication (Pejchar and Mooney 2009, Weeks and Packard 2009, McLean et al. 2021*b*). To help reduce intentional translocation for hunting, states have implemented policies to help manage wild pig population expansions, which include restrictions on wild pig transport (Grady et al. 2019). The success of future policies will undoubtedly depend upon hunters' awareness and support, particularly given that hunters have shown interest in maintaining or establishing new wild pig populations for hunting and given that they are key stakeholders in wildlife policy decisions (Organ et al. 2012).

In successfully managing wildlife, the integration of human dimensions research findings into wildlife management decision holds promise (Decker et al. 1989, Manfredo et al. 1995, Ring 2008). For example, understanding stakeholders' attitudes toward local wildlife population sizes and management methods (e.g., aerial shooting, use of a toxicant) is critical for effective wild pig management (Gigliotti et al. 2000). The concept of attitudes is defined as an evaluation of an object as either favorable or unfavorable (Fishbein and Ajzen 2011). We examined attitudes toward wild pig management methods in terms of their level of acceptability (Heneghan and Morse 2019). In addition, we examined attitudes toward wild pigs in terms of their preferences in the animals' population size in Texas, also known as Wildlife Acceptance Capacity (WAC; Brenner and Metcalf 2020). Wildlife Acceptance Capacity has been used as an attitudinal measure to quantify tolerance for wildlife (Decker and Purdy 1988, Riley and Decker 2000, Lischka et al. 2019, McLean et al. 2021*a*). Tolerance for wildlife can be defined as "an individual's or group's ability and willingness to accept the costs of living with wildlife and desire for positive

effects that arise from interactions with wildlife" (McLean et al. 2021*b*:2). Like acceptability of wildlife management actions, tolerance for wildlife is recognized as a key component of modern wildlife management (Gigliotti et al. 2000) that can help managers quantify stakeholder preferences (Lischka et al. 2019).

If wildlife managers are aware that hunters in a community are, for example, largely intolerant of wild pigs and less accepting of the use of a toxicant, they could pursue alternative removal strategies or engage in outreach aimed at informing the community of the benefits of using a toxicant. With the understanding that there are likely differences in stakeholder tolerance and acceptability of management methods, research that can tease out these differences can aid in the development of tailored outreach materials for different communities (Jaebker et al. 2021, McLean et al. 2021*b*). Additionally, stakeholder understanding of tolerance and acceptability of management methods can help managers anticipate and respond to any resulting conflicts in an area and develop more socially acceptable and contextually appropriate wild pig management plans moving forward. While there have been several human dimensions studies that examined attitudes toward wild pigs and their management (Carlisle et al. 2020, Jaebker et al. 2021, McLean et al. 2021*b*), the extent to which these studies have reached wildlife managers and informed on-the-ground decision-making is unclear. It is plausible that there may be a mismatch between the geographic scope of human dimensions studies and the level at which wild pig management decisions are made.

In the United States, management of the wild pig population is largely undertaken at the state level and generally involves a combination of regulatory measures (e.g., legal restrictions on transport) and management efforts (e.g., trap and remove). The federal agency with primary responsibility for managing the wild pig population nationwide is the U.S. Department of Agriculture's (USDA) Animal and Plant Health Inspection Service (APHIS) Wildlife Services (WS), which with allocations from Congress, developed the National Feral Swine Damage Management Program (NFSDMP). The NFSDMP provides funding to states with wild pig-specific programs for the purpose of monitoring and managing wild pigs and assisting individual landowners who experience wild pig damage. The NFSDMP report from fiscal years 2014–2018 states that part of their objectives for Texas is to support reduction of range and size of the wild pig population, as well as manage the damage wild pigs cause (APHIS 2020).

In Texas, the federal Texas WS Program has formed a collaborative partnership with other federal and government agencies, private landowners, and producer associations to assist in the reduction of wild pigs on the landscape. By state statute, the Texas WS Program is the only program in Texas with a mandate to manage negative interactions with wild pigs and is divided into 8 different management districts, each of which comprises multiple counties: Canyon District, Fort Worth District, College Station District, Corpus Christi District, Kerrville District, Uvalde District, Fort Stockton District, and San Angelo District (Figure 1). The districts were originally designated based on livestock predation management, rodent management, the protection of various agricultural commodities, local program participation (i.e., cost share funding), and the availability of appropriations to cost share (B. Leland, Wildlife Services, personal communication). Decisions regarding how to manage wild pigs are made at the district level and are primarily driven by landowner requests for assistance, the nature and extent of the conflict, and availability of program resources.

