FERAL HOGS IN CENTRAL MISSISSIPPI: HOME RANGE,
HABITAT USE AND SURVIVAL

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I examined home range, habitat use, and survival of 29 feral hogs in central Mississippi using radio telemetry. During the dry season (1 April - 31 October 2005), densely-vegetated habitats were very important in home range placement (2nd-order selection) with selection favoring seasonally-flooded old fields, followed by old fields and managed openings. During the wet season (1 November 2005 - 31 March 2006), old fields were still preferred followed by agricultural fields, but flooded old fields were not preferred. For habitat selection within the home range (3rd-order selection), hogs preferred old fields and managed openings during the dry season. All habitats were used randomly within home ranges during the wet season. Dry and wet season survival rates were 80.8% and 41.4%, respectively. Hunting was the major cause of mortality (80 – 100%). Seasonal differences in habitat selection may have been caused by flooding of preferred habitats, food availability and hunting.
DEDICATION

This thesis is dedicated to my wife, Elizabeth. For her interminable support and almost unbelievable capacity to tolerate my peculiarities.
I would first like to thank Dr. Sam Riffell who gave me the opportunity to come to Mississippi and work on this study. You have always had an open door and have gone out of your way to help me in every way possible. Also, Dr. Richard Minnis for his guidance in the GIS realm and always being there to help clean up those messy shape files. I would like to thank Brad Holder for your guidance and generous contributions to this study. To Dale Adams, your immense help in contacting private landowners proved invaluable. Thank you, Dr. Demarais for your guidance and insight as a committee member. And to all the private landowners and managers, mainly Mark Cooper and J. R. Lee, who so graciously allowed me to trudge through their fields and backwoods in search of hogs, I say thanks. Also, I would like to thank the Mississippi Department of Wildlife, Fisheries and Parks (Study #63, Project # W-84-53) and the Mississippi Agricultural and Forestry Experiment Station.
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CHAPTER I
INTRODUCTION

Feral hogs (*Sus scrofa*) may be the most destructive non-native vertebrate species in North America. Because of foraging behavior and other destructive traits of feral hogs, they are often at odds with natural resource managers and farmers. Feral hogs tend to “root” through the soil in search of tubers, grubs and insects thereby causing a variety of damage in natural and agricultural systems. This trait can cause extensive damage to sensitive plant communities (Engeman et al. 2006) as well as increase the potential for soil erosion. For example, in the Great Smokey Mountains, feral hogs reduced plant cover by 80% and leaf litter by over 50% in study plots (Singer et al. 1984). This destructive behavior may reduce nesting cover and available forage for some species of high economic value such as white-tailed deer (*Odocoileus virginianus*), northern bobwhite (*Colinus virginianus*) and wild turkey (*Meleagris gallopavo*). In agricultural systems, they can cause economic losses through depredation of crops and livestock (Beach 1993).

Feral hogs can directly and indirectly impact native wildlife. Feral hogs have been shown to prey on dummy nests representing the nests of ground nesting birds (Matschke 1965, Henry 1969). Also, feral hogs have been recorded preying on fawns (Springer 1977). Aside from direct predation, feral hogs may serve to reduce available
forage such as oak (*Quercus* spp.) mast (Yarrow 1987). Yarrow (1987) suggests that in times of low mast availability, competition for scarce resources may limit white-tailed deer and feral hog populations.

Since their introduction into North America, feral hogs have expanded their range to include most of the southeastern United States extending westward into Kansas and Colorado and north to Indiana and Ohio (Gipson et al. 1998). A large population also exists west of the Rocky Mountains in California (Waithman et al. 1999). With little competition and few predators, feral hog numbers have increased steadily. In California alone, number of counties where feral hogs have been reported has more than tripled since the 1960s (Frederick 1998). In Texas, feral hog numbers may exceed 1,000,000 animals (Taylor et al. 1998).

The range expansion of feral hogs has been exacerbated by the deliberate transport of hogs to new areas to establish new populations (Gipson et al. 1998). Mayer and Brisbin (1991) suggest that hog hunters are responsible for numerous releases to establish huntable populations. Hog hunting is popular in many states, and when coupled with possible financial gain (Rollins 1993), the motives for relocating feral hogs are apparent.

Home range is one very important area of consideration in managing feral hogs. Existing studies (see Table 2.1 for citations) show a great deal of variation in home range size, probably caused by several factors. First, the areas where feral hogs occur are extremely varied, and home range size is generally thought to reflect habitat diversity and resource availability on the study area (Saunders 1966). Saunders (1966) suggested that
home ranges should be smaller if living requirements could be found in a relatively small area. Second, there is no standardized method to calculate home ranges for feral hogs, and, due to varying assumptions, many of the methods are not comparable (Harris et al. 1990, Saunders and McLeod 1999).

The gender of the animal, in addition to spatial complexity of the study area, also may influence home range size. It is generally accepted that boars have larger home ranges than sows (Barber and Coblentz 1986, Saunders and Kay 1991, Saunders and Kay 1996), but Saunders and McLeod (1999) pooled data from several home range studies and found there was no difference in mean home range size once body mass was considered.

Habitat use of feral hogs is another area of major importance. Although hogs can use a diversity of habitats, there are some general habitat characteristics that hogs tend to associate with no matter where they are found. During warm weather, hogs seem to be drawn to habitats with cool, moist areas (Wood and Brenneman 1980, Barber and Coblentz 1986). Feral hogs also show an affinity for dense cover throughout their range. The strength of habitat preference increased with density of vegetation in California (Barrett 1982).

Although feral hogs are attracting more attention from biologists, information about survivorship and mortality in feral hogs is still lacking. Jezierski (1977) and Massei et al. (1997) studied wild boar in Europe, and both found that juvenile males tend to experience higher mortality than do juvenile females. However, in adults, the relationship is opposite with females having a greater mortality than males (Jezierski
mortality varied with season. Both found that mortality in hogs was generally greater in summer as opposed to winter. Differences in mortality between seasons were attributed to food shortage caused by hardened ground (Massie et al. 1997).

A basic knowledge of the factors that influence survival of feral hogs is important in determining how best to manage this species. Increased understanding of feral hog survival rates may help give natural resource managers some of the knowledge needed to better control hog populations in their areas.

Feral hogs can often be destructive pests in natural and agricultural systems, yet there has been surprisingly little research focused on the species. This study will serve to expand on the limited knowledge concerning the home range, habitat use, and survival of feral hogs in central Mississippi.


Matschke, G. H. 1965. Predation by European wild hogs on dummy nests of ground nesting birds. Pages 154-156 in Proceedings of the 18th annual conference of southeastern association of game and fish commissioners, Tulsa, Oklahoma, USA.


Yarrow, G. W. 1987. The potential for interspecific resource competition between white-tailed deer and feral hogs in the post oak savannah region of Texas. Dissertation, Steven F. Austin State University, Nacogdoches, Texas, USA.
CHAPTER II
FERAL HOGS IN CENTRAL MISSISSIPPI: HOME RANGE AND HABITAT USE

ABSTRACT

Feral hogs have the potential to negatively impact native wildlife and sensitive plant communities. Since their first introduction into North America, they have steadily increased their range to include most of the United States. I examined seasonal home ranges and habitat use of feral hogs in central Mississippi from April 2005 through April 2006. I trapped and radio-collared 29 hogs and located them 2 - 3 times weekly via radio telemetry. Based on climate, I split the year into a “dry” season (1 April – 31 October) and a “wet” season (1 November – 31 March) when some areas were flooded and thus rendered inaccessible to hogs. Mean dry season home ranges (6.36 km\(^2\)) were larger than wet season home ranges (2.99 km\(^2\); \(P = 0.044\)), but gender and weight had little effect on seasonal home range size (\(P = 0.430, 0.522\), respectively), suggesting that home range size may have been primarily influenced by food and/or habitat availability. I used Euclidian distance techniques to estimate 2\(^{nd}\)-order (home range placement) and 3\(^{rd}\)-order (habitat use within the home range) habitat selection for both seasons. For 2\(^{nd}\)-order habitat selection, densely vegetated areas were very important in home range placement. Home range placement during the dry season
was influenced positively by seasonally-flooded old fields, followed by old fields and managed openings. During the wet season, old field habitat continued to be preferentially-selected, but flooded old fields were not. Agricultural fields were ranked 2\textsuperscript{nd} to old field habitat in the wet season regarding home range placement. For habitat use within the home range(3\textsuperscript{rd}-order habitat selection), hogs preferentially used old field and managed openings during the dry season. All habitat types appeared to be used randomly within the home range during the wet season. Hunting pressure and/or flooding may have influenced feral hog habitat use and home range size during the wet season.
INTRODUCTION

Since first being introduced to North America in the 1500’s, feral hogs have steadily spread over much of the United States (Gipson et al. 1998). Although there are some recreational and economic benefits of feral hogs (Chambers 1999), they are an exotic species that has the potential to impact sensitive communities (Singer et al. 1984) and cause large economic losses (Beach 1993) in areas where they occur.

