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ENVIRONMENTAL RESOURCE MANAGEMENT | RESEARCH ARTICLE

Damage caused to rangelands by wild pig rooting activity is mitigated with intensive trapping

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Abstract: The wild pig (*Sus scrofa*), an exotic and invasive species, has caused great concern at a global scale, particularly within agricultural landscapes. The objective of this study was to determine whether intensive trapping and wild pig removal resulted in a concomitant decrease in damage to rangelands. Removal of 356 wild pigs over 2 years showed an immediate reduction in rooting damage that carried over after trapping ceased. After only one trap session, rooting damage across the three sites was reduced 43–82% and total damage reduction from the beginning to the end of the project was 90%. With intensive trapping (1 pig/22.7 ha/year), damage may also be reduced on neighboring areas that are not being trapped, as indicated by data from our non-trapped units. Although we reduced rooting damage locally, and on nearby areas, large-scale, intensive control will be needed for the long-term effective reduction in damage and wild pig numbers because wild pigs have high reproductive rates, high survival, and can recolonize areas rapidly.

Subjects: Agriculture; Environmental Sciences; Plant Ecology; Plant & Animal Ecology; Vertebrates; Animal Ecology; Resource Management - Environmental Studies; Conservation - Environment Studies; Ecology - Environment Studies

Keywords: corral traps; drop net; eradication; feral swine; management; population control; *Sus scrofa*

1. Introduction

Invasive wildlife species are known to rapidly exploit natural resources and undergo dramatic expansion in their distribution due to lack of co-evolved population regulation mechanisms (e.g., a

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PUBLIC INTEREST STATEMENT

In the United States, wild pigs (also known as feral hogs or feral swine) are a non-native and invasive species. As wild pigs increase in abundance and distribution, producers and land managers are searching for strategies to mitigate rooting damage. Eradication of wild pigs is improbable so wild pigs are likely to increasingly inhabit rangelands, forests, and agricultural lands. Because damage from wild pig rooting can cost billions of dollars per year in the United States, we sought to understand if rooting damage could be reduced by intensive trapping and removal of wild pigs. Our study demonstrates that intensive trapping of wild pigs using two trapping techniques drastically reduces damage across, and even beyond, the extent at which control efforts were implemented.

paucity of intra-guild competitors, or absence of effective top-down control by native predators; Massei & Genov, 2004; Pimentel, Zuniga, & Morrison, 2005; Pyšek & Richardson, 2010; Seward, VerCauteren, Witmer, & Engemen, 2004). Exotic and invasive species can create a landscape scale wave of biodiversity loss, habitat destruction, disease transmission, and shifts in trophic interactions and nutrient cycling (Barrios-Garcia & Ballari, 2012; Massei & Genov, 2004; Pyšek & Richardson, 2010). An exotic and invasive species, the wild pig (*Sus scrofa*), has caused great concern at a global scale, particularly within agricultural landscapes (Bankovich, Boughton, Boughton, Avery, & Wisely, 2016). Wild pigs have a high reproductive potential (Taylor, Hellgren, Gabor, & Ilse, 1998) and are omnivores, which allows them the ability to inhabit a wide range of habitat types (Mersinger & Silvy, 2007), resulting in rapid expansion in distribution and abundance.

Economic losses from wild pigs is a global problem, receiving much research attention (Pimentel, Lach, Zuniga, & Morrison, 2002; Poudyal et al., 2017). Large populations of wild pigs may destroy agricultural plantings and reduce crop yields to levels that impose economic burdens on farmers (Choquenot, McIlroy, & Korn, 1996). In one estimate, economic losses in agricultural cropland resulted in ~\$200 USD of damage/pig/year (Pimentel et al., 2002). However, costs associated with native ecosystems (e.g., repairing fragile ecosystems, protecting endangered species, loss of range utilization, and invasion of rangeland by non-native species) can be difficult to quantify (Engeman et al., 2004, 2006). In a recent estimate, annual damage and control costs for wild pigs were estimated at 1.5 billion dollars in the United States alone (Bannerman & Cole, 2014). It is therefore expected that as wild pig density and distribution increases, a concomitant increase in damage and economic burdens will occur.