With district level management decision making units in place, our study matches them with useful units of analysis, i.e., hunter attitudes. We hope that demonstrating the practical and applied approach to human dimensions research will facilitate its adoption in other management domains. Moreso, our study may allow for an improved understanding of hunters' preferences in Texas WS districts and allow managers to make tangible and socially acceptable decisions regarding wild pig management on a smaller, more practical scale. The specific objectives of our study were to (i) measure and compare hunter acceptability levels for 3 different wild pig management methods (trap and lethally remove, aerial shooting, and government/agency hunting) across Texas WS management districts, rural and urban residence, and landowner status (own or manage land in Texas), (ii) measure and compare hunter tolerance levels for wild pigs across Texas WS management districts and urban/rural residence, and (iii) measure and compare the potential for conflict (levels of consensus and polarization) with respect to the 3 wild pig management methods across Texas WS management districts.

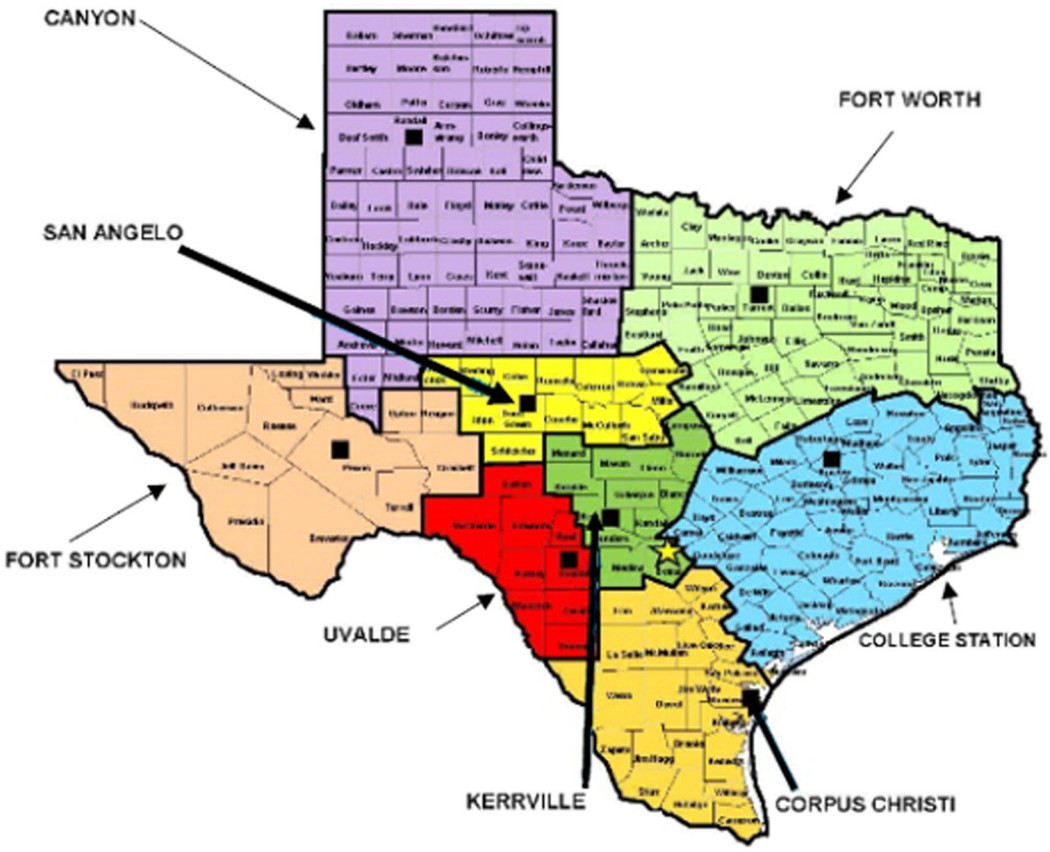

FIGURE 1 Texas Wildlife Services District Delineation Map 2021. From Texas Wildlife Services Teaching, Research, Extension and Service, n.d. (https://agrilife.org/txwildlifeservices/who-to-contact/).

