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Tools and Technology Article

Feral Swine Behavior Relative to Aerial Gunning in Southern Texas

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ABSTRACT Feral swine (*Sus scrofa*) impact resources through their destructive feeding behavior, competition with native wildlife, and impacts to domestic animal agriculture. We studied aerial gunning on feral swine to determine if aerial gunning altered home range and core area sizes, distances between home range centroids, and distances moved by surviving individuals. We collected data before, during, and after aerial gunning in southern Texas. Using Global Positioning System collars deployed on 25 adult feral swine at 2 study sites, we found home range and core area sizes did not differ before and after aerial gunning. However, feral swine moved at a greater rate during the aerial gunning phase than during the before and after periods. We concluded that aerial gunning had only minor effects on the behavior of surviving swine and that this removal method should be considered a viable tool in contingency planning for a foreign animal disease outbreak.

KEY WORDS aerial gunning, feral swine, Global Positioning System, helicopter, hog, home range, movement, pig, *Sus scrofa*, telemetry.

Feral swine (*Sus scrofa*) are an invasive species that occupy rural and increasingly urban portions of the United States (Adams et al. 2006). Feral swine affect resources through their destructive feeding behavior, competition with native wildlife, and impacts to domestic animal agriculture (Sweeney et al. 2003). In many states, the United States Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services program helps to mitigate damage caused by feral swine.

Feral swine pose a significant disease risk to the commercial swine industry and the disease status for national program diseases in the United States (Witmer et al. 2003). For example, classical swine fever (CSF) and foot-and-mouth diseases (FMD) have been eradicated from many developed countries, but they are endemic in much of the world. An introduction of either CSF or FMD into the United States would have severe impacts to producers due to high swine mortality; both CSF and FMD introductions would cause severe restrictions on exporting pork and pork products (Thomson et al. 2001, Van Campen et al. 2001). Costs incurred from eradication and control of these diseases, plus the loss of markets, would be economically devastating. The role that feral swine might play in the event of a CSF or FMD outbreak in the southern Texas border region, USA, is complicated by their frequent contact with domestic swine in low biosecurity herds (Wyckoff et al. 2009). Consequently, contingency plans are being developed for the introduction of foreign animal diseases into feral swine populations.

In fiscal year 2007, Wildlife Services programs in 23 states or territories removed 19,586 feral swine; of these animals, 6,752 (34%) were removed by aerial gunning (Wildlife Services 2007). The southern Texas border region is particularly conducive to the use of aerial gunning because of favorable, low-growing vegetative characteristics (Campbell and Long 2009). However, studies from Australia indicate 1) aerial gunning reduces populations by only 65–80% and survivors continue to cause damage and potentially spread disease (Hone 1990, Saunders 1993); 2) feral swine modify behavior to avoid detection from helicopters (Saunders and Bryant 1988); and 3) the efficiency of aerial gunning is influenced by feral swine density (Choquenot et al. 1999). In New South Wales, Australia, Dexter (1996) found no differences in hourly distances moved, diel variation in distances moved, home range sizes, or positions of home ranges among surviving feral swine monitored before, during, and after aerial gunning operations. Dexter (1996) concluded that harassment caused by aerial gunning had little effect on the movements of survivors. No studies have been performed on the impacts of aerial gunning to feral swine behavior in the United States.

Given the widespread use of aerial gunning in the control of feral swine damage in southern Texas and the likelihood that this technique would be used as a disease control tool in the event of a CSF or FMD outbreak, we studied its effects on surviving feral swine movements and corresponding likelihood of disease spread. Our objectives were to determine if aerial gunning of feral swine altered home range and core area sizes, distances between home range centroids, and distances moved by survivors before, during, and after aerial gunning. We hypothesized that aerial gunning would cause a short-term increase in movement that would temporarily push feral swine out of core areas but not their home ranges. However, if our data suggested that feral swine ranged widely and permanently moved outside of

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home ranges after harassment by helicopters, aerial gunning would be a poor alternative to control the spread of foreign animal diseases.