A variety of pig control techniques are implemented to mitigate damage. Damage abatement strategies vary regionally and seasonally and the search for comprehensive methods are ongoing. Intensive wild pig removal has occurred (Choquenot, Kilgour, & Lukins, 1993; Saunders, Kay, & Nicol, 1993), but linking removal efforts with damage reduction may be critical to understand because of the economic losses associated with damage. Damage monitoring can help quantify how much area wild pigs are impacting, and regular assessment may be used to detect fluctuations in wild pig populations or measure success of control programs. Herein, we use transects for assessing wild pig damage, resulting from rooting of the surficial layers of soil on rangelands, to determine whether intensive wild pig control efforts effectively reduce damage. Rooting is a behavior in which wild pigs turn the soil over in search of food items (Bankovich et al., 2016). From 2009 through 2011, we conducted transects across three study sites to assess damage, comprising one pre-trapping period, three trapping periods, and one post-trapping period. We report on how intensive trapping and removal of wild pigs leads to reduction in rooting activity and damage.

2. Materials and methods

2.1. Study area

This study was conducted on rangelands from 2009 through 2011 at the Noble Research Institute's (NRI) Oswalt Road Ranch (ORR; 2,093 ha), NRI Coffey Ranch (CR; 1,024 ha), and Hoffmann Ranch (HR; 930 ha) in south-central, Oklahoma, USA. Study sites were in the Cross Timbers and Prairies ecoregion, which is characterized by a mixture of wooded areas and openings (Gee, Porter, Demarais, & Bryant, 2011). All hunting and trapping of wild pigs was prohibited for one calendar year prior to our study. Animal capture and euthanasia techniques were approved in accordance with Animal Use Protocol number 2008-160 issued by Texas A&M University.

2.2. Trap types

We divided each property (ORR, CR, and HR) into two approximately equal-sized units, for a total of six units. Within a study site, the two units were proximal, without any spatial separation. Each of the six units were assigned at random to one of the three treatments (i.e., corral traps, drop nets, and a no-harvest/non-trap unit) (Table 1). Corral traps and drop nets were used on ORR, drop nets and a non-trap unit were assigned to CR, and corral traps and a non-trap unit were implemented

Table 1. Treatments and distribution of damage assessment transects, and trapping and removal of wild pigs (n = 356) across three study sites (Coffey Ranch, Hoffmann Ranch, and Oswalt Road Ranch) in south-central Oklahoma, USA, from 2010 to 2011. Treatments consisted of non-trapped units, corral traps, and drop nets. Corresponding damage surveys for wild pig rooting activity were conducted from 2009 through 2011

Study site	Size (area; ha)	Damage transects (n) (density)	Treatment	Year 1		Year 2	
				Traps (n)	Pigs removed (n)	Traps (n)	Pigs removed (n)
Coffey Ranch	1,024	30 (1 transect/34.13 ha)	Drop net Non-trap	4 —	52 —	3 —	84 —
Hoffmann Ranch	930	30 (1 transect/31.0 ha)	Corral trap Non-trap	2 —	8 —	2 —	11 —
Oswalt Road Ranch	2,093	92 (1 transect/22.75 ha)	Corral trap Drop net	7 6	41 91	0 2	0 39

on HR (Table 1). Trapping was conducted from January to April when natural forage was least available; trap treatments remained unchanged during 2010 and 2011.

Corral traps (West, Cooper, & Armstrong, 2009) consisted of two adjoining compartments with two different gate openings (i.e., single spring and saloon style) facing opposite one another. These traps were capable of capturing additional pigs in the adjacent compartment once the opposite compartment had been triggered. Corral traps were 1.5 m in height and constructed with *t*-posts (1.8 m) spaced every 1.5 m, and cattle panels that were 4.9 m in length with a mesh size of 10 × 10 cm. Drop nets were designed based on specifications described by Gee, Holman, and Demarais (1999). Drop nets were 18.3 × 18.3 m and required human presence to operate the trap. The system incorporated multiple rope harnesses, a release mechanism, solenoids, batteries, and a line-of-sight remote control to trigger the net to drop. A Trailmaster active infrared trail monitor (TM1050, Goodson & Associates, Inc., Lenexa, KS, USA), in combination with a radio-frequency transmitter and two-way radio, was used to monitor activity under nets, eliminating the need for constant observation. The drop net system also was equipped with a remote-controlled infrared-filtered spotlight to facilitate trapping at night. For a complete description of trapping systems, with figures, refer to Gee et al. (1999) and Gaskamp (2012).