Understanding the home range of feral hogs is important for minimizing negative interactions between feral hogs and native wildlife. Existing research on feral hogs shows a great deal of variation in home range size and habitat use patterns, probably due to the spatial complexity of the study sites and different methods of calculating home range (see references in Table 2.1). Yarrow (1987) observed feral hogs in Texas and estimated seasonal home ranges to be between 8.3 km$^2$ and 24.2 km$^2$. Kurz and Marchinton (1972), working in the Upper-Coastal Plain of South Carolina, estimated much smaller home ranges, averaging 4.0 km$^2$ (for 4 boars and 1 sow). Wood and Brenneman (1980), working in the Lower-Coastal Plain of South Carolina reported an even smaller mean home range, averaging 2.3 km$^2$ for boars and 1.8 km$^2$ for sows. Although the 2 studies in South Carolina were geographically close, Kurz and Marchinton (1972) reported a lower habitat diversity than did Wood and Brenneman (1980). This variation in spatial complexity between the 2 study sites may explain differences in mean home range between the 2 studies.

Home ranges also may vary by gender. Several studies have suggested that boars tend to have larger home ranges than sows (Barber and Coblentz 1986, Saunders and Kay
1991, Saunders and Kay 1996). However, Saunders and McLeod (1999) pooled data from several home range studies and found that there were no differences in home range size between boars and sows once body mass was considered.

Several factors may influence habitat use by feral hogs. First, it is generally accepted that hogs prefer moist areas during hot weather. Barber and Coblentz (1986) found that California hogs preferred cooler, moist canyon bottoms during hot, dry conditions. Wood and Brenneman (1980) also reported heavy use of wet areas, particularly in the hot months. Second, food availability may influence habitat use. Kurz and Marchinton (1972) reported hogs shifting from bottomland habitat to upland pine plantations when plums were ripening. Barber and Coblentz (1986) showed especially heavy use of cultivated areas where hogs were feeding on vegetative growth and oats during summer after hay had been cut. Finally, a need for cover might influence habitat use (Barber and Coblentz 1986). Working in the Sierra foothills of California, Barrett (1982) showed that habitat use by hogs increased with increased density of vegetation.

Home range and habitat use of feral hogs has received relatively little attention, especially in the southeastern United States. To properly manage a species, it is important to understand the home range and basic habitat requirements for that species. My objectives were to describe home range size and habitat use of feral hogs in central Mississippi.
STUDY AREA

I worked in the southwest corner of Grenada County Mississippi on Malmaison Wildlife Management Area (MWMA) and surrounding lands (Figure 2.1). The area fell within the alluvial floodplain of the Yalobusha River. Available habitats at MWMA included agricultural fields, bottomland hardwoods, old fields, managed wildlife openings, seasonally-flooded bottomlands and seasonally-flooded old fields (Figure 2.2).

Sycamore (*Platanus occidentalis*), elm (*Ulmus* spp.), sugarberry (*Celtis laevigata*), sweetgum (*Liquidambar styrasiflua*), water oak (*Quercus nigra*), willow oak (*Q. phellos*), overcup oak (*Q. lyrata*), swamp chestnut oak (*Q. michauxii*), and cherrybark oak (*Q. pagoda*) were the dominant tree species in the bottomland hardwood habitat. Other less dominant species included common persimmon (*Diospyros virginiana*) and red mulberry (*Morus rubra*). Ground cover in bottomland habitat was comprised mainly of sedges (*Carex* spp.), switch cane (*Arundinaria gigantea*), greenbriar (*Smilax* spp.), poison ivy (*Toxicodendron radicans*), muscadine grape (*Vitis rotundifolia*) and blackberry (*Rubus* spp.).

Dominant tree species in seasonal flooded bottomlands were similar to bottomland with the addition of some cypress (*Taxodium* spp.) and black gum (*Nyssa* sp.). Ground cover in seasonally flooded bottomlands was typically sparse.

Both old field and seasonally flooded old field were characterized by very thick vegetation comprised mainly of blackberry, trumpet creeper (*Campsis radicans*), plume grass (*Saccharum* sp.), smartweed (*Polygonum* spp.), foxtail (*Setaria* spp.), honeysuckle (*Lonicera japonica*) and a variety of other grasses and forbs and a few woody species.
such as common persimmon and willow (*Salix* sp.). The vegetation in these 2 habitats was often dense enough to reduce vision to little more that a few feet.

Many small (< 3 ha), managed openings were scattered throughout the study area. These openings were planted with a variety of species including corn (*Maize* sp.), millet (*Echenechloa* spp.), sorghum (*Sorghum* sp.), and clover (*Trifolium* spp.), and were specifically managed to benefit waterfowl, wild turkeys (*Meleagris gallopavo*) and white-tailed deer (*Odocoileus virginianus*). Agricultural fields were planted in corn, cotton (*Gossypium* sp.), and soybeans (*Glycine* sp.).

METHODS

**Trapping and Processing**

I began trapping on 1 April 2005 and ended with the onset of hunting season in early October. Approximately 15 trap sites were used during the trapping session. I used box-style panel live traps with root-type gates (Littauer 1993). Once a suitable area with abundant hog sign was discovered, I baited the area with corn. If the hogs returned to the area, a trap was placed at the site and baited again. I set the traps after the hogs were moving about the trap freely (usually < 2 nights).

Upon capture, I anesthetized hogs with a mixture of 3.2 mg/kg Telazol© and 1.6 mg/kg Xylezine (Sweitzer et al. 1997). I weighed each individual and recorded gender. I marked all individuals with unique ear tags and fitted animals > 23 kg with collar
transmitters from Lotec© (Lotec Wireless, Newmarket, ON). The transmitters featured a mortality signal (40 pbm) that was activated after 24 hrs of inactivity.

Hogs were processed and released on site as quickly as possible to minimize handling stress. Hog handling and marking procedures were approved by the Institutional Animal Care and Use Committee (IACUC), Mississippi State University (IACUC Protocol # 04-090).

Telemetry Procedures

I located collared hogs using a 3-element Yagi antenna and a multi-frequency receiver (Advanced Telemetry Systems, Isanti, MN). I attempted to locate each radio-collared hog once daily on at least 3 days weekly from the time of capture until the animal’s death or the end of the field season (31 March 2006). I collected hog locations using a rotational schedule designed to evenly distribute sampling intensity over a complete 24-hr period (night and day). Each sampling day consisted of one of 4 temporally-distinct, 6-hr sampling shifts (0600 - 1200 CST, 1200 - 1800 CST, etc.). On each successive collection day, I progressed to the next shift. To triangulate hog locations, I took 3 – 4 bearings from fixed telemetry stations in the direction of the strongest signal. Visual locations were recorded using UTM coordinates of observer location, one bearing toward the animal and a distance estimate. Hogs were occasionally spotted in open habitats, and did not usually alter their behavior (foraging, etc.) while under observation; therefore, collection of occasional locations by visual observation had minimal effects on hog locations. Bearing data were entered into LOAS software
(Ecological Software Solutions, Urnäsch, Switzerland) to generate UTM coordinates of hog locations.