STUDY AREA

Texas is in the southern region of the United States and has the largest population of wild pigs of any state, with an estimated 2.5 million animals as of 2016 (Lewis et al. 2019). At the time of our study, Texas was considered a high-priority state for the NFSDMP. In addition, Texas agricultural producers have suffered considerable losses to wild pigs. In a study of wild pig damage to high-value crops in 11 states, Anderson et al. (2016) found that producers in Texas suffered more losses than those of the other 10 states, at approximately $90 million state-wide total. The study from Anderson et al. (2016) reports on a small fraction of the total damage, since only 6 crops were examined.

METHODS

Data were collected through a self-administered questionnaire hosted on Qualtrics (Qualtrics XM, Provo, UT, USA), an online survey platform, by the Texas A&M AgriLife Extension Service. Three of the individuals who helped develop the questionnaire had local subject matter expertise and were licensed hunters in Texas. At the time of survey administration, a general hunting license (not specific to wild pigs) was mandatory to hunt wild pigs in Texas, which were not managed as a game animal (i.e., no regulated hunting season, take limit, or means/methods restriction). In Texas, wild pigs are considered a free-roaming domestic livestock animal, which is the same

categorization as exotic ungulates and does not fall under the regulatory purview of Texas Parks and Wildlife Department (TPWD). However, hunting licenses for exotic species are issued by TPWD and the agency provided the sample for our study. The sample comprised both resident and nonresident adults in the United States who purchased a hunting license for the 2018–2019 hunting year and had their email address on record (n = 169,619 out of 1,106,625 licensed adult hunters). Following Dillman's Tailored Method (Dillman et al. 2014), subjects received an email invitation to participate in the online survey on 4 June 2019, and 2 reminder emails were sent on 7 and 10 June 2019. The survey closed on 13 August 2019. Data were exported from Qualtrics into FileMakerPro (v. 14; Claris International Inc., Cupertino, CA, USA). We followed the methodology from Lindner et al. (2001), using an extrapolation method to test for nonresponse bias. Respondents were divided into 2 equal groups of early and late responders. To assess statistical differences, we conducted a Pearson's chi-squared test between the 2 groups on the variables of interest.

Three attitudinal statements were presented in the questionnaire to assess the acceptability of wild pig management actions. Acceptability of management actions was measured on a 5-point scale from 1 = completely unacceptable to 5 = completely acceptable. We measured tolerance using WAC, which was intended to understand respondents' preferences for future changes to the specific wild pig population size in the state of Texas. Tolerance was measured by assessing the respondent's preference for whether they wanted the population of wild pigs to be completely removed, reduced, remain the same, or increased. We chose to measure attitudes towards management methods and the wild pig population size in Texas by urban and rural residence. Previous studies have shown that the amount of exposure one has had to nature and rural areas may influence their attitude toward wildlife (Heberlein and Ericsson 2005, Grady et al. 2019). Rural areas are often more susceptible to wild pig damages because of the amount of agricultural land in those areas, and residents in rural areas may have had more experience with wild pig damage to agriculture. Landownership was measured to add to the growing body of research that has focused largely on landowner perspectives of wild pigs (Harper et al. 2016, Caplenor et al. 2017). Given that wild pig management often requires participation and cooperation of private landowners, we were interested in understanding whether landowners (who may also be hunters) have different attitudes and preferences from nonlandowners.

To aid in the interpretation of findings and to inform and improve decision making, Potential for Conflict Index 2 (PCI_2) was used measure and compare the levels of consensus and polarization with respect to the 3 wild pig management methods across Texas WS management districts, thereby helping managers anticipate potential conflict. The PCI_2 values range from 0.0 to 1.0 and the greatest potential for conflict occurs when the PCI_2 value is equal to 1. Conversely, the least potential for conflict occurs when the PCI_2 value is equal to 0. To further aid in understanding and interpretation of survey findings, results can be visualized by bubble graphs (Vaske et al. 2010). Each bubble's size represents the magnitude of PCI_2, depicting the level of potential conflict (or consensus) surrounding the acceptance of an issue. To assess respondents' potential for conflict, we used the PCI_2 mean value of each of the acceptability of management action items to depict the level of potential conflict (or consensus) surrounding the acceptance of an issue. We used a bubble graph to visualize the data, with a large bubble representing a high variance of responses around the mean (i.e., low consensus), signifying a higher potential for conflict, and a small bubble representing a low variance of responses around the mean (i.e., high consensus), signifying a lower potential for conflict (Vaske 2018).