2.3. Trap site selection

Trap sites were identified where wild pig presence was documented using remotely triggered cameras at bait piles. The densities of camera sites were 1/52 ha on ORR, 1/39 ha on CR, and 1/40 ha on HR. Whole kernel corn (~16 kg/day) was provided at bait sites for 7 days, and if ≥1 pig was patterned (pigs consuming bait over ≥3 consecutive diel periods), then a trap was installed. Consequently, the number of traps or nets (range = 0–7) installed varied among sites and years. However, based on camera surveys and the lack of wild pig presence, no corral traps were set at ORR during Year 2.

Corral trap gates were tied open (3 days minimum) to allow pigs to become familiar with the trap, after which time they were set for trapping. Drop nets were baited with corn around the center pole to concentrate pig feeding activity to facilitate capture. Traps were relocated for a particular site after five consecutive days without a capture event; traps were abandoned after pigs were no longer detected by camera at a given trap location. All trapping efforts were concluded before 30 April or when pigs were no longer observed at sites throughout each treatment area. Complete information on trap site selection and trapping methods are provided in Gaskamp (2012). No other pig harvest or removal was allowed on the study areas during the study period. Wild pigs were euthanized upon capture via a shot to the brain from a .22 caliber rifle. Animal capture and euthanasia procedures were conducted in accordance with Animal Use Protocol 2008–160 issued by Texas A&M University.

2.4. Transect sampling

Wild pig damage assessments to surficial layers of soil on rangeland (i.e., rooting activity) were conducted five times over the course of the study on each study site (CR: June 2010 and 2011; December 2009, 2010, and 2011; HR: March 2010 and 2011; June 2009, 2010, and 2011; ORR: May 2010 and 2011; September 2009, 2010, and 2011). We used 100-m transects (ORR: $n = 92$; CR: $n = 30$; HR: $n = 30$) for quantifying rooting damage by wild pigs; the density of transects on ORR was greater because damage assessment transects were used in conjunction with established vegetation transects. We used stratified random sampling on ORR as part of a vegetation study where the total number of transects were split in proportion to the size and number of ecological sites (Ecological Site Descriptions, Natural Resources Conservation Service, United States Department of Agriculture); then within ecological site, random starting points were identified. We enforced a minimum distance criterion (200 m) from ecological site and property boundaries, as well as other starting GPS locations. On CR and HR, we used simple random sampling to identify starting locations for transects by specifying the same criteria as above. Transects were fixed throughout the study where GPS coordinates marked the beginning of each transect, and followed a North

heading unless the transect crossed ecological sites, then a random bearing was taken until the transect stayed within an ecological site. We sampled for new rooting damage at 20, 40, 60, 80, and 100 m along each transect. New rooting damage, from wild pigs turning over the soil to search for food, was identified as exposed surficial soil; other signs of pig presence (e.g., scat, tracks, and hair) were used to confirm that soil disturbance was caused by wild pigs. Old damage (i.e., any damage occurring previously and counted during prior transect sampling) was identified by crusted soil, re-vegetation, or a layer of thatch covering the damage. Rooting damage at each stop along transects was assessed in four quadrants out to 10 m using the stop location to center the quadrants. An estimate of area impacted by wild pig rooting was measured in each quadrant at each of the five stops using rectangular 0.18-m² quadrats. The final damage estimate (m²) for each transect was the sum of quadrats with rooting damage in the four quadrants at five stops ($n = 20$ units) multiplied by 0.18 m².

