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***Abstract*:**
During the last decade, surface lignite mines in eastern Texas have experienced damage by feral hogs (*Sus scrofa*) to reclaimed areas. Specifically, feral hogs have caused damage to plants used in reclamation. In addition to vegetative losses, erosion control problems and water quality impacts have been noted. Big Brown Lignite Mine in Freestone County, Texas, had tried to control feral hogs through year-long trapping, which proved expensive. We hypothesized that hogs were using reclaimed areas only at night and seasonally. If so, knowledge of travel lanes into the mine and seasonal use would help concentrate trapping efforts and reduce costs. To determine travel lanes and season use, we radio-monitored 6 male and 10 female feral hogs from January 1998 to January 1999 at Big Brown Mine. We determined annual range size and habitat selection using a geographic information system. Contrary to our hypothesis, we found feral hogs remained on reclaimed lands. We observed that male feral hogs had a significantly ($P < 0.02$) larger mean annual range (15.8 km^2) than did female hogs (6.5 km^2), and hogs of both sexes preferred reclaimed wildlife areas and non-mined riparian corridors on the mine site, which had higher screening cover than other vegetation types. We found free water to be another important landscape feature that influenced hog movements. We observed that feral hogs moved greater distances from free water and screening cover during night hours. Feral hogs also traveled greater distances from both free water and screen cover during winter and spring than during summer or fall ($P < 0.001$). Based on the information obtained from our study, we recommend vegetation management (mowing of tall grass areas where hogs hide during daylight hours) be implemented to reduce hog impacts that occur mostly during night at the mine site. Reducing vegetative cover around water sources may also reduce hog impacts.

***Key Words*:** dial activities, feral hog, habitat use, human–wildlife conflicts, ranges, *Sus scrofa*

Several studies (Kurz and Marchinton 1972, Singer et al. 1981, Baber and Coblenz 1986, Hartin et al. 2007) have examined distributions, habitat use, range size, and dial activities of feral hogs (*Sus scrofa*) in the United States. In addition, Yarrow (1987), Ilse and Hellgren (1995), Gabor (1997), and Adkins and Harveson (2007) have studied feral hog movements and habitat use specifically in Texas. However, no studies have examined feral hog movements and habitat use on reclaimed surface-mined lands in Texas. Feral hogs can spread diseases to livestock (Hartin et al. 2007) and humans (Conover and Vail 2007), degrade water quality (Kaller et al. 2007) and destroy vegetation (Engeman et al. 2007*a*, 2007*b*). These potential problems have created a challenge for reclamation experts at TXU Corporation's Big Brown Mine (BBM; Richard L. White, TXU Environmental Services, personal communication). The Surface Mining Control and Reclamation Act of 1977 requires mining companies to establish and maintain certain vegetation densities and types, ensure erosion control, and maintain water quality standards on reclaimed mine lands. Once the land is reclaimed, the operator is responsible for maintaining certain vegetation densities and for controlling erosion on these lands for an extended period of time specified in their permit. Since the early 1990s, impacts of feral hogs on reclaimed lands at BBM have resulted in substantial costs to repair rooted areas where feral hogs have dug up the soil during their foraging for roots. Feral hogs have also created the potential problem with regulatory compliance violations due to vegetation losses, erosion control, and water quality impacts (R. L. White, TXU Environmental Services, personal communication). From 1991 to 1999, TXU trapped and removed approximately 750 hogs from the permit area of BBM (R. Hart, TXU, personal communication).

The situation at BBM provided justification to conduct a study to gather detailed, on-site information about feral hog use of reclaimed surface-mined lands, both temporal and spatial. The objectives of this paper are to analyze and quantify habitat selection of feral hogs in and around reclaimed areas and to evaluate the importance of water resources and screen cover on how feral hogs use reclaimed mine lands.

Our hypothesis was that feral hogs would use vegetation types that provided greater screening cover or were close to water. By gathering data on radio-monitored feral hogs, valuable information about spatial and temporal hog behavior can be analyzed and used to help develop management strategies to reduce the impacts of these animals. Core use areas by feral hogs not only identify an animal's center of activity over a given period, but they can also be used in making management decisions about that species. By identifying specific characteristics of habitats selected by feral hogs, resource managers could increase removal success by concentrating management efforts within areas with comparable characteristics and times when feral hogs use these areas.