The independent variables in our study consisted of WS districts, rural or urban hunter residency, and ownership or management of land in Texas. To achieve groupings of districts from survey data, we used ZIP codes given by respondents. We also used ZIP codes to categorize respondents as rural or urban, which we cross-checked with U.S. Census designations. Respondents with out-of-state ZIP codes were removed. Land ownership/management (hereafter landowners) was measured using the following survey item question: Do you own or manage land in Texas? (yes/no).

All data were analyzed using SPSS software (v. 27; IBM SPSS statistics, Chicago, IL, USA). We conducted a one-way Welch's ANOVA with a Games-Howell post hoc test (used due to unequal variances) to explore differences in

the acceptability of management actions and tolerance for wild pigs across Texas WS districts. Independent sample t-tests were conducted to determine if differences existed among urban and rural Texas residents for both acceptability of management actions and tolerance and land ownership. Finally, we used PCI_2 to measure the level of consensus regarding the acceptability of management actions of wild pigs in Texas WS districts. For the one-way Welch's ANOVAs, we calculated effect size measures (η) as an indicator of practical significance, in part due to the increased chance of finding statistical significance with large sample sizes. For the independent t-tests, we used Cohen's *d* to determine effect sizes. We used the criteria specified in Vaske (2019) to denote minimal ($\eta > 0.10$), typical ($\eta > 0.24$), and substantial effects ($\eta > 0.37$). Values were statistically significant at $P < 0.001$.

RESULTS

Of the 169,619 surveys administered for our study, 10,199 (6%) were undeliverable and 37,317 were returned, for a response rate of 23%. After removing nonresidents, 24,201 respondents remained. We removed nonresidents because we wanted to focus on hunters residing within the state of Texas. Remaining respondents were almost exclusively male (95%) and predominately white (91%). The mean age of respondents was 52 years old, 58% had obtained a bachelor's degree or higher, and 65% had an average household income of $100,000 per year. Our sample was largely representative of the study population based on material provided by TPWD, which included their sociodemographic information above matching the known population demographics. Most respondents lived in the College Station (45%) and Fort Worth (32%) WS districts. Each of the other 6 districts had 8% or less of the overall respondent distribution: about 6% of respondents lived in the Canyon district, 6% lived in Corpus Christi district, <1% lived in the Fort Stockton district, 8% lived in the Kerrville district, 1% lived in the San Angelo district, and <1% lived in the Uvalde district.

Approximately 51% of resident respondents owned or managed land in Texas, and 88% resided in an urban area. Most respondents in each district found all 3 management actions to be acceptable (Table 1). Across Texas, 88% of respondents indicated that trapping and lethal removal was somewhat or completely acceptable, and 77% indicated that aerial shooting was somewhat or completely acceptable. Government or agency hunting had the lowest level of acceptability of the 3 methods in all districts, with 58% of respondents marking this practice as somewhat or completely acceptable. Wild pig management actions had similar acceptance levels among urban and rural residents (Table 2).

Our analysis with 5 acceptability categories (i.e., completely acceptable, somewhat acceptable, neutral, somewhat unacceptable, and completely unacceptable) indicated that 2 of the 3 management methods were rated as completely acceptable by most respondents: trapping and lethal removal (73%) and aerial shooting (61%). Government/agency hunting was found to be completely acceptable by 43% of respondents, while 18% were neutral, and 16% found it to be completely unacceptable. We also found that respondents had relatively low tolerance for wild pigs. Approximately 20% of respondents wanted to see wild pigs completely removed, 63% wanted them to be reduced, 14% wanted populations to remain the same, and 2% wanted populations to increase.