I used 2 methods (during leaf-on and off periods) to estimate telemetry error. First, a technician held a dummy transmitter in a habitat similar to, but separate from, my study area while 3 bearings toward the strongest signal were collected. Second, I used radio-collared hogs from which I was receiving a mortality signal as the test transmitter (Withey et al. 2001). I used 30 test locations totaling 90 bearings to estimate telemetry error. My telemetry tests indicated a mean distance error of $\pm 50$ m ($SE = 6; n = 30$) from actual location to estimated location, which I considered acceptable considering the dense vegetation and habitat patch sizes where hogs were often located. To minimize telemetry error due to hog movements, I kept the time between the first and last bearing under 12 minutes (Holder 2006). After collecting locations, I rejected any locations with an error ellipse that was greater than 3.0 times the interquartile range above the 75$^{th}$ percentile (Phillips et al. 2004).

**Estimating Available Habitat**

Habitat types were delineated using a combination of aerial photo interpretation and field observations and then digitized into a habitat coverage map in ArcMap 9.0 (ESRI 2004). I defined the following habitat types: agricultural fields (AG), bottomland hardwood forests (BLHD), seasonally-flooded bottomland hardwoods (FLHD), old fields (OF), seasonally-flooded old fields (FLOF), and managed openings (MGDO). Small openings ($< 3$ ha) that were planted and managed specifically for wildlife were classified
as MGDO. Areas that were characterized by dense ground cover, including hardwood regeneration areas, clear-cuts, and fallow fields 2-8 years old were classified as OF. Flooded old field (FLOF) habitat was similar to OF in vegetative structure except for presence of some moist soil plants such as smartweed and water lily (*Lotus* spp.). Bottomland hardwoods and old fields that were flooded ≥ 3 months of the year were considered seasonally flooded. I monitored flood water levels by visual observation and obtained flooding dates for managed water levels from area managers.

I conducted 2 separate analyses because seasonal flooding created a distinct change in the available habitats. I defined the “dry” season as 1 April – 31 October and the “wet” season as 1 November – 31 March. November 1 marked the beginning of the wet season because this was the date when most of the wetlands (FLOF and FLHD) were flooded, naturally or by pumping, to provide winter duck habitat (M. Cooper, *personal communication*), general gun hunting season began on 18 November, and agricultural crops such as corn were maturing. All of these events had the potential to profoundly influence habitat availability and/or feral hog distributions. The beginning date (April 1) for the dry season was approximately the time when most of the water had receded from the flooded areas. Also, general gun hunting season had closed by this date. I calculated home ranges and conducted habitat use analyses separately for each time period.

**Home Range Analysis**

Seasonal home ranges for each hog were generated using the 95% adaptive kernel estimator within the Animal Movement Extension (Hooge and Eichenlaub 1997) in
ArcView 3.2 (ESRI 2002). The adaptive kernel method is a nonparametric technique that is less affected by small numbers of observations (Worton 1989). I estimated annual home ranges (i.e., across both wet and dry seasons) for hogs monitored ≥ 8 months ($n = 7$). I estimated seasonal home ranges for hogs with ≥ 30 locations (Seaman et al. 1999) in either season (dry $n = 10$, wet $n = 4$). To compare my results to other studies (Saunders and McLeod 1999), I also calculated seasonal MCP home ranges using the Animal Movement Extension (Hooge and Eichenlaug 1997) in ArcView 3.2 (ESRI 2002). MCP estimates are listed in Table 2.1 only.

To determine effects of gender and season on home range size, I conducted unequal variance $t$-tests to test the hypothesis that mean home range size did not differ between genders and seasons. I used simple linear regression to determine the effects of mid-point weight (estimated wt. at mid-point of observation for each individual) on home range size. During the course of the study, some hogs formed groups and were not truly independent. To avoid pseudoreplication, I dropped closely associated animals and kept only the individual with the greatest number of locations to include in analysis. I used $\alpha = 0.10$ for significance. I was able to obtain a second weight for 12 hogs (5 boars and 7 sows) through recapture or hunter cooperation. An average weight gain per day was calculated for boars (0.115 kg/day, $n = 5$) and sows (0.049 kg/day; $n = 7$) using this data. To calculate mid-point weight, I used the average weight gain per day for boars and sows to project the hog’s weight to the mid-point of observation for that animal.
Habitat Use Analysis

To estimate Johnson’s (1980) 2\textsuperscript{nd}-order habitat use, all habitats within the study area were considered available. To define extent of the study area, I created a 100% minimum convex polygon of all hog locations and then created a 500-m buffer around that polygon (Harveson et al. 2004). To estimate Johnson’s (1980) 3\textsuperscript{rd}-order habitat use, habitats within each hog’s home range were considered available for analysis.

I restricted analysis to independent animals with ≥ 30 locations during either season (dry \(n = 10\); wet \(n = 4\)). For Johnson’s 2\textsuperscript{nd}-order analysis, I generated 10,000 random points in the study area and calculated distances between random points and the nearest representative of each habitat type using ArcView Calculate Distance command (ESRI 2002). Following Conner and Plowman (2001), distances were then calculated from actual hog locations to habitat types. I compared the mean of these distances for each animal (\(u\)) to the mean distances of random points to each habitat type (\(r\)). I calculated ratios for each animal by dividing the mean animal distance (\(u\)) by the mean random distance (\(r\)). Conner and Plowman (2001: 278) suggested using a MANOVA to determine if the mean of the ratio vectors (\(\rho\)) differed from a vector of 1’s. Then, for each habitat type, univariate \(t\)-tests are used to test the hypothesis that individual ratios did not differ from 1. A significant difference would indicate disproportionate use of the habitat.

Because small sample sizes precluded me from conducting a MANOVA to test for an overall difference in habitat use in the wet season, I performed all possible pairwise comparisons and constructed a ranking matrix of \(t\)-statistics (following Conner and
Plowman (2001) above). In lieu of a MANOVA (the purpose of which is to ensure an overall Type I error rate of $\alpha = 0.10$), I controlled overall error rate by conducting a sequential Bonferroni correction (which provides stricter control than a MANOVA) on the $t$-tests for the individual habitat types (Holm 1979, Westfall et al. 1999).

RESULTS

Home Range

Annual home ranges (95% adaptive kernel - see table 2.2) averaged 10.0 (± 2.57) km$^2$. Five boars averaged 8.06 (± 3.17) km$^2$ and 2 sows averaged 14.99 (± 1.85) km$^2$ (mean # locations/hog = 83). Mean seasonal home range estimates for all hogs (Table 2.2) were 6.36 (± 1.34) km$^2$ for the dry season ($n = 10$; mean # locations/hog = 56) and 2.99 (± 0.66) km$^2$ for the wet season ($n = 4$; mean # locations/hog = 36). My home range estimates are listed with other published estimates in Table 2.1. Home range sizes were significantly larger in the dry season compared to the wet season ($t_{12} = 2.25$, $P = 0.044$; Figure 2.3). I did not observe any significant effects of gender ($t_{11} = 0.82$, $P = 0.430$; Figure 2.3) or weight ($t = -.066$, $P = 0.522$) on home range sizes.

2nd-order Habitat Use Analysis

Available habitat in the study area was 24% agricultural fields (AG), 40% bottomland hardwoods (BLHD), 10% seasonally flooded hardwoods (FLHD), 4%
seasonally flooded old fields (FLOF), 2% managed openings (MGDO), and 20% old field (OF).