Study area

This study was conducted on BBM located 16 km east of Fairfield, Texas (96° 10'W, 31° 43'N). The coal mine was located within the Post Oak Savannah vegetation region of Texas (Gould 1975) about 100–270 m above sea level (Mott and Zuberer 1991). Topography of the region ranges from level to gently rolling hills (0–5% slopes) on pre-mined areas and slightly more rolling (0–15% slopes) on post-mined areas (Reynolds 1989). Average annual rainfall for the area was about 98 cm (Harris and Zuberer 1993). Reclaimed mine sites have been vegetated primarily with coastal Bermudagrass (*Cynodon dactylon*), with blocks of woody vegetation planted within these sites (see Reynolds 1989 for a detailed description of plant species). Switchgrass (*Panicum virgatum*) was planted in some areas to aid in erosion control and to provide screening cover for wildlife.

The study area had 6 major vegetation types: (1) improved pasture, (2) upland hardwoods, (3) bottomland hardwoods, (4) reclaimed wildlife areas, (5) non-mined riparian stringers, and (6) recently reclaimed areas (see Reynolds 1989 for a detailed description of plant species within the major vegetation types). Improved pastures were dominated by Bermudagrass and were seeded with different clover varieties in certain pastures. Upland hardwoods (non-mined) were dominated by upland oak (*Quercus* spp.) species with various shrubs and herbaceous species sparsely occupying the understory. Bottomland hardwoods and riparian stringers (non-mined) were dominated by bottomland oak species and elms (*Ulmus* spp.) with various understory vines and shrubs. Reclaimed wildlife areas (reforested areas forming a hardwood-conifer-shrub composite in blocks of 2.5–30.0 ha and generally in a rectangular shape and surrounded by pasture) were dominated by switchgrass and other native bunch grasses, oaks, and pines (*Pinus* spp.). Many areas were heavily infested with the exotic plant willow baccharis (*Baccharis salicina*). Recently reclaimed lands (areas in Bermudagrass for ≤1year after grading and contouring) were dominated by Bermudagrass with blocks of seedlings of various woody species (e.g., oaks, pines) interspersed throughout.

Methods

Range size

We used box and corral traps (Mersinger 1999) to capture feral hogs on the reclaimed mine sites. We fitted adult hogs with motion-sensitive (mortality sensors) radio-transmitters manufactured by Advanced Telemetry Systems (ATS; Isanti, Minnesota, USA) to evaluate yearly range. We located hogs approximately 4 times/week from January 1998 through January 1999 using an ATS R2000 receiver with a 5-element yagi antenna mounted on a vehicle. We used a hand-held compass to take 2 azimuths at approximately right angles from known locations from Global Positioning System (GPS; Trimble Navigation, Sunnyvale, Calif., USA) verified tracking stations. Due to the extensive road system on the reclaimed land, we took fixes at locations as close as possible to the animal to minimize telemetry error, and we took all readings within approximately 10 minutes. We estimated observer error for telemetry locations by placing transmitters in likely hog habitats throughout the study area and comparing GPS verified locations with estimated locations. Standard deviation of azimuths was 3.000 (n = 35).

We verified habitat use by driving completely around a vegetation type to ensure the accuracy of the location and obtain visual confirmation of vegetation use. We took subsequent locations of feral hogs >18 hours following the previous locations to reduce the likelihood of autocorrelation of location data (Swihart and Slade 1985). We attempted to locate each hog at night during every third tracking period.

We calculated yearly ranges using ArcView (ESRI, Redlands California, USA) by tracing the minimum convex polygon (100%) around the perimeter of the locations of each hog and then calculating the area of the polygon. We used all locations of hogs for range calculations. We determined differences between male and female yearly ranges using a *t*-test.