STUDY AREA

We conducted our study in mixed shrub rangelands in Kleberg and San Patricio counties, Texas. Our Kleberg County study site (KCSS) was approximately 3,700 ha, occurred on the Laureles Division of the King Ranch (27°29′N, 97°37′W), and received an average of 67 cm of rainfall annually. Our KCSS was bordered to the north by expansive agriculture fields and to the south, east, and west by rangeland under the same private ownership. Overstory vegetation was dominated by huisache (*Acacia farnesiana*) and honey mesquite (*Prosopis glandulosa*). Our San Patricio County study site (SPCSS) was approximately 3,100 ha, occurred on the Rob and Bessie Welder Wildlife Foundation (28°06′N, 97°22′W), and received an average of 79 cm of rainfall annually. Our SPCSS site was bordered on the north by the Aransas River, on the west by United States Highway 77, and on the south and east by private rangeland. Overstory vegetation consisted of huisache, honey mesquite, live oak (*Quercus virginiana*), cedar elm (*Ulmus crassifolia*), net-leaved hackberry (*Celtis laevigata* var. *reticulata*), anaqua (*Ehretia anacua*), and muscadine (*Vitis rotundifolia*).

METHODS

We trapped feral swine in January 2008 on the KCSS and in May 2008 on the SPCSS using 20 rooter-door box traps (2.5 m × 1 m × 1 m) baited with fermented whole kernel corn distributed throughout the properties. We immobilized and ear-tagged all feral swine captured and placed Global Positioning System (GPS) collars (GPS 3300S; Lotek Wireless Inc., Newmarket, ON, Canada) on animals estimated to be ≥82 kg. We used physical restraint and chemical immobilization (4.4 mg/kg body weight Telazol® [Fort Dodge Animal Health, Fort Dodge, IA] plus 2.2 mg/kg body weight xylazine; Kreeger et al. 2002). Following chemical immobilization, we used an intramuscular injection of yohimbine hydrochloride (0.15 mg/kg body weight; Kreeger et al. 2002) as a reversal agent. Our GPS collars emitted a very high frequency signal from 0800 hours to 1700 hours and were equipped with a 6-hour mortality sensor. We recorded sex and aged feral swine by tooth eruption, replacement, and wear (Matschke 1967). Capture and handling procedures were approved by the National Wildlife Research Center's Institutional Animal Care and Use Committee (QA-1528).

We deployed GPS collars on individuals for ≤15 weeks because of the challenge of maintaining collars on feral swine (Wyckoff et al. 2007). We programmed collars to collect locations every 4 hours on 5 days out of the week and every 15 minutes on the remaining 2 days out of the week. We recovered all collars by radio-controlled drop-off mechanisms in mid-April 2008 on the KCSS and mid-August 2008 on the SPCSS. We uploaded location data into ARCVIEW®.

We conducted aerial gunning operations by helicopter on 29 February 2008 on the KCSS and 24–25 June 2008 on the SPCSS. We selected days on which locations were collected every 15 minutes for aerial gunning experiments. We attempted to remove all feral swine observed without collars. We recorded the flight time and path, number of marked (ear-tagged) and unmarked feral swine removed, and number of collared feral swine seen. Our helicopter was equipped with a GPS unit (Garmin, Olathe, KS), and we uploaded flight paths into ARCVIEW. We report the estimated minimum distance between individual feral swine and the helicopter during aerial gunning.

We estimated home ranges and core areas using swine locations collected before (11 Jan–28 Feb on the KCSS and 6 May–23 Jun on the SPCSS) and after (1 Mar–17 Apr on the KCSS and 26 Jun–13 Aug on the SPCSS) aerial gunning on days when locations were collected every 4 hours. We used the fixed-kernel method (Worton 1989) to generate 95% home range areas and 50% core areas using the Animal Movement Extension of ARCVIEW (Hooge and Eichenlaub 1997). We used least square cross validation as the smoothing parameter on the kernel distributions (Silverman 1986). We overlaid home ranges and core area polygons on coverage maps of the study areas using ARCVIEW. We calculated home range centroids (arithmetic mean of Universal Transverse Mercator coordinates of locations) from feral swine locations collected before and after aerial gunning and report the mean distance between centroids by site.

We determined movement rates from feral swine locations collected before, during, and after aerial gunning from days on which locations were collected every 15 minutes. We used the Animal Movement Extension of ARCVIEW to calculate the distance between sequential locations. We calculated the mean distance moved per hour for each of the 3 periods (before, during, and after). Additionally, we report the distance moved and duration spent outside of home ranges in response to aerial gunning.