Dry season 2nd-Order Habitat Use. Hogs were found closer to FLOF ($\rho_{\text{FLOF}} = 0.40 \pm 0.12, t_9 = -4.81, P < 0.001$), OF ($\rho_{\text{OF}} = 0.62 \pm 0.06, t_9 = -6.58, P < 0.001$), and MGDO ($\rho_{\text{MGDO}} = 0.66 \pm 0.10, t_9 = -3.33, P = 0.007$) habitats than expected. There were no differences in hog locations and random points for BLHD ($\rho_{\text{BLHD}} = 0.93 \pm 0.13, t_9 = -0.52, P = 0.612$), AG ($\rho_{\text{AG}} = 1.07 \pm 0.14, t_9 = 0.49, P = 0.637$), and FLHD ($\rho_{\text{FLHD}} = 1.32 \pm 0.16, t_9 = 1.99, P = 0.074$) habitats (Table 2.3).

Pair-wise comparisons of distance ratios (i.e., the elements in $\rho$) indicated that hogs were significantly closer to FLOF than all other habitats (experiment-wise $P < 0.10$, Table 2.4). Use of OF and MGDO’s did not differ significantly from each other, but differed significantly from all other habitat types (Table 2.4). There were no significant differences among BLHD, FLHD, and AG habitat types during the dry season (Table 2.4). Thus, feral hog 2nd-order habitat preferences could be ranked (proportional habitat use based on $\rho$) as follows: FLOF - greatest preference; OF and MGDO - secondary preference; and no preference for BLHD, AG and FLHD.

Wet season 2nd-order Habitat Use. Hogs were closer to OF ($\rho_{\text{OF}} = 0.38 \pm 0.11, t_3 = -5.54, P = 0.012$) habitat than expected. AG ($\rho_{\text{AG}} = 0.42 \pm 0.15, t_3 = -3.84, P = 0.031$), MGDO ($\rho_{\text{MGDO}} = 0.91 \pm 0.28, t_3 = -0.33, P = 0.763$), FLOF ($\rho_{\text{FLOF}} = 1.22 \pm 0.61, t_3 = 0.36, P = 0.740$), FLHD ($\rho_{\text{FLHD}} = 1.04 \pm 0.38, t_3 = 0.11, P = 0.919$) and BLHD ($\rho_{\text{BLHD}} = 1.81 \pm 0.22, t_3 = 3.67, P = 0.035$) were used no differently than expected (Table 2.3). Pair-wise comparisons of distance ratios (Table 2.5) confirmed a general ranking of wet season 2nd-
order habitat use of: OF - greatest preference; AG, MGDO, FLHD, FLOF and BLHD (in that order).

3rd-order Habitat Use Analysis

For 3rd-order habitat use, the area within a hog’s home range was considered available. The mean composition for all hog home ranges for the dry season was 29% AG, 32% BLHD, 5% FLHD, 3% FLOF, 6% MGDO, and 25% OF. Mean composition for wet season home ranges were 28% AG, 34% BLHD, 4% FLHD, 2% FLOF, 6% MGDO, and 26% OF.

**Dry season 3rd-order Habitat Use.** For the dry season, OF ($\rho_{OF} = 0.81 \pm 0.04, t_9 = -4.56, P = 0.001$) and MGDO ($\rho_{MGDO} = 0.88 \pm 0.04, t_9 = -2.82, P = 0.018$) were used significantly more than expected. FLOF ($\rho_{FLOF} = 0.85 \pm 0.06, t_9 = -2.38, P = 0.039$) was intermediate between OF and MGDO, but was not shown to be significant. BLHD ($\rho_{BLHD} = 0.92 \pm 0.04, t_9 = 1.83, P = 0.097$), AG ($\rho_{AG} = 0.98 \pm 0.04, t_9 = -0.59, P = 0.567$), and FLHD ($\rho_{FLHD} = 1.07 \pm 0.05, t_9 = 1.36, P = 0.204$) were not used differently from random (Table 2.3). Pair-wise comparisons of distance ratios (Table 2.6) confirmed the ranking of habitat use: OF - most preferred, followed by FLOF and MGDO; no preference for BLHD, AG, or FLHD.

**Wet season 3rd-order Habitat Use.** Euclidian distance analysis indicated that habitat was used randomly in the wet season; thus, pair-wise comparisons were not conducted (Table 2.3).
DISCUSSION

Home Range Size

Saunders and McLeod (1999) pooled data from several home range studies and found body mass (but not gender) to be an indicator of home range size. However, I did not find significant effects of gender or body mass on home range size. My data indicated that season was the most important determinant of home range size. Although the home ranges that Saunders and McLeod (1999) calculated were considered seasonal (over at least 100 days), they did not specify which season. On average, I found that home ranges were larger during the dry season than in the wet season.

In contrast to my results, Kurz and Marchinton (1972), working in the upper coastal plain of South Carolina, reported larger hog home ranges during their winter-spring season (1 Jan.-31 Mar.) than either summer (1 June-30 Sept.) or fall (1 Oct.-31 Dec.) They attributed these larger home range estimates to lower food availability at this time of year (Kurz and Marchinton 1972). However, during my wet season, which overlapped with their winter-spring season, abundant food sources were available to hogs on my study area. Early in the wet season, waste grain was abundant in agricultural fields, acorns were available in bottomlands, and MGDO’s were planted in various crops. Saunders (1966) suggested that home ranges should be smaller if living requirements were provided in a smaller area. This may account for smaller mean home ranges for hogs on my study area during the wet season. Several of the study animals experienced range shifts at the time the seasons changed. Although I was not able to collect enough
observations to calculate reliable home ranges during both seasons, several animals moved to areas where corn was being harvested. There was an abundance of food in this area, and hogs would not have to travel far to forage (R. C. Hayes, personal observations).

Flooding of preferred habitats may be another possible explanation for smaller home ranges during the wet season. Habitats that hogs used preferentially during the dry season were unavailable during the wet season due to flooding (see discussion of habitat use below). Thus, home ranges may have been restricted, and hence smaller, during the wet season simply because hogs were excluded from part of their home range. Although they give no estimation of home range size, Beyers and Labisky (2005) reported white-tailed deer being driven from preferred habitats by floodwaters in the Everglades, Florida.

2nd-order Habitat Use Analysis

Dry-season 2nd-order Habitat Use. Second-order habitat use describes how hogs incorporate different habitat types into their home range, and placement of the home range within the study area. Seasonally-flooded old field and old field habitats were most associated with home range placement within the study area during the dry season (Tables 2.3 and 2.4). Hogs in my study area used OF habitats greater than expected for both wet and dry seasons. Old field habitats at MWMA were characteristically comprised of thick, tangled vegetation and it is generally accepted that hogs prefer densely-vegetated habitats (Barrett 1982). My results substantiate this claim. Of the 2 old field habitats, seasonally-flooded old fields were ranked as the most preferred habitat.
during the dry season. Wood and Brenneman (1980) showed heavy use of wet areas during hot months. These areas may have provided moist areas for rooting, cool areas for wallowing and ready food sources during the dry season. FLOF habitats often retained some moist areas during the dry season. Hogs were observed feeding on smartweed (a common moist soil plant in these areas) and rooting in FLOF after the water had receded early in the dry season (R. C. Hayes, *personal observations*).

Home ranges also were located in areas associated with managed openings during the dry season. These areas were managed for wildlife and may have provided another important food source for hogs. Barber and Coblentz (1986) reported that cultivated areas, similar to MGDO, composed only 1% of their study area yet were heavily exploited. Land managers around MWMA often complained of hog damage to these openings (D. Adams, *personal communication*).

The remaining 3 habitats, BLHD, AG, and FLHD, were used no differently from random. Although bottomland has been shown to be an important habitat for feral hogs (Kurz and Marchinton 1972), BLHD did not influence home range placement in my study area. This may simply have been because it was the most abundant habitat type and was not limiting. Hogs would have had access to ample BLHD habitat wherever their home range was positioned.

It is not surprising that AG was not preferred (*P* = 0.637) by hogs for most of the dry season. There was little food or cover available in AG habitat until the end of the dry season. Although hogs may have used AG at the end of the dry season when crops were
beginning to mature, there was not enough time left in this season to collect the number of observations needed to show non-random use.