Vegetation types

We determined vegetation types within the reclaimed and non-mined areas by using the visually dominant vegetation, location within the study area, and current land use practices. We processed and georeferenced a 1:24,000 color aerial photograph of BBM and adjacent properties (Landiscor Corporation, Dallas, Texas, USA) in ArcView to delineate habitat polygons on-screen. We then layered them over the photograph and verified vegetation types with 1 year of on-site ground truthing. We included improved pasture, upland hardwoods, bottomland hardwoods, reclaimed wildlife areas, non-mined riparian stringers, and recently reclaimed areas as vegetation types. We calculated the total area of each vegetation type within the GIS by using polygon-area calculations.

Habitat use

We evaluated feral hog use of vegetation types and landscape features using digitized radio locations within each vegetation type. We compared the percent of hog locations within each vegetation type to the percent of that vegetation type available to determine observed use versus the expected use by using Bonferroni confidence intervals (Cherry 1998). We compared vegetation type use on a seasonal and yearly basis.

We evaluated the use by feral hogs of 2 landscape features (screening cover and distance to water). We calculated screening cover using an obstruction of vision (OV) method (Robel et al. 1970) where a range pole was used to determine obstruction of vision by ground-level vegetation within each vegetation type. We evaluated hog locations based on proximity to screening cover using a grid analysis in the GIS that calculated the nearest location of preferred screening cover (determined in habitat use analysis). We used a grid analysis in the GIS to determine the closest source of free water to any given hog location.

We used a 1-way analysis of variance (ANOVA; MINITAB, Minitab Incorporated, State College, Pennsylvania, USA) to test for differences in the mean OV values of each vegetation type, and to test for differences in the proximity of hogs to free water and screening cover by season. We used Bonferroni confidence intervals to evaluate the difference between hogs' use of vegetation types by day and by night. We used unpaired *t*-tests to evaluate the difference between their day and night use of vegetation types with reference to distance to water source and distance from preferred screening cover. For all statistical tests, individual hogs were the experimental unit.

Results

Range size

In January 1998, we fitted 16 adult (>40 kg for females and >60 kg for males) hogs with radio collars (Mersinger 1999). We monitored 10 adult females (each from a different female group) and 6 adult males. However, during the fall of 1998, 4 transmitters failed and 1 was lost, leaving 6 adult females and 5 adult males with functioning transmitters at the termination of the study. We obtained 2,267 radio fixes on feral hogs from January 1998 to January 1999. Yearly ranges for individual hogs varied from 2.6 km^2 to 25.7 km^2. The mean yearly range of 10 female hogs ($\bar{x}$ = 6.5 km^2, SE = 0.83) was significantly ($t = 3.55$, $df = 14$, $P < 0.003$) smaller than that of the 6 males ($\bar{x}$= 15.8 km^2, SE = 2.45).

Vegetation types

The study area was 92.7 km^2 and included all reclaimed mine land at BBM and some surrounding areas as defined by telemetry fixes. We calculated the area of each vegetation type as 45.3 km^2 for improved pasture, 14.7 km^2 for upland hardwoods, 13.1 km^2 for bottomland hardwoods, 10.0 km^2 for reclaimed wildlife areas, 4.2 km^2 for non-mined riparian stringers, and 4.6 km^2 for recently reclaimed areas.

Habitat use

In general, hogs selected the reclaimed wildlife area vegetation type in greater proportion than any other of the study area. In all seasons during the course of this study, 1,760 (77.7%) of 2,266 hogs recorded by radiotelemetry were in this vegetation type. Hogs used non-mined riparian stringers next in frequency. All other vegetation types in the study area were used with proportionately less frequency (Table 1).

Mean OV values for vegetation types used by feral hogs were 0.21 m (n = 51, SD = 0.20) for improved pastures, 0.1 m (n = 35, SE = 0.17) for recently reclaimed areas, 0.08 m (n = 26, SE = 0.10) for upland hardwoods, 0.24 m (n = 25, SE = 0.34) for non-mined riparian stringers, and 1.01 m (n = 37, SE = 0.71) for reclaimed wildlife areas. OV values for recently reclaimed areas and upland hardwoods were considered the same. OV values for improved pastures and non-mined wildlife areas were considered different from recently reclaimed areas and upland hardwoods but were not different from each other, and reclaimed wildlife areas were considered different from all other types (F = 106.1; df = 4, 169; P < 0.001). Habitat use analysis illustrated that feral hogs selected reclaimed wildlife areas and non-mined riparian stringers. Hence, these 2 vegetation types were labeled as having sufficient screen and canopy cover.