For both study sites we compared feral swine home range and core area sizes before and after aerial gunning using paired t-tests and compared movement rates among periods of before, during, and after aerial gunning with a repeated measure analysis of variance. For the latter model we used the individual as the repeated factor (von Ende 2001). For all analyses we considered individual swine as the experimental unit. When appropriate, we used Tukey's honestly significant difference for multiple comparisons. We performed all statistical procedures using SAS software (Littell et al. 2006).

RESULTS

We trapped 76 feral swine on the KCSS and 67 on the SPCSS. We placed GPS collars on 13 feral swine (9 M and 4 F) on the KCSS and 12 feral swine (5 M and 7 F) on the SPCSS. We uploaded 27,069 GPS locations from recovered collars on the KCSS and 18,053 locations from recovered collars on the SPCSS. Our collars deployed on the KCSS and SPCSS were successful in generating GPS

Table 1. Mean and standard error feral swine movement rate (m/hr) before, during, and after aerial gunning in Kleberg (n = 9) and San Patricio (n = 8) counties, Texas, USA, during 2008.

	Kleberg County (m/hr)		San Patricio County (m/hr)	
Aerial gunning period	$\bar{x}$	SE	$\bar{x}$	SE
Before	173	11	163	21
During	264	29	221	49
After	195	20	250	40

locations on 87% and 61% of attempts, respectively. On the KCSS, 2 males were harvested before we conducted aerial gunning, and 2 males emigrated from their site shortly after we deployed collars. On the SPCSS, we found one male and one female dead prior to aerial gunning.

On the KCSS our helicopter flight time was 5.7 hours, during which we removed 151 feral swine (27 feral swine removed/hr). We estimated there were 54 marked feral swine without collars alive during aerial gunning, of which 16 were shot from the helicopter (30%). On the SPCSS our helicopter flight time was 9.4 hours, during which we removed 84 feral swine (9 feral swine removed/hr). We estimated there were 49 marked feral swine without collars alive during aerial gunning, of which 11 were shot from the helicopter (22%). We determined the mean minimum distance between individual feral swine and the helicopter during aerial gunning on the KCSS and SPCSS to be 67 ± 27 m and 25 ± 5 m, respectively.

On the KCSS home range sizes before ($\bar{x}$ = 554 ± 287 ha) and after ($\bar{x}$ = 221 ± 80 ha) aerial gunning did not differ (t_9 = 0.835, P = 0.425). Similarly core area sizes before ($\bar{x}$ = 58 ± 30 ha) and after ($\bar{x}$ = 25 ± 7 ha) aerial gunning did not differ (t_9 = 0.772, P = 0.46). On the SPCSS, home range sizes before ($\bar{x}$ = 126 ± 26 ha) and after ($\bar{x}$ = 108 ± 37 ha) aerial gunning did not differ (t_6 = 0.485, P = 0.645). Similarly, the core area sizes before ($\bar{x}$ = 17 ± 6 ha) and after ($\bar{x}$ = 14 ± 6 ha) aerial gunning did not differ (t_6 = −0.381, P = 0.716). Shifts in estimated mean home range centroids from locations collected before and after aerial gunning on the KCSS and SPCSS were 614 ± 433 m and 559 ± 192 m, respectively.

On the KCSS we determined that 7 of 9 (78%) feral swine moved outside of their pregunning home range boundary a mean distance of 446 ± 204 m for a mean duration of 7.5 ± 1.4 hours in response to aerial gunning (Table 1). On the SPCSS we found that 5 of 10 (50%) feral swine moved outside of their pregunning home range boundary a mean distance of 120 ± 35 m for a mean duration of 3.4 ± hours. We noted one female from the SPCSS crossed the Aransas River during aerial gunning. We found evidence for differences in movement rates among the periods before, during, and after aerial gunning on the KCSS ($F_{2,16}$ = 8.46, P = 0.003) and on the SPCSS ($F_{2,14}$ = 2.85, P = 0.092). Feral swine on the KCSS and SPCSS generally moved at a greater rate during aerial gunning than during the before and after periods (Table 1).