Random use of FLHD ($P = 0.075$) habitat is not surprising. These habitats often had poor mast crops, when compared to adjacent BLHD habitat (R.C. Hayes, *personal observation*). Supporting my observation, Francis (1983) found that acorn production in a flooded hardwood stand near Rolling Fork, MS was nearly half that of adjacent unflooded hardwoods. Aside from poor mast production, these areas offered little vegetative ground cover, often appearing open and park like.

**Wet-season 2nd order Habitat Use.** Old field (OF) habitat replaced FLOF as the most preferred habitat type during the wet season (Tables 2.3 and 2.5). A likely explanation is OF habitat was rarely disturbed by humans (R. C. Hayes, *personal observation*) and may have provided a safe loafing and feeding area at this time of year when the FLOF habitat was inundated. Also, hunting season was just getting underway as the wet season began. Similarly, Swenson (1982) found that mule deer (*Odocoileus hermionus*) selected habitats with more cover during hunting season, presumably in response to hunting pressure. Kilgo et al. (1998) also found that white-tailed deer in Florida seek out habitats offering more cover in response to hunting pressure. OF habitat also was frequently adjacent to agricultural habitat where crops such as corn and cotton were maturing. Thus, old field habitat may have provided excellent escape cover immediately adjacent to a viable food source during a time of high hunting pressure.

Phenology of crops may have caused a higher use of agricultural habitats during the wet season compared to the dry season (Table 2.3). Early in the dry season, there was
little food or cover in agricultural habitats, but food (and to some extent cover) was plentiful later when crops were maturing. In the early part of the wet season, corn and cotton were either mature or recently harvested, and waste grain was abundant in the fields. I often observed hogs foraging in these areas at this time, and > 5% of all wet season locations fell within AG habitats. Thus, hogs likely adjust the locations of their home ranges in response to the change in food availability in the AG habitats.

For the wet season, use of MGDO did not differ significantly from random (Table 2.3). This is likely due to some combination of hunting pressure (e.g., some hunters may have concentrated efforts around MGDO habitats), flooding of some of these areas for waterfowl, or simply my small sample size (n = 4) in the wet season.

The apparent random use of BLHD habitat is surprising. Hogs are generally thought to be attracted to bottomland hardwood habitats when mast is available (Kurz and Marchinton 1972). There are 3 possible explanations. First, hogs may have avoided bottomland hardwoods during the wet season because these habitats are relatively open and frequented by hunters, although this would not explain random use for the dry season when this habitat was relatively free of human intrusion and mast crops such as acorns and persimmons would have been available. Second, I was not able to separate oak (Quercus spp.) stands from other bottomland habitat while digitizing habitat types. Mast producing trees, such as oaks, often grow in small clusters that should attract hogs. Wood and Brenneman (1980) reported a similar problem. Third, bottomland hardwood was the most common habitat type in my study area (and all home ranges contained substantial hardwood habitat), thus other habitat types (like old fields) may have been
more limiting. Placement of home ranges relative to bottomland hardwood may have appeared random because hogs were forced to focus on less abundant, but still necessary, habitat types.

3rd-order Habitat Use Analysis

Dry-season 3rd-order Habitat Use. Third-order habitat use describes how hogs use the different habitats that are within their home range (Johnson 1980). Habitat use within the home ranges differed slightly from that of home range placement within the study area (Johnson’s 2nd-order selection). For 3rd-order use, OF, FLOF and MGDO were still the top-ranked habitat types, but OF (rather than FLOF) was ranked highest and FLOF did not differ significantly from random (Table 2.3). While placement of a home range (2nd-order) must include a variety of life-history needs, 3rd-order selection reflects the area of high-frequency use within those home ranges. Old fields likely represent the core use area for feral hogs. During the dry season, OF habitats may have provided a shaded escape from the hot summer sun in a place that was probably well protected from human intrusion. Some of these areas were so thick that vision was often limited to < 1 meter into these areas and the only access into them would be “tunnels” created by the hogs (R. C. Hayes, personal observation). These type areas were completely covered from above, providing shade for the animals. Also OF habitat was frequently adjacent to MGDO. These areas would have provided excellent food resources for the hogs within easy access of escape cover. I observed 3rd-order preference for MGDO (Table 2.3), and collared hogs were observed feeding in these areas (R. C. Hayes, personal observation).
Barber and Coblentz (1986) reported that cultivated areas similar to MGDO habitat were used heavily during the spring.

*Wet-season 3rd-order Habitat Use.* Habitat use within the home range during the wet season appeared to be random for all habitat types, although the rankings are similar to my other habitat analyses (Table 2.3). This may be a function of the smaller sample size (n= 4) for the wet season, but there is at least one plausible explanation for random habitat use at this time. After the main part of the hunting season ended (January), many hunters turned their attention to hogs, often using dogs (J. R. Lee, *personal communication*). In fact, 2 collared hogs were harvested in this manner. Frequent harassment may have driven hogs from preferred habitat types, pushed them around among other habitats, and caused their habitat use to appear random.

**Potential for Competition with Other Wildlife**

The potential for competition between feral hogs and native wildlife has been well documented (Wood and Lynn 1977, Yarrow 1987, Rollins and Carroll 2001). Predation of wild turkey nests by hogs is one negative interaction possible on Malmaison WMA. Although evidence that feral hogs are important nest predators is conflicting (Rollins 1993), Matschke (1965) and Henry (1969) both concluded that feral hogs may prey on the nests of several ground nesting birds, including northern bobwhite and wild turkey. Also, feral hogs may prey on fawns and calves (Beach 1993, Springer 1977). Hogs may also compete with native wildlife for available forage such as oak mast (Yarrow 1987). This interspecific competition may often be trivial, but may become important in times
when resources are limited. Yarrow (1987) suggests that in times of low mast availability, competition for scarce resources may limit white-tailed deer and feral hog populations. In addition to direct predation and competition, hogs may reduce ground cover vegetation and leaf litter important to ground nesting birds and forest floor dwelling mammals, amphibians, and invertebrates (Singer et al. 1984).

Holder (2006) studied habitat use of wild turkey hens during spring and summer of 2003 and 2004 on MWMA and surrounding lands (the area where I worked). Using methods similar to mine, Holder (2006: 48) found that hens used managed openings more than expected. He also found that turkey nests were often associated with dense cover near managed openings. Although there is no temporal overlap between Holder (2006) and my study, these findings suggest potential for competition (or other negative interactions) between feral hogs and wild turkey hens around managed openings on MWMA. In my study, managed openings ranked high in all seasons so there may be potential for nest predation, incidental or otherwise, by hogs during the spring nesting season. Because turkey (Holder 2006) and hog (my study) habitat preferences were otherwise dissimilar there may be little potential for negative interaction between feral hogs and wild turkeys in habitat types other than managed openings. For example, Holder (2006:48) reported random use of agriculture and old field (both of which hogs preferred in my study) for wild turkey hens in the Delta (the area where my study was conducted) of MWMA. Holder (2006:48) also showed wild turkey hens preferred bottomland hardwoods which was used randomly and ranked low in habitat preference of hogs during my study.
These conclusions are drawn from data collected over 1 year. Water levels, habitat composition, and other factors may change from year to year. Thus, patterns of habitat use and home range may vary between years and locations.

MANAGEMENT IMPLICATIONS

Feral hogs present a unique challenge to land managers. The question is: How do we reduce feral hog damage while to provide quality habitat for native fauna? Most of the literature addressing this topic focuses on feral hog population control (Peine and Farmer 1990, Mapston 1999, Bieber and Ruff 2005). Engeman et al. (2006) reported that after 1.7 years of supplemental trapping they were able to remove 631 hogs and reduce damage by 78% in unhunted areas totaling about 94,000 ha. Although hunting and trapping has been shown to be a viable way of reducing damage (Engeman et al. 2006), many land managers lack the time and funding to implement effective control measures. Peine and Farmer (1990) demonstrate the need for proper funding and “man power” for effective control of hogs. I suggest a slightly different approach to reducing damage caused by feral hogs. Based on the results of this study and other literature centered on feral hogs I can make a few recommendations.