2.5. Statistical analysis

Damage assessments were analyzed using general linear models in SAS® 9.3 (SAS Institute, Inc., Cary, NC, USA) and the GLM procedure. We calculated the total area of each transect with damage (total number of quadrats with damage \times 0.18 m²) to assess damage extent by wild pigs as a function of time period and treatment, while blocking for study site; a time period \times treatment interaction also was modeled. Time periods were defined as: pre-trapping (period = 1), trapping (periods = 2, 3, and 4), and post-trapping (period = 5) and modeled as a continuous variable. We natural log-transformed transect damage (area + 0.01; m²) to satisfy statistical assumptions. When a significant *F*-test was observed, we used Tukey's honestly significant difference test to compare means; means with the same letter are not statistically different at $p > 0.05$. Back-transformed means and 95% CI are reported.

3. Results

We removed 356 wild pigs over 2 years on three study sites. Using the drop net, 136 and 130 wild pigs were removed on CR ($n = 52$ and 84 in Years 1 and 2, respectively) and ORR ($n = 91$ and 39 in Years 1 and 2, respectively), respectively (Table 1). Nineteen wild pigs were removed on HR (8 in Year 1, 11 in Year 2) and 41 during Year 1 on ORR using corral traps (Table 1).

Wild pig damage along transects (m²) was influenced by treatment ($F_{2, 615} = 2.88, p = 0.057$) and time period ($F_{1, 615} = 46.72, p < 0.001$), but not the interaction between treatment and time period ($F_{2, 615} = 1.75, p = 0.174$). The block effect for study site also was significant ($F_{2, 615} = 44.58, p < 0.001$). The non-trapped unit (0.089 m²; 95% CI 0.058–0.137) had greater damage per transect than did the treatment units with corral traps (0.021 m²; 95% CI 0.016–0.028) and drop nets (0.042 m²; 95% CI 0.032–0.054), but the only statistical difference of means occurred between the non-trapped unit and the corral trap treatment. Across study sites and treatments, damage was reduced over the course of the study (-0.513 ± 0.283 SE). Plotting means by time period, each subsequent sampling period had reduced damage, with the greatest reduction occurring after the first trapping session (Figure 1).

Although not statistically significant, the interaction between time period and treatment revealed that damage was reduced in each treatment over the five sampling occasions (Figure 2). Despite being reduced, damage was still greater in the non-trapped unit compared to the corral trap and drop net treatments, potentially with the exception of post-trapping damage assessment (Figure 2). From pre-trapping (Period 1) to the first period of trapping (Period 2), damage decreased by 82%, 43%, and 79% on CR, HR, and ORR, respectively. Total damage reduction from the beginning to the end of the project averaged 90% with CR and ORR showing the greatest reduction in damage.

4. Discussion

Removal of 356 wild pigs over 2 years on three study sites resulted in immediate and drastic reductions in surficial soil damage on rangelands. After one trapping session, overall rooting damage observed on transects was reduced by an average of 68% (range: 43–82% across study sites). At the termination of the study, rooting damage across all study sites was reduced by 90%. Wild pig removal efforts are conducted under the assumption that if wild pig numbers are reduced,

Figure 1. Trends in rooting damage by wild pigs along transects (m^2 /transect) across five time periods from 2009 through 2011 in south-central Oklahoma, USA. Period 1 = pre-trapping; periods 2, 3, and 4 = trapping; and period 5 = post-trapping. Back-transformed means and 95% CI are reported.