DISCUSSION

Previous reports from Australia on the efficiency of aerial gunning showed removal rates in southwestern New South Wales of 11 feral swine per hour (Hone 1983), in western New South Wales of 39 feral swine per hour (Saunders and Bryant 1988), and in the Northern Territory of 37 feral swine per hour (Hone 1990). Our removal rates of 27 feral swine per hour on the KCSS and 9 feral swine per hour on the SPCSS are comparable to these, with removal rates on the SPCSS being somewhat lower. We attribute the disparity in removal rates between the KCSS and SPCSS to differing feral swine densities and to habitat conditions. We estimated feral swine densities before gunning to be 9/km^2 on the KCSS and 4/km^2 on the SPCSS (T. A. Campbell, National Wildlife Research Center, unpublished data), which may partially explain the differences in removal rates. Also, we conducted our aerial gunning during the growing season on the SPCSS, when more foliage was available for escape cover. Our data suggested that where deciduous canopies existed, it was more efficient to perform aerial gunning during the dormant season.

Ilse and Hellgren (1995) determined minimum convex polygon home ranges of adult female feral swine to range 82–233 ha on the SPCSS (Mohr 1947). Our observations that home range and core area sizes did not differ before and after aerial gunning suggested gunning had little effect on the amount of space used, though we noted decreasing trends after gunning at both study sites. We found that feral swine shifted centers of activity >550 m after aerial gunning. We hypothesize that these shifts were toward areas of favorable or abundant resources made available by aerial gunning through the removal of intraspecific competitors.

Previous findings from northwestern New South Wales, Australia, suggest that feral swine movement rates before aerial gunning (579 m/hr) did not differ from movement rates during and after (560 m/hr; Dexter 1996). Although our movement rates (163–264 m/hr) were generally less than those reported above from Australia, feral swine on the KCSS responded differently in that their rates of movement during aerial gunning exceeded those from before and after periods. When assessing the behavior of feral swine on the KCSS and SPCSS, we observed several differences. First, the minimum distance between animals and the helicopter were greater on the KCSS, suggesting that these animals flushed more readily. Second, 78% of animals moved outside of their initial home range boundary on the KCSS compared to only 50% of animals on the SPCSS. Lastly, feral swine that moved outside of their initial home range boundaries moved farther and remained outside longer on the KCSS compared to the SPCSS. We believe that the behavior of feral swine at both sites was affected by aerial gunning. However, our data suggested feral swine on the KCSS were more mobile, whereas feral swine on the SPCSS were more sedentary. This might be explained by the seasonal difference in available escape cover between the sites. Alternative explanations, such as possible diverging histories of aerial gunning on the properties cannot be discounted (Saunders and Bryant 1988).

Our findings that feral swine moved <1.5 km outside of their initial home ranges and returned to their home ranges by 2115 hours the night that aerial gunning was performed suggested this technique could be a viable option to accomplish disease control. Feral swine appeared to have fidelity to their home ranges and are unlikely to spread pathogens widely in response to aerial gunning. A common concern of adjacent landowners not engaged in aerial gunning is that this activity permanently pushes surviving feral swine onto their property. Our data did not support this, but we acknowledge that this may be influenced by the size of the landholding on which aerial gunning occurs.

Our data suggested that although rivers are permeable to feral swine, these animals are reluctant to cross them. For example, on the SPCSS out of 18,053 locations collected, only 6 locations from 4 animals were found to be on the north side of the Aransas River. Furthermore, during aerial gunning, only one animal crossed the Aransas River, and she remained on the north side of the river <30 minutes. Conversely, paved roads were readily crossed and used as travel corridors at both sites.

Our collars were successful at collecting and storing scheduled GPS locations, remained on animals, and dropped off properly. These findings were counter to a previous feral swine movement study using GPS technology in southern Texas (Wyckoff et al. 2007). We recommend a smaller collar design (approx. 300 g) with shorter-term deployments ($\leq$4 months), recognizing that the latter limits the types of management (e.g., Judas pig technique) and research functions that can be performed.

MANAGEMENT IMPLICATIONS

Our assessment of aerial gunning efficiency and feral swine movements in the presence of aerial gunning suggested that the tool was efficient and that only short distance and short duration reactions occurred. Aerial gunning had only minor effects on the behavior of surviving swine, and we recommend that this removal method be considered a viable tool in contingency planning for a foreign animal disease outbreak.

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