Although hunting and trapping on a small scale may not serve to reduce hog numbers; when applied correctly, they may help to reduce hog damage to localized resources such as managed openings. Hunting, trapping, and general harassment of hogs near sensitive areas may cause hogs to relocate to areas where they may not cause as much damage (Barrett and Birmingham 1995). Engeman et al. (2006) found that
although sport hunting removed only a small number of animals (92 animals over 3 years), hog damage in areas open to hunting was less than half that in unhunted areas. Hunting and trapping should be encouraged and concentrated at times when resources are most susceptible to damage. Hunting with dogs may be particularly effective if the object is to remove a few animals and cause the remaining ones to relocate. Maillard and Fournier (1995) found that frequent disturbance by hunters with dogs caused wild boar in Italy to search for more tranquil areas.

On my study area, managed openings and agricultural fields planted in grain crops received the most hog damage when the grain was maturing and before harvesting or flooding, in the case of managed openings for waterfowl (R. C. Hayes, personal observation). Hunting and harassing hogs in general could be encouraged around these areas at this time, but with consideration of potential disturbances to non-target wildlife.
LITERATURE CITED


Holder, B. D. 2006. Survival, habitat use, and nest-site characteristics of wild turkeys in central Mississippi. Thesis, Mississippi State University, Starkville, Mississippi, USA.


Matschke, G. H. 1965. Predation by European wild hogs on dummy nests of ground-nesting birds. Proceedings of the Southeastern Association of Game and Fish Commissioners 26: 236-244.


Yarrow, K. G. 1987. The potential interspecific resource competition between white-tailed deer and feral hogs in the post oak savannah region of Texas. Dissertation, Stephen F. Austin State University, Nacogdoches, USA.
Table 2.1. Feral hog body mass estimates (kg) and home range estimates (km$^2$) from published sources.

<table>
<thead>
<tr>
<th>Location</th>
<th>Body Mass</th>
<th>Time/Season</th>
<th>MCP Boar ($n$)</th>
<th>MCP Sow ($n$)</th>
<th>Other Methods Method</th>
<th>Other Methods Boar</th>
<th>Other Methods Sow</th>
<th>Source$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mississippi</td>
<td>67</td>
<td>50</td>
<td>2.1 (3)</td>
<td>3.8 (1)</td>
<td>95% AK</td>
<td>2.9</td>
<td>3.2</td>
<td>1</td>
</tr>
<tr>
<td>Mississippi</td>
<td>62</td>
<td>53</td>
<td>7.6 (6)</td>
<td>4.1 (4)</td>
<td>95% AK</td>
<td>7.5</td>
<td>4.6</td>
<td>1</td>
</tr>
<tr>
<td>Mississippi</td>
<td>59</td>
<td>46</td>
<td>6.8 (5)</td>
<td>23.3 (2)</td>
<td>95% AK</td>
<td>8.1</td>
<td>15.0</td>
<td>1</td>
</tr>
<tr>
<td>California</td>
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<td>27</td>
<td>1.4 (6)</td>
<td>0.9 (4)</td>
<td>95% ellipse</td>
<td>2.0</td>
<td>0.9</td>
<td>2</td>
</tr>
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<td>California</td>
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<td></td>
<td></td>
<td></td>
<td>HM</td>
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<td>1.5</td>
<td>2</td>
</tr>
<tr>
<td>South Carolina</td>
<td>58</td>
<td>57</td>
<td>5.3 (4)</td>
<td>4.4 (1)</td>
<td>MMA</td>
<td>10.2</td>
<td>8.1</td>
<td>3</td>
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<tr>
<td>South Carolina</td>
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<td></td>
<td>1.1 (6)</td>
<td>1.2 (3)</td>
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<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>South Carolina</td>
<td></td>
<td></td>
<td>2.3 (3)</td>
<td>1.8 (3)</td>
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<td></td>
<td>3.8 (9)</td>
<td>3.5 (4)</td>
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<td></td>
<td>5</td>
</tr>
<tr>
<td>Tennessee</td>
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<td></td>
<td>3.9 (9)</td>
<td>2.7 (4)</td>
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<td>MOU</td>
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<td>16.2</td>
<td>6</td>
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<td>1.1 (4)</td>
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<td>Galapagos</td>
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<td>0.9 (3)</td>
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<td>New South Wales</td>
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<td>63</td>
<td>10.7 (7)</td>
<td>4.9 (5)</td>
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<td>11.1 (6)</td>
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<td>1.5 (3)</td>
<td>0.6 (4)</td>
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<td></td>
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<td>12</td>
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</tbody>
</table>

$^1$ Abbreviations for methods as follows: AK = adaptive kernel; HM = Harmonic Mean; MMA = Modified Minimum Area; MOU = multivariate Ornstein-Uhlenbeck

Table 2.2. 95% Adaptive Kernel home range estimates for feral hogs at Malmaison WMA, Mississippi, and surrounding lands, 1 April 2005 – 31 March 2006.

<table>
<thead>
<tr>
<th>Animal</th>
<th>Gender</th>
<th>Mass (kg)</th>
<th>Dry (ha)</th>
<th>Wet (ha)</th>
<th>Annual (ha)</th>
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<tr>
<td>0120</td>
<td>Boar</td>
<td>98</td>
<td>--</td>
<td>271</td>
<td>313</td>
</tr>
<tr>
<td>8289</td>
<td>Boar</td>
<td>74</td>
<td>484</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>8300</td>
<td>Boar</td>
<td>63</td>
<td>1319</td>
<td>--</td>
<td>1622</td>
</tr>
<tr>
<td>8261</td>
<td>Boar</td>
<td>54</td>
<td>1275</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>8140</td>
<td>Boar</td>
<td>54</td>
<td>334</td>
<td>144</td>
<td>267</td>
</tr>
<tr>
<td>0220</td>
<td>Boar</td>
<td>48</td>
<td>--</td>
<td>462</td>
<td>--</td>
</tr>
<tr>
<td>8099</td>
<td>Boar</td>
<td>41</td>
<td>296</td>
<td>--</td>
<td>286</td>
</tr>
<tr>
<td>8121</td>
<td>Boar</td>
<td>39</td>
<td>803</td>
<td>--</td>
<td>1542</td>
</tr>
<tr>
<td>0280</td>
<td>Sow</td>
<td>69</td>
<td>162</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>8280</td>
<td>Sow</td>
<td>54</td>
<td>197</td>
<td>--</td>
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<tr>
<td>8240</td>
<td>Sow</td>
<td>50</td>
<td>--</td>
<td>317</td>
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<tr>
<td>0240</td>
<td>Sow</td>
<td>48</td>
<td>908</td>
<td>--</td>
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<tr>
<td>8221</td>
<td>Sow</td>
<td>43</td>
<td>582</td>
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<td>1684</td>
</tr>
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</table>
Table 2.3. Ranking and associated $P$ and $t$ values for 2nd- and 3rd-order habitat selection by hogs at Malmaison WMA, Mississippi and surrounding lands, 1 April 2005 – 31 March 2006.