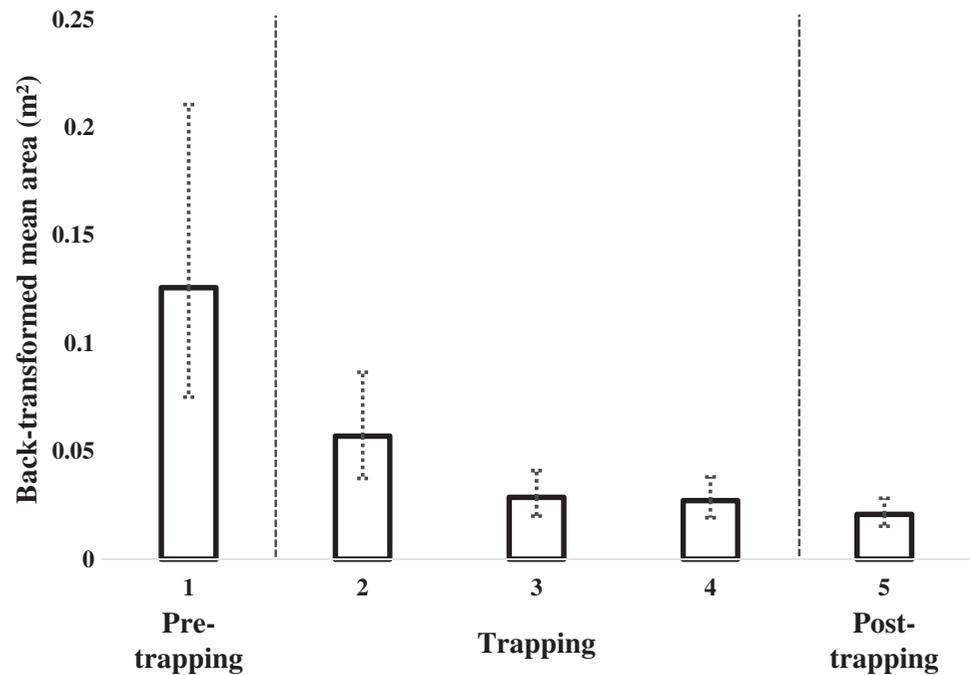
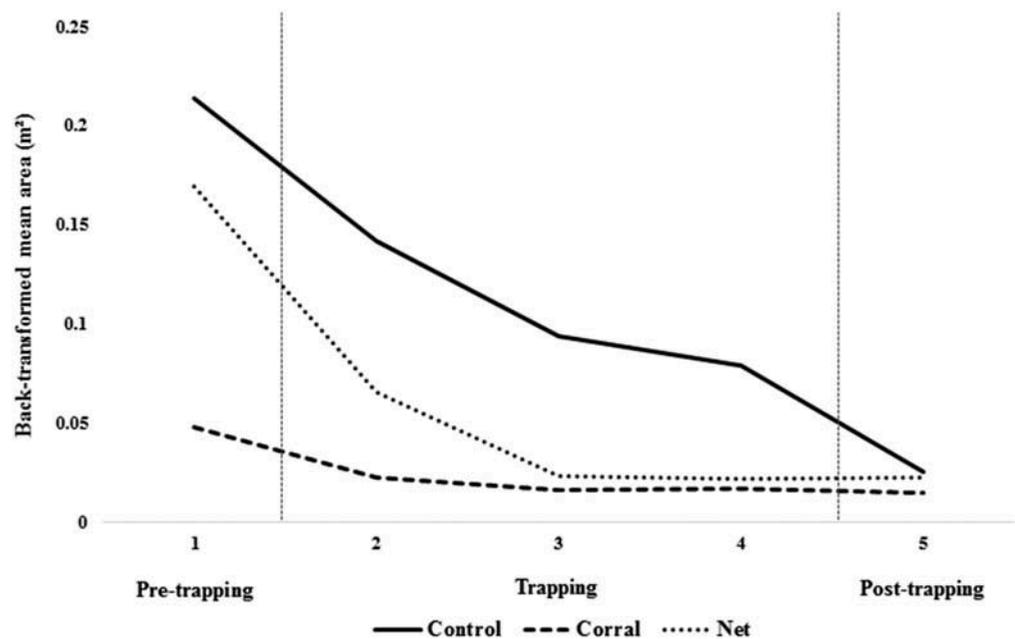


Figure 2. Temporal trends in damage reduction (area; m^2) within each treatment (control, corral trap, and drop net) across five periods from 2009 through 2011 in south-central Oklahoma, USA. The interaction was not significant ($p = 0.264$) due to the model specification, but the patterns show that damage, despite being reduced because of spillover effects, was still greater in the control unit compared to the corral trap and drop net treatments.



then damage also will be reduced. However, few studies have jointly assessed wild pig removal on damage reduction. Although we did not have numbers on population abundance, we were able to determine the percentage of the identifiable pig population that was removed. We removed 85.7% and 48.5% of the identifiable population across drop net and corral trap treatments, respectively (Gaskamp, 2012). The empirical data presented herein also show a direct link between wild pig removal and damage reduction from rooting.