We found no statistical differences or effect sizes (*V*) that reached the minimum threshold in our test for nonresponse bias. The variables were (i) trap and lethally remove acceptability ($\chi^2 = 12.320$, $P = 0.772$, $V = 0.035$), (ii) government/agency hunting acceptability ($\chi^2 = 16.110$, $P = 0.445$, $V = 0.020$), (iii) aerial shooting acceptability ($\chi^2 = 8.626$, $P = 0.928$, $V = 0.015$), (iv) tolerance ($\chi^2 = 7.244$, $P = 0.612$, $V = 0.016$), and (v) ownership of land in Texas ($\chi^2 = 0.678$, $P = 0.410$, $V = -0.008$).

The mean acceptability scores for each of the 3 management actions differed statistically among the 8 Texas WS districts (Table 3), but the effect sizes were minimal for each method ($\eta = 0.066$; $\eta = 0.043$; $\eta = 0.067$, respectively), indicating a less-than-minimal or small effect (Cohen 1988, Vaske 2019). Post hoc comparisons revealed differences among WS management districts on the acceptability of management methods. For example, all districts except for Fort Stockton were different from one another in terms of acceptability of the trap and

TABLE 1 Acceptability of wild pig management actions across Wildlife Services Districts in Texas, USA, 2019.

Management Action[a]	Unacceptable (%)	Neutral (%)	Acceptable (%)
Canyon District			
Trap & lethally remove	5	7	88
Government or agency hunting	23	17	59
Aerial shooting	7	10	83
College Station District			
Trap & lethally remove	5	6	89
Government or agency hunting	23	18	58
Aerial shooting	11	11	76
Corpus Christi			
Trap & lethally remove	10	10	80
Government or agency hunting	28	20	52
Aerial shooting	15	13	72
Fort Stockton			
Trap & lethally remove	8	14	78
Government or agency hunting	16	22	62
Aerial shooting	6	10	84
Fort Worth			
Trap & lethally remove	5	7	88
Government or agency hunting	24	17	58
Aerial shooting	12	12	76
Kerrville			
Trap & lethally remove	5	6	89
Government or agency hunting	22	17	61
Aerial shooting	13	11	77
San Angelo			
Trap & lethally remove	5	4	91
Government or agency hunting	18	15	67
Aerial shooting	7	7	86
Uvalde			
Trap & lethally remove	6	7	88
Government or agency hunting	28	15	57
Aerial shooting	10	6	84
Total Districts			
Trap & lethally remove	5	7	88

(Continues)

TABLE 1 (Continued)

Management Action[a]	Unacceptable (%)	Neutral (%)	Acceptable (%)
Government or agency hunting	24	18	58
Aerial shooting	12	11	77

[a]Management actions were combined from 5 categories into 3 for the purposes of reporting: unacceptable, neutral, and acceptable.

TABLE 2 Acceptability of wild pig management actions by urban/rural residency of respondents, Texas USA, 2019.

Management Action[a]	Unacceptable (%)	Neutral (%)	Acceptable (%)
Urban Residence			
Trap & lethally remove	5	7	88
Government or agency hunting	23	18	59
Aerial shooting	12	11	77
Rural Residence			
Trap & lethally remove	5	6	88
Government or agency hunting	26	19	54
Aerial shooting	12	10	78
Total			
Trap & lethally remove	5	7	88
Government or agency hunting	24	18	58
Aerial shooting	12	11	77

[a]Management actions were combined from 5 categories into 3 for the purposes of reporting: unacceptable, neutral, and acceptable.

lethally remove method, with Uvalde district respondents having the lowest level of acceptability for the method ($M = 4.28$).

A t-test revealed that the only difference between urban and rural residents regarding the acceptability of management methods was for government/agency hunting ($t_{3325} = 4.599$, $P < 0.001$) (Table 4). For the other 2 management methods, there were no differences between rural and urban residents ($t_{3535,3442} = -2.662$ and -0.869, $P = 0.008$ and 0.385 respectively). A t-test comparing the acceptability of management actions between landowners and non-landowners indicated that there were differences for all 3 of the management methods for trap and lethally remove, government/agency hunting, and aerial shooting, respectively ($t_{28171,26035,26959} = 10.930$, -23.803, and -4.856, respectively, $P < 0.001$). The effect sizes were minimal for trap and lethally remove and aerial shooting ($d = 0.13$ and $d = 0.058$, respectively), and typical for government or agency shooting ($d = 0.289$; Table 5).