<table>
<thead>
<tr>
<th>Habitat</th>
<th>Wet</th>
<th>Dry</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\rho$</td>
<td>$T$</td>
</tr>
<tr>
<td>2nd-order</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OF</td>
<td>0.380</td>
<td>-5.54</td>
</tr>
<tr>
<td>AG</td>
<td>0.422</td>
<td>-3.84</td>
</tr>
<tr>
<td>MGDO</td>
<td>0.906</td>
<td>-0.33</td>
</tr>
<tr>
<td>FLOF</td>
<td>1.223</td>
<td>0.36</td>
</tr>
<tr>
<td>FLHD</td>
<td>1.042</td>
<td>0.11</td>
</tr>
<tr>
<td>BLHD</td>
<td>1.813</td>
<td>3.67</td>
</tr>
<tr>
<td>3rd-order</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OF</td>
<td>0.691</td>
<td>-1.17</td>
</tr>
<tr>
<td>MGDO</td>
<td>0.818</td>
<td>-2.18</td>
</tr>
<tr>
<td>FLHD</td>
<td>0.871</td>
<td>-2.06</td>
</tr>
<tr>
<td>FLOF</td>
<td>0.985</td>
<td>-0.35</td>
</tr>
<tr>
<td>AG</td>
<td>1.097</td>
<td>0.73</td>
</tr>
<tr>
<td>BLHD</td>
<td>1.114</td>
<td>0.73</td>
</tr>
</tbody>
</table>

* Significant using a sequential Bonferroni correction (experiment wise $\alpha = 0.10$)
Table 2.4. Ranking and $t$-statistics ($P$-values) for 2$^{nd}$-order habitat use by hogs during the dry season at Malmaison WMA, Mississippi and surrounding lands, 1 April 2005 – 31 March 2006.

<table>
<thead>
<tr>
<th></th>
<th>AG</th>
<th>BLHD</th>
<th>FLHD</th>
<th>FLOF</th>
<th>MGDO</th>
<th>OF</th>
</tr>
</thead>
<tbody>
<tr>
<td>AG</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BLHD</td>
<td>-0.389 (0.055)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLHD</td>
<td></td>
<td>0.919 (0.001)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLOF</td>
<td></td>
<td></td>
<td>-0.262 (0.003)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MGDO</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.041 (0.607)</td>
<td></td>
</tr>
<tr>
<td>OF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2.5. Ranking and $t$-statistics ($P$-values) for 2\textsuperscript{nd}-order habitat use by hogs during the wet season at Malmaison WMA, Mississippi and surrounding lands, 1 April 2005 – 31 March 2006.

<table>
<thead>
<tr>
<th></th>
<th>AG</th>
<th>BLHD</th>
<th>FLHD</th>
<th>FLOF</th>
<th>MGDO</th>
<th>OF</th>
</tr>
</thead>
<tbody>
<tr>
<td>AG</td>
<td>-1.391 (&lt;0.001)</td>
<td>-0.620 (0.101)</td>
<td>-0.802 (0.371)</td>
<td>-0.484 (0.340)</td>
<td>0.042 (0.876)</td>
<td></td>
</tr>
<tr>
<td>BLHD</td>
<td></td>
<td>0.770 (0.026)</td>
<td>0.589 (0.532)</td>
<td>0.906 (0.169)</td>
<td>1.433 (0.022)</td>
<td></td>
</tr>
<tr>
<td>FLHD</td>
<td></td>
<td></td>
<td>-0.181 (0.866)</td>
<td>0.136 (0.847)</td>
<td>0.663 (0.272)</td>
<td></td>
</tr>
<tr>
<td>FLOF</td>
<td></td>
<td></td>
<td></td>
<td>0.317 (0.438)</td>
<td>0.844 (0.201)</td>
<td></td>
</tr>
<tr>
<td>MGDO</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.527 (0.086)</td>
</tr>
<tr>
<td>OF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2.6. Ranking and $t$-statistics ($P$-values) for 3rd-order habitat use by hogs during the dry season at Malmaison WMA, Mississippi and surrounding lands, 1 April 2005 – 31 March 2006.

<table>
<thead>
<tr>
<th></th>
<th>AG</th>
<th>BLHD</th>
<th>FLHD</th>
<th>FLOF</th>
<th>MGDO</th>
<th>OF</th>
</tr>
</thead>
<tbody>
<tr>
<td>AG</td>
<td>0.058 (0.376)</td>
<td>-0.089 (0.140)</td>
<td>0.126 (0.145)</td>
<td>0.091 (0.159)</td>
<td>0.169 (0.001)</td>
<td></td>
</tr>
<tr>
<td>BLHD</td>
<td></td>
<td>-0.147 (0.021)</td>
<td>0.068 (0.470)</td>
<td>0.033 (0.614)</td>
<td>0.111 (0.164)</td>
<td></td>
</tr>
<tr>
<td>FLHD</td>
<td></td>
<td></td>
<td>0.215 (0.071)</td>
<td>0.180 (0.025)</td>
<td>0.258 (0.001)</td>
<td></td>
</tr>
<tr>
<td>FLOF</td>
<td></td>
<td></td>
<td></td>
<td>-0.034 (0.687)</td>
<td>0.044 (0.570)</td>
<td></td>
</tr>
<tr>
<td>MGDO</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.078 (0.180)</td>
<td></td>
</tr>
<tr>
<td>OF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 2.1. Location of Malmaison WMA, Mississippi, and surrounding lands.
Figure 2.2. Habitat types within the study area at Malmaison WMA and surrounding lands, 2005-2006.
Figure 2.3. 95% Adaptive Kernel home range estimates (means ± 1 SE) for feral hogs at Malmaison WMA, Mississippi and surrounding lands, 1 April 2005 – 31 March 2006.
CHAPTER III
SURVIVAL OF FERAL HOGS IN CENTRAL MISSISSIPPI

ABSTRACT
Feral hogs have the potential to negatively impact native wildlife and sensitive plant communities. Since their first introduction into North America, feral hogs have steadily increased their range to include most of the United States. I examined seasonal survival and cause-specific mortality of feral hogs in central Mississippi from April 2005 through March 2006. Based on known climate changes, I split the year into a “dry” season (1 April – 31 October) and a “wet” season (1 November – 31 March) when, due to flooding, some areas were rendered inaccessible to hogs and hunting season opened. Survival was modeled as a function of gender, season, and capture weight using Program MARK and a nest survival model. A reduced 2-season model was the best approximating model. Seasonal survival rates for the dry and wet seasons were 80.8% and 41.4%, respectively. There was little evidence to suggest that gender or initial weight had any effect on survival rates. Of the 15 mortalities that occurred during the study, 12 were from hunting (6 boars and 6 sows). I was not able to determine, with certainty, the cause of mortality for the 3 remaining sows. An understanding of survival and the factors influencing survival are important in making sound management decisions regarding feral hog management.
INTRODUCTION

Since their first introduction into North America in the 1500s, feral hogs have steadily increased their range and, with the aid of additional introductions, continue to move into new areas (Gipson et al. 1998). Feral hogs have been known to cause damage in natural communities (Singer et al. 1984) and severe economic losses in agricultural settings (Beach 1993).

Relatively little quantitative information exists about feral hog survivorship. Jezierski (1977) and Massei et al. (1997) documented mortality of wild boar in Europe. Both found that juvenile males tend to experience greater mortality than do juvenile females. The differential mortality among juveniles was attributed to juvenile males dispersing from their natal areas more readily than juvenile females. However, in adults, the relationship is opposite with females having a greater mortality than males (Jezierski 1977, Massei et al. 1997). In adults, the high cost of reproduction and care of young may stress females during summer (Massei et al. 1997).

Mortality also may vary among seasons. Jezierski (1977) and Massie et al. (1997) both found that mortality in hogs was generally greater in the summer as opposed to winter. Massie et al. (1997) attributed greater mortality in summer to food shortage due to hardened ground. They reported a sharp drop in mortality soon after the first precipitation softened the ground. Woodall (1983) also reported pig mortality was negatively related to rainfall.

Although feral hogs are attracting more attention from researchers, information regarding survival of this species is scarce. The objectives of this study were to estimate
gender and season specific survival rates as well as cause specific mortality of feral hogs in central Mississippi.

STUDY AREA

I worked in the southwest corner of Grenada County Mississippi on Malmaison Wildlife Management Area (MWMA) and surrounding lands. The area fell within the alluvial floodplain of the Yalobusha River. A complete description of the study area including available habitats and dominant species can be found in Chapter 2.