The average distance of feral hog locations from these screening covers (reclaimed wildlife areas and non-mined riparian stringers) by season was 53.3 m (n = 447, SE = 10.66) for winter, 58.8 m (n = 613, SE = 8.1) for spring, 20.0 m (n = 682, SE = 3.14) for summer, and 19.2 m (n = 535, SE = 3.93) for fall. Distances from screening cover were similar during winter and spring, but were different from both summer and fall, and summer and fall were also considered to be the same (F = 10.1; df = 3, 2273; P <0.0001). Mean distance of feral hog locations from a free water source on a seasonal basis was 64.4 m (n = 447, SE = 3.58) for winter, 66.2 m (n = 613, SE = 3.49) for spring, 46.2 m (n = 682, SE = 2.44) for summer, and 46.7 m (n = 535, SE = 2.98) for fall. Distances for winter and spring were not considered different from each other but different from both summer and fall, which were considered the same (F = 12.6; df = 3, 2273; P < 0.001).

Table 1. Availability and use by feral hogs of different vegetation types within the study area by percent (%), Big Brown Mine, Fairfield, Texas, January 1998–January 1999.

Vegetation types in study area	Amount of vegetation types available (%)	Use by hogs (%)
Bottomland hardwoods	14.1	2.6
Non-mined riparian stringers	4.5	9.6
Upland hardwoods	15.9	0.1
Improved pasture	48.9	8.4
Reclaimed wildlife areas	10.8	77.7
Recently reclaimed areas	4.9	1.2

Dial activity

The mean distance of hog locations from preferred screening cover during daylight hours ($\bar{x}$ = 23.4 m, SE = 0.02) also was significantly less (t = 5.41; df = 2,276; P <0.001) than during nighttime hours ($\bar{x}$ = 68.7 m, SE = 1.14). The mean distance of feral hog locations from a free water source during daytime hours ($\bar{x}$ = 43.1 m, SE = 0.55) was significantly less (t = 9.97; df = 2,276; P < 0.001) than during nighttime hours ($\bar{x}$ = 84.3 m, SE = 2.09).

Daytime use of vegetation types was consistent with overall results in that hogs selected reclaimed wildlife habitat areas and non-mined riparian stringers but used other habitat types in proportion to their availability. Nighttime was the only period when habitat use changed. Hogs used recently reclaimed areas and non-mined riparian stringers in proportion to their availability on the mine site. Hogs used improved pastures approximately 10 times as much at night as during the day. However, they used improved pastures less than randomly at night (Table 2).

Table 2. Availability of different vegetation types within the study area (by %) and diurnal (n=1,598) and nocturnal (n = 668) use of different vegetation types by feral hogs (by % of sightings), Big Brown Mine, Fairfield, Texas, January 1998–January 1999.

Vegetation type	Vegetation types availability (%)	Diurnal use (%)	Nocturnal use (%)
Bottomland hardwoods	14.1	2.6	2.4
Non-mined riparian stringers	4.5	11.6	4.8
Upland hardwoods	15.9	0.1	0.0
Improved pasture	48.9	1.9	24.0
Reclaimed wildlife areas	10.8	83.0	65.0
Recently reclaimed areas	4.9	0.0	3.9

Discussion

In general, data analysis of feral hog movements, habitat use, and dial supported our hypothesis that feral hogs would prefer habitats that provide greater screen cover or were closer to water. At BBM, radio-monitored feral hogs used reclaimed wildlife areas and non-mined riparian stringers in greater proportion to their occurrence on the mine site. All other vegetation types were used less than their occurrence. Although, used less than random, most of the observed hog damage occurred in improved pasture (Mersinger, unpublished data), which represented about 49% of the study area. Results indicated that feral hogs foraged in these areas at night. During daylight hours, feral hogs used reclaimed wildlife areas and non-mined riparian stringers for bedding cover.