On average, respondents from the San Angelo district were the least tolerant of wild pigs ($M = 1.67$), followed by those from the Fort Stockton district ($M = 1.77$). Respondents from the Corpus Christi district had slightly higher tolerance levels for wild pigs on average than the other districts ($M = 2.13$). Mean tolerance differed across all Texas WS districts with a minimal effect size ($F_{7,x} = 27.459$, $P < 0.001$, $\eta = 0.091$). Post hoc comparisons for tolerance and

TABLE 3 Results of ANOVA comparing acceptability of wild pig management actions across Wildlife Services Districts in Texas, USA, 2019. Means with different superscripts across each row are significantly different at $P < 0.05$ using Games-Howell post hoc tests.

Management Action[a]	Canyon (*n* = 1,499) (6%)	College Station (*n* = 10,919) (45%)	Corpus Christi (*n* = 1,341) (6%)	Fort Stockton (*n* = 169) (1%)	Fort Worth (*n* = 7,835) (32%)	Kerrville (*n* = 1,912) (8%)	San Angelo (*n* = 336) (1%)	Uvalde (*n* = 182) (1%)	*F*-value	*P*-value	Eta(η)
Trap and lethally remove	4.52^{B}	4.54^{C}	4.28^{A}	4.32^{ABC}	4.53^{BC}	4.54^{BC}	4.61^{BC}	4.56^{BC}	15.097	<0.001	0.066
Government or agency hunting	3.64^{AC}	3.63^{A}	3.42^{B}	3.80^{AC}	3.61^{A}	3.69^{AC}	3.89^{C}	3.53^{BC}	5.985	<0.001	0.043
Aerial shooting	4.40^{C}	4.20^{AB}	4.01	4.39^{ABC}	4.17^{AB}	4.17^{A}	4.48^{C}	4.31^{BC}	14.470	<0.001	0.067

[a]Management actions coded as (1) completely unacceptable, (2) somewhat unacceptable (3) neutral, (4) somewhat acceptable, and (5) completely acceptable.

TABLE 4 Comparison of mean acceptability of wild pig management actions between urban and rural areas in Texas, USA, 2019.

Management Action[a]	Urban (*n* = 20,197) (88%)	Rural (*n* = 2,681) (12%)	t-statistic	*P*-value	Cohen's *d*
Trap and lethally remove	4.52	4.57	−2.662	0.008	0.053
Government or agency hunting	3.64	3.49	4.599	<0.001	0.098
Aerial shooting	4.19	4.22	−0.869	0.385	0.018

[a]Management actions coded as (1) completely unacceptable, (2) somewhat unacceptable (3) neutral, (4) somewhat acceptable, and (5) completely acceptable.
[b]All values are statistically significant at $P < 0.001$.

TABLE 5 Comparison of mean acceptability of wild pig management actions between landowners and nonlandowners in Texas, USA, 2019.

Management Action[a]	Landowner or manager (*n* = 12,481) (51%)	Nonlandowner or manager (*n* = 12,126) (49%)	t-statistic	*P*-value	Cohen's *d*
Trap and lethally remove	4.56	4.43	10.930	<0.001	0.130
Government or agency hunting	3.39	3.82	−23.803	<0.001	0.289
Aerial shooting	4.16	4.23	−4.856	<0.001	0.058

[a]Management actions coded as (1) completely unacceptable, (2) somewhat unacceptable (3) neutral, (4) somewhat acceptable, and (5) completely acceptable.
[b]All values are statistically significant at $P < 0.001$.

districts revealed a difference between Corpus Christi and all other districts, while the San Angelo district was different from all but one district (Fort Stockton) in respondents' mean tolerance level. A t-test comparing the mean tolerance level between urban ($M = 1.99$) and rural ($M = 1.831$) residents in Texas revealed a difference (stats, $P < 0.001$), but the effect size was typical ($d = 0.275$).