Removal efforts will have to consider the scale and intensity of trapping as well as trapping technique used. Damage reductions may occur at a larger scale than the area treated (Engeman

et al., 2006). On two of the three study sites, a treatment without trapping restricted removal to half of the property. Even though trapping did not occur on these units, damage was still reduced within the non-trap units, which showed decreasing damage over time (Figure 2) and on each site. Although reduced, non-trapped units still had greater damage than the trapped treatment units.

Uniquely identifiable pigs within sounders allowed us to document areas used by pigs at camera sites. Most sounders used 2–3 camera sites, indicating that wild pigs traveled >1,600 m and traversed areas >200 ha (assuming a circular home range). Based on pig movement among camera sites on each study site, it is conceivable that wild pigs likely were using adjacent control units that were not trapped, which is further corroborated by study site wide reductions of damage even on non-trapped control units. Thus, trapping efforts on treatment sites (with drop nets and corral traps) probably removed pigs that also were using adjacent non-trap units. This finding is consistent with the observed decrease in damage over time on the non-trapped units.

Research suggests that trapping removes more pigs than ground hunting, hunting with dogs, and Judas pig techniques (McCann & Garcelon, 2008), with some trap designs being more effective than others (Gaskamp, 2012). Trapping technique, in addition to scale and intensity, should be a primary consideration for removing pigs to reduce damage. Some animals are inherently wary of traps (i.e., trap shy), reducing the efficacy of capture techniques (Diong, 1980; Saunders et al., 1993). Methods that capture large numbers of pigs and reduce trap shyness will result in quicker reductions of damage because more pigs can be removed before other pigs in the sounder become educated to certain trap designs (Gaskamp, 2012). With effective trapping techniques, wild pig numbers can be reduced, resulting in less damage, which allows landscapes and wild animal populations to recover (Bankovich et al., 2016). However, wild pig populations can recover rapidly because of high fecundity and early primiparity. For these reasons, wild pig control measures often are conducted at regular intervals or even on a year-around basis (Bengsen, Gentle, Mitchell, Pearson, & Saunders, 2013).

Damage assessment transects offer several advantages for identifying areas where wild pigs occur and for prioritizing control measures because they may serve as an index to relative population abundance (Choquenot et al., 1996). As most transects in this study were part of ongoing vegetation research projects, documenting damage while in the field was a time-saving method of collecting data on wild pig presence and damage. However, if damage assessments are to be used to estimate population abundance, then more direct correlations between damage and population estimates are needed (Choquenot et al., 1996). Damage assessments also can be used to gauge the level of success in removal of pigs through trapping efforts, or to index expanding populations when damage transects are used as an early detection tool (Choquenot et al., 1996). Damage assessment transects are a cost-effective means to detect and prioritize management actions targeted at removing wild pigs for localized reduction at scales approximating the home range size of pigs.

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Competing Interests

The authors declare no competing interests.