The annual ranges of both female and male feral hogs at BBM were larger in this study than in many previous studies. Some researchers suggest that range sizes may be a reflection of resource availability within a given area (Adkins and Harveson 2007). Baber and Coblenz (1986) suggested smaller hog range sizes indicated abundant resources, whereas larger hog range sizes indicated limited resources in a given area. This hypothesis suggests that the animals must travel greater distances to meet their basic metabolic needs. Our data suggested otherwise. During summer 1998, extremely hot and dry conditions were present at BBM. Hogs remained closer to screening cover and free water during that season than in the spring and winter seasons. In this case, free water sources at BBM were less in number and size, and feral hog food sources were also limited. However, hogs remained in high-use areas and were less likely to travel during these conditions.

There are many variables at work in this situation, but the necessity for the animals to thermoregulate was probably paramount. During winter and spring, feral hogs traveled greater distances from screening cover and free water. Lower mean temperatures and shorter daylight hours probably accounted for some of the increased travel. However, their feeding habits probably changed seasonally (Springer 1975), and winter and spring food sources required more travel to reach them than did summer or fall food sources.

Radio-tagged hogs remained within the permit area of the mine almost exclusively; only 1 male hog left the permit area during the last 3 months of the study. At BBM, feral hogs selected the reclaimed wildlife areas. Two factors present within this vegetation type influenced hog use: dense screening cover and abundant free water in the form of ponds and streams. Many of the reclaimed wildlife areas were constructed around drainages or were associated with sedimentation ponds as part of the reclamation plan. The screening cover in this vegetation type was similar to improved pasture at ground level. However, shading cover provided by the tree canopy and availability of free water probably attributed to its greater use.

There was no seasonal difference in habitat selection by feral hogs, but dial differences in habitat use did exist. During daylight hours, feral hogs preferred non-mined riparian stringers and reclaimed wildlife areas. However, nighttime habitat use was different in that non-mined riparian stringers were used in proportion to their availability; recently reclaimed areas were also used in proportion to their availability, and reclaimed wildlife areas were used more than other areas that were available. Kurz and Marchinton (1972) and Singer et al. (1981) also noted an increased use of open areas during nighttime hours, especially during summer months.

Management implications

Habitat management is a tool that has not been thoroughly evaluated in feral hog control. Based on the results of our research, screening cover is critical for daytime bedding and resting. By reducing screening cover in high-use areas, feral hog use of those areas could potentially be reduced. At BBM, willow baccharis and switchgrass were found in many of the reclaimed wildlife areas (Mersinger 1999). This vegetation complex is dense at ground level and provided screening cover to feral hogs. Willow baccharis is an invader shrub with no real value to the reclamation efforts at BBM. In addition, this shrub could be replacing desirable, erosion-preventing vegetation. Various herbicide combinations should be evaluated in the control of willow baccharis. Periodic prescribed fires or mowing could be implemented in the wildlife areas to reduce the density of rank switchgrass and other ground-level vegetation. Periodic grazing of habitat areas by domestic cattle could be used to decrease screening cover in high-use areas. However, timing of grazing events should be carefully planned to avoid damage to desirable plants used in the reclamation process.

Even though total eradication of feral hogs from a given landscape is unlikely, a carefully designed and implemented management plan can be effective in reducing impacts of these animals on that landscape. Range size data from the hogs at BBM suggest that traps used for controlling hog numbers should be placed no more than 2.4 km apart if traps are located within the same drainage system.

During summer and early fall, trapping should be concentrated as close as possible to free water sources. Traps should be placed under the canopy cover of trees or brush in summer and early fall to ensure shading cover. Heavy trapping and baiting intensities should be encouraged in all areas of the mine site during winter due to limited food availability and increased rooting activity. During months with increased mast production (i.e., fall and spring), portable trapping should be concentrated in areas with dense food availability.

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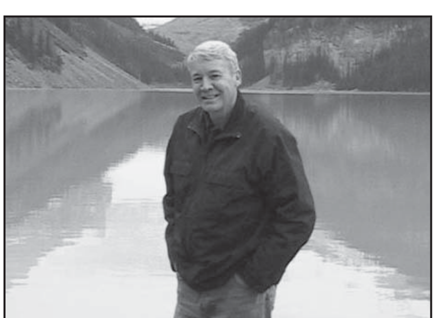

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