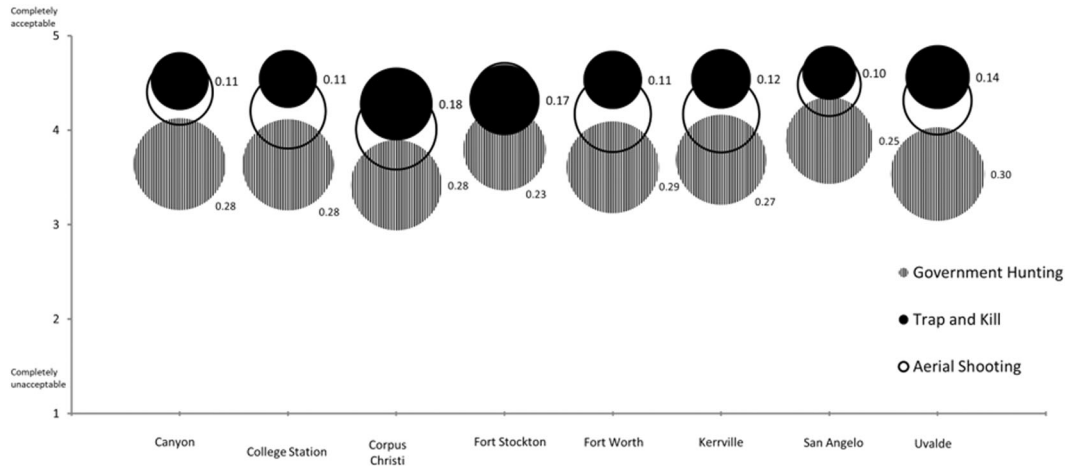

FIGURE 2 Potential for Conflict Index2 associated with acceptability of management actions in each of the 8 Wildlife Services districts in Texas, 2019.

The level of consensus was generally high for the trap and lethally remove method, with PCI_2 values ranging from 0.11 to 0.17, while the level of consensus was generally lower for the government or agency hunting method, with PCI_2 values ranging from 0.23 to 0.30 (Figure 2). The PCI_2 bubble corresponding to government/agency hunting in the Corpus Christi district was located at the lowest point on the graph, indicating that the action was relatively less acceptable to the respondents in our survey than were other methods. The bubble representing the Uvalde district for the government/agency hunting method was the largest overall (0.30), indicating the greatest degree of polarization for both management method and district. The PCI_2 bubble corresponding to the trap and lethally remove management method in the Uvalde district was located at the highest point, suggesting this action was most acceptable by respondents. The small size of this bubble (0.14) also indicated that trap and lethally remove methods in the Uvalde district would likely have more consensus among hunters in that area. The PCI_2 bubble corresponding to the San Angelo district regarding the trap and lethally remove method showed the smallest size bubble of any, indicating that trap and lethally remove methods in this district would likely have the least potential for conflict among hunters in that area.

DISCUSSION

For effective wild pig management, it is useful to understand stakeholder's attitudes toward local wild pig population sizes and management methods. We found that hunters supported the 3 lethal wild pig management actions. Although we observed differences in acceptability of management actions across Texas WS districts, the practical differences we found were relatively small. While we cannot conclude there was no nonresponse bias, the results of our study provided no evidence thereof. It is important to note, however, that we surveyed a single stakeholder group of hunters, and it is possible that they were more homogenous in their management preferences across the state than other stakeholder groups (e.g., agricultural producers) or the general public. However, although all respondents were hunters, many were also members of other stakeholder groups, including Texas landowners (52% of all respondents) and crop producers (43% of landowner respondents). The other stakeholder interests did not affect respondents' management preferences across management districts in a significant way. Because other stakeholder interests did not affect management preferences within our study, this could indicate that lethal removal of wild pigs has similar levels of support among broader segments of the

population. Carlisle et al. (2020) found that a majority of the general public across the United States held negative attitudes toward wild pigs and approved of trapping and lethally removing them without dogs. Nevertheless, we did find that there were significant differences among our respondents for each management action and landownership. Landowners were slightly less accepting of government/agency hunting and aerial shooting methods than nonlandowners, which could reflect antigovernment sentiment. In addition, research from Watkins et al. (2019) on landowners and wild pigs suggested that attitudes may differ depending on their personal experience with the species on their property, hunting participation, and income threatened by wild pig damage. Wild pigs may be seen from a landowner's perspective as a resource rather than an invasive species (Connally et al. 2021). In addition, in areas where meat consumption and hunting are popular, cultural importance may be contributing to these differences. We suggest future research into identifying these specific differences within the contextual bounds of our study, including the benefits and barriers to landowners from the presence of wild pig populations.