METHODS

Trapping and Processing

I located each radio-collared hog once daily on at least three days weekly from the time of capture until the animal’s death or the end of the field season (31 March 2006). A description of all trapping and handling methods can be found in Chapter 2.

Statistical Analysis

I used the nest survival model within program MARK (White and Burnham 1999, Dinsmore et al. 2002, Holder 2006) to determine effects of selected factors on daily survival rates (DSR) of feral hogs. I chose the nest survival model because it allows the time of death to occur within an interval. Through the cooperation of local hunters and land managers I was able to determine the exact date of death for most hogs, but not all.
For individuals where exact mortality date (or censoring) was unknown, the interval in which mortality or censoring could have taken place was from relatively small (2-4 days).

Five values are needed to construct the encounter history file for the nest survival model. (1) the day the animal was marked (i), (2) the last day the animal was known to be alive (j), (3) the last day the animal was observed (k), (4) the fate of the animal (1= mortality; 0= surviving animal), and (5) number of animals with the same encounter history.

Individual covariates used in model selection were selected *a priori*. I modeled effects of season, gender, and initial weight on DSR. To model effects of season on DSR, I developed a reduced 2-season model. Previous studies have reported gender to influence survival rates of wild boar in Europe (Jezierski 1977, Massei et al. 1997). I chose to include gender as a covariate to investigate gender-specific survival rates. I used Akaike’s information criterion (AIC\(_c\): Akaike 1973) to determine which model best fit the data while maintaining an acceptable level of precision (White and Burnham 1999). The model with the lowest AIC\(_c\) value was selected as the best approximating model and was used to estimate survival rates. To calculate seasonal survival estimates, I raised the DSR to the power of the days included in the season (DSR\(^{(# \text{ days in season})}\)). For example, the wet season had 164 days and DSR = 0.9946, so the estimated survival for the wet season was \(0.9946^{164}\).
RESULTS

Throughout the study, I observed 29 individuals for a periods ranging from 15 – 346 days. Of the 15 mortalities that occurred during the study, 12 (6 boars and 6 sows) were known to be from hunting or trapping. I was not able to determine, with certainty, the cause of mortality for the 3 remaining hogs. Twelve hogs died during the wet season and 3 deaths occurred during the dry season.

A reduced 2-season model was the best approximating model (Table 3.1). The next best were initial mass ($\Delta AIC_c = 6.29; w_i = 0.02$) and constant survival models ($\Delta AIC_c = 6.29; w_i = 0.04$), but both had low weights ($w_i < 0.05$). The reduced 2-season model indicated that hogs had lesser daily survival in the wet season than in the dry season (Figure 3.1). Daily survival rates for the dry and wet seasons were 0.9990 (95% CI = 0.9970, 0.9997) and 0.9946 (95% CI = 0.9906, 0.9970), respectively. Seasonal survival rates were 80.8% over the 204-day dry season and 41.4% over the 164-day wet season. There was little evidence to suggest that gender or initial weight had any effect on DSR.

DISCUSSION

Several studies have documented greater mortality during dry weather, but I observed the opposite pattern on my study area. Massei et al. (1997) showed a rapid decrease in mortality after the first precipitation of the year, indicating that food shortage caused by hardened ground may have been the leading cause of mortality. Woodall (1983), working in northeast Australia, also found that pig mortality was negatively
related to rainfall. These studies were conducted in arid to semiarid environments that do not reflect the conditions on my study area.

Hogs on my study area experienced lesser daily survival during the wet season. Food resources were abundant at this time (R.C. Hayes, personal observation), indicating that availability of food had little to do with daily survival of feral hogs on my study area, at least during the wet season. Although the wet season was favorable regarding food supply, general gun hunting season for deer began 18 November and hunting continued through most of the wet season. Hunting was the major cause of mortality among the animals that died during the study. Of the 15 mortalities that occurred during the study, 80% (12) were known for certain to be from hunting/trapping. Although I was not able to determine the cause of mortality for the remaining 3 hogs, they could have been linked to hunting.

Few studies have documented the effect of hunting on feral hog survival. Studies of feral hog abundance in California indicate that hog densities are less in areas that receive high hunting pressure as opposed to areas where hunting is restricted (Pine and Gerdes 1973, Sweitzer et al. 2000). Engeman et al. (2006) did not address survival, but did show that feral hog damage to sensitive wetlands in hunted areas was less than half that of unhunted areas and that supplemental removal (trapping) of hogs in unhunted areas reduced damage by 78% in those areas.

Initial weight and gender had little or no effect on DSR. One might hypothesize that boars would have lesser survivorship because of their propensity to be more wide-ranging and/or engaging in conflicts with other boars, but this was not the case in my
study area. Similarly, initial weight could have been an indicator of overall health, but I did not find any effects of weight on survivorship, perhaps because food resources were likely abundant during my entire study period. Conversely, larger animals are often targeted by hunters (thus, larger hogs could have been more likely to be shot), but hunters at MWMA tended to shoot the first hog that presented itself (J. R. Lee, personal communications). Hogs often traveled in groups of mixed gender and weights, therefore, each hog may have had an equal probability of being shot.

**MANAGEMENT IMPLICATIONS**

Other studies of abundance of feral hogs have expressed the need for a large portion of the total population to be removed each year to maintain stable hog numbers (Dzieciolowski et al. 1992, Caley 1993). Caley (1993), working in a tropical woodland habitat of Australia, estimated that over 55% of the population would need to be removed in any one year to suppress the population for that year. Sweitzer et al. (2000) found that hunting may significantly reduce density of hog populations in California. On my study area, hunting/trapping accounted for 80-100% of the recorded mortality, and the DSR was less during the wet season when most hunting activity occurred. In light of these findings and those of other research, I suggest that more emphasis should be placed on hunting/trapping feral hogs. Geisser and Reyer (2004) make a similar suggestion in their study of the efficacy of various methods to reduce damage by hogs, stating that only hunting clearly reduced hog damage. A combination of hunting and trapping may be the most effective means to reduce damage. Engeman et al. (2006) showed supplemental
removal of hogs from hunted areas reduced hog damage by 60%. Waithman et al. (1999) reported that up to 40% of California’s hog population was removed annually by a combination of hunting, natural predation and poaching. This was enough to control hog numbers in some areas of the state, but not others (Waithman et al. 1999). On my study area, I found no evidence of predation, or other natural mortality; further emphasizing the importance of hunting/trapping as a regulating factor.


Holder, B. D. 2006. Survival, habitat use, and nest-site characteristics of wild turkeys in central Mississippi. Thesis, Mississippi State University, Starkville, Mississippi, USA.


Table 3.1. Model selection results for feral hog daily survival at Malmaison WMA, Mississippi and surrounding lands, 1 April 2005 – 31 March 2006.

<table>
<thead>
<tr>
<th>Model</th>
<th>AIC&lt;sub&gt;c&lt;/sub&gt;</th>
<th>ΔAIC&lt;sub&gt;c&lt;/sub&gt;</th>
<th>AIC&lt;sub&gt;c&lt;/sub&gt; w&lt;sub&gt;i&lt;/sub&gt;</th>
<th>k</th>
<th>Deviance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seasonal survival</td>
<td>194.27</td>
<td>0.00</td>
<td>0.92</td>
<td>2</td>
<td>190.27</td>
</tr>
<tr>
<td>Constant survival</td>
<td>200.56</td>
<td>6.29</td>
<td>0.04</td>
<td>1</td>
<td>198.56</td>
</tr>
<tr>
<td>Initial mass</td>
<td>200.56</td>
<td>6.29</td>
<td>0.02</td>
<td>2</td>
<td>198.56</td>
</tr>
<tr>
<td>Gender</td>
<td>201.97</td>
<td>7.70</td>
<td>0.02</td>
<td>2</td>
<td>197.968</td>
</tr>
</tbody>
</table>
Figure 3.1. Daily survival rates and 95% CI for feral hogs at Malmaison WMA, and surrounding lands, 1 April – 31 March 2006.