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References

- Bankovich, B., Boughton, E., Boughton, R., Avery, M. L., & Wisely, S. M. (2016). Plant community shifts caused by feral swine rooting devalue Florida rangeland. *Agriculture, Ecosystems and Environment*, 220, 45–54. doi:10.1016/j.agee.2015.12.027
- Bannerman, C., & Cole, L. (2014). *USDA announces \$20 million effort to reduce damage caused by feral swine*. Riverdale, MD: United States Department of Agriculture, Animal and Plant Health Inspection Service.
- Barrios-Garcia, M. N., & Ballari, S. A. (2012). Impact of wild boar (*Sus scrofa*) in its introduced and native range: A review. *Biological Invasions*, 14, 2283–2300. doi:10.1007/s10530-012-0229-6
- Bengsen, A. J., Gentle, M. N., Mitchell, J. L., Pearson, H. E., & Saunders, G. R. (2013). Impacts and management of wild pigs *Sus scrofa* in Australia. *Mammal Review*, 44, 135–147. doi:10.1111/mam.12011
- Choquenot, D., Kilgour, R. J., & Lukins, B. S. (1993). An evaluation of feral pig trapping. *Wildlife Research*, 20, 653–665. doi:10.1071/WR9930015
- Choquenot, D., McIlroy, J., & Korn, T. (1996). *Managing vertebrate pests: Feral pigs*. Canberra, Australia: Bureau of Resource Services, Australian Government Publishing Service.
- Diong, C. H. (1980, June 4–6). Responses of wild pigs to trap types and food baits. In: C. W. Smithed. *Proceedings of the Third Conference in Natural Sciences*, Hawaii Volcanoes National Park, University of Hawaii, Department of Botany, Honolulu, Hawaii, USA.
- Engeman, R. M., Smith, H. T., Severson, R., Severson, M. A., Woolard, J., Shwiff, S. A., . . . Griffin, D. (2004). Damage reduction estimates and benefit-cost ratios for feral swine control from the last remnant of a basin marsh system in Florida. *Environmental Conservation*, 31, 207–211. doi:10.1017/S0376892904001572
- Engeman, R. M., Stevens, A., Allen, J., Dunlap, J., Daniel, M., Teague, D., & Constantin, B. (2006). Feral swine management for conservation of an imperiled wetland habitat: Florida's vanishing seepage slopes. *Biological Conservation*, 134, 440–446. doi:10.1016/j.biocon.2006.08.033
- Gaskamp, J. A. (2012). *Use of drop-nets for wild pig damage and disease abatement*. College Station, TX: Texas A&M University.
- Gee, K. L., Holman, J. H., & Demarais, S. (1999). A man-power efficient drop-net system for capturing white-tailed deer. *Proceeding of the Annual Southeast Deer Study Group*, 22, 31.
- Gee, K. L., Porter, M. D., Demarais, S., & Bryant, F. C. (2011). *White-tailed deer: Their foods and management in the Cross Timbers* (3rd ed.). Ardmore, OK: The Samuel Roberts Noble Foundation, Inc.
- Massei, G., & Genov, P. V. (2004). The environmental impact of wild boar. *Galemys*, 16, 135–145.
- McCann, B. E., & Garcelon, D. K. (2008). Eradication of feral pigs from Pinnacles National Monument. *Journal of Wildlife Management*, 72, 1287–1295. doi:10.2193/2007-164
- Mersinger, R. C., & Silvy, N. J. (2007). Range size, habitat use, and diel activity of feral hogs on reclaimed surface-mined lands in east Texas. *Human-Wildlife Conflicts*, 1, 161–167.
- Pimentel, D., Lach, L., Zuniga, R., & Morrison, D. (2002). Environmental and economic costs associated with non-indigenous species in the United States. In D. Pimentel (Ed.), *Biological invasions: Economic and environmental costs of alien plant, animal, and microbe species* (pp. 285–303). Boca Raton (FL): CRC Press.
- Pimentel, D., Zuniga, R., & Morrison, D. (2005). Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecological Economics*, 52, 273–288. doi:10.1016/j.ecolecon.2004.10.002
- Poudyal, N. C., Caplenor, C., Joshi, O., Maldonado, C., Muller, L. I., & Yoest, C. (2017). Characterizing the economic value and impacts of wild pig damage on a rural economy. *Human Dimensions of Wildlife*, 22. doi:10.1080/10871209.2017.1368103
- Pyšek, P., & Richardson, D. M. (2010). Invasive species, environmental change and management, and health. *Annual Review of Environment and Resources*, 35, 25–55. doi:10.1146/annurev-environ-033009-095548
- Saunders, G., Kay, B., & Nicol, H. (1993). Factors affecting bait uptake and trapping success for feral pigs (*Sus scrofa*) in Kosciusko National Park. *Wildlife Research*, 20, 653–665. doi:10.1071/WR9930653
- Seward, N. W., VerCauteren, K. C., Witmer, G. W., & Engemen, R. M. (2004). Feral swine impacts on agriculture and the environment. *Sheep and Goat Research Journal*, 19, 34–40.
- Taylor, R. B., Hellgren, E. C., Gabor, T. M., & Ilse, L. M. (1998). Reproduction of feral pigs in southern Texas. *Journal of Mammalogy*, 79, 1325–1331. doi:10.2307/1383024
- West, B. C., Cooper, A. L., & Armstrong, J. B. (2009). Managing wild pigs: A technical guide. *Human-Wildlife Interactions Monograph*, 1, 1–55.



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