We found no significant differences between urban residents and rural residents when it came to management method acceptability. The result of our findings is contrary to most wildlife management acceptability studies, particularly those involving lethal removal of native predators. Studies have found, for example, that rural residents were less opposed than urban residents to lethal removal of cougars, bears (i.e., native), and predators more generally (Reiter et al. 1999, Teel et al. 2002), and they were more opposed to efforts to reintroduce and maintain wolves (Vaske et al. 2021). The absence of an urban/rural divide in our study findings could partly explain why we found no significant differences in management method acceptability across the Texas WS management districts, despite differences in urban/rural respondent composition among the districts. Respondents from the College Station district, for example, were 90.6% urban, while respondents from the Fort Stockton District were 46.7% urban. Additional research would be required to determine whether the lack of an urban/rural divide for wild pig management preferences would hold true for other stakeholder groups and the general public more broadly.

Limitations of our study provide avenues for future research. For example, while we understand and recognize that management preferences for and tolerance of wild pigs may vary contextually, including on a state-by-state or county-level basis, research should focus on other states with wild pig populations. Future research should explore the differences of multiple stakeholder groups and their influence on acceptability of management actions including nonresident hunters and their influence on local management and decisions. Moreover, our understanding may be improved by investigating differences between resident and nonresident hunters in Texas and other states with large wild pig populations. There is a need to further explore the key differences we found in the acceptability of management actions between the aerial shooting and government/agency hunting methods. While we cannot conclusively pinpoint the reasons for the differences, our understanding may be enhanced through prior research that has shown to affect acceptability of management actions, particularly in the context of chronic wasting disease (CWD) management. Factors such as trust and concern have been shown to predict hunter support for increasing acceptability of management actions (Meeks et al. 2022). The future success of wild pig management in Texas will depend partly on hunter and landowner trust and the level of concern with agencies in charge of controlling wild pig populations. Given that 95% of Texas is privately owned (Anderson et al. 2014), hunter and landowner stakeholder involvement and support will be vital in ensuring effective management for the species, as well as meeting the management goals of the NFSDMP. Similarly, it would be advantageous to further asses the differences in the terminology/phrasing used to describe management actions in surveys. For example, our survey used government or agency hunting to describe a management technique used to control wild pigs. In other studies, the term ground shooting is used to describe the same technique (van Eeden et al. 2019). It is possible that respondents in our study may have been reacting to the phrasing used within the survey for government or agency hunting, and therefore, the other management options may have yielded less support if they were phrased in terms of government or agency action. We recognize another limitation of our study, in which email addresses of individuals who purchased a

Texas hunting license for the 2018–2019 hunting year was the only way to determine the percentage of hunters in each district. Given the low number of respondents from the Uvalde and Fort Stockton districts, it seems possible that a sampling error may have been introduced yielding higher margins of error for those districts, compared to districts with more responses. Lastly, research-driven outreach materials aimed at informing hunters and landowners of feasible goals to manage wild pig damage could result in more effective management for the species, as support from these groups is particularly important.

MANAGEMENT IMPLICATIONS

While much research on invasive species has focused primarily on ecological and biological characteristics and the problems they cause (McNeely 2001), such problems cannot be mitigated without a clear understanding of affected stakeholders and their views concerning the acceptability of various management strategies. Results from our study suggest that wildlife managers in all Texas WS management districts can utilize the full range of tools available to them in controlling wild pigs without significant risk of conflict or backlash from the study population. Given past conflicts in Texas over wild pig control (e.g., when use of a wild pig toxicant was approved in 2017), our findings provide practical information that should be reassuring for any decision makers or professionals involved in wild pig control in Texas. More broadly, our study illustrates an applied approach to human dimensions research that could be used in other human-wildlife issue areas. By matching the geographic unit of analysis to relevant management districts or areas, the results should resonate more with the intended management audience and render the research more useful.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The authors report no conflict of interest.

ETHICS STATEMENT

The study was reviewed and approved for use with human subjects by the (IRB: Texas A&M University) (Protocol No. IRB2018-1219M).

DATA AVAILABILITY STATEMENT

Participants of this study did not agree for their data to be shared publicly, so supporting data are not available.

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