Home Range Sizes of Fox Squirrels in Southwest Georgia

L. Mike Conner, *Joseph W. Jones Ecological Research Center, Rt. 2 Box 2324, Newton, GA 31710*

Abstract: Home range size quantifies space needed by an animal in a given area and time. Because fox squirrel *(Sciurus niger)* home range estimates in the Southeast are rare, I radio-monitored fox squirrels to determine their seasonal and composite (i.e., total duration of monitoring) home range size in southwest Georgia between March 1998 and September 1999. There was no sex by season interaction ($P=0.11$). Male seasonal and composite home ranges (35.8±4.4 ha and 37.0±3.6 ha, respectively) were larger ($P<0.001$) than female home ranges (seasonal = 13.3±1.5 ha, composite = 21.0±6.3 ha). Seasonal home ranges were largest (34.3±5.9 ha) during March–May of 1998 and smallest (5.9±1.2 ha) during January–February of 1999. Southeastern fox squirrels require more space than midwestern fox squirrels, perhaps a result of patchily distributed and/or temporally variable food supplies. Food abundance and breeding behavior may explain seasonal variation in home range size.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 54:400–406

In many areas of the Southeast, fox squirrel populations are declining. Most fox squirrel research, however, has taken place in the Midwest. Midwestern fox squirrels are ecologically different from southeastern fox squirrels, and management recommendations derived from midwestern studies may not apply to southeastern subspecies (Loeb and Moncrief 1993, Tappe and Guynn 1998). Therefore, fox squirrel research is needed to specifically address management needs of this species in the Southeast.

It is important to quantify space use patterns to assist in effective management of fox squirrels, yet there are few home range estimates of southeastern fox squirrels (Hilliard 1979, Edwards 1986, Weigl et al.1989, Kantola and Humphrey 1990). Therefore, I initiated a study to estimate home ranges of fox squirrels in southwest Georgia. My objectives were to provide estimates of seasonal and composite (i.e., calculated from all telemetry locations associated with an animal) fox squirrel home ranges and to determine if fox squirrel home ranges varied between sexes and among seasons.

I. Godbois, T. Story, L. Welch, B. Plowman, W. Cotton, and B. Massery assisted with data collection. D. Miller, B. Rutledge, and G. Conner provided editorial advice.

M. Chamberlain, D. Guynn, M. Whiting, and an anonymous reviewer greatly improved the manuscript. The Joseph W. Jones Ecological Research Center and the Woodruff Foundation funded this project.

Methods

Study Area

The study took place on Ichauway, the 12,000-ha former hunting plantation of Robert W. Woodruff and current research site of the Joseph W. Jones Ecological Research Center. Ichauway is located in Baker County, Georgia, approximately 20 km south of Newton, Georgia. Prescribed fire was used to maintain a longleaf pine *(Pinus palustris)* dominated overstory and a herbaceous understory. Scattered individual hardwoods and hardwood patches existed within the longleaf matrix, and these hardwoods provided valuable mast for wildlife. Oak (*Quercus* spp.) mast production was excellent during fall and winter 1997–1998 and was considered average during fall and winter 1998–1999 (unpubl. data). Additionally, historical management for northern bobwhite *(Colinus virginanus)* resulted in a diverse habitat mosaic of interspersed food plots and small weedy openings within the forested matrix. Rainfall averaged 132 cm/year, and average daily temperature was 11 C during winter and 27 C during summer. Although both fox squirrels and gray squirrels *(S. carolinensis)* were found on the study site, gray squirrels were generally restricted to hardwood-dominated sites, and the 2 species were seldom found together (Conner et al. 1999).

Animal Capture and Monitoring

Squirrels were captured in wooden box traps (Baumgartner 1940) baited with dried corn. I periodically placed traps in areas known to have fox squirrels and trapped squirrels throughout the study period (i.e., there were no defined trapping seasons).

I placed captured squirrels into a nylon mesh bag. Squirrels were then sedated using either Methoxyflorane or Ketamine hydrochloride. While squirrels were sedated, I determined sex, took standard measurements, affixed ear tags, and aged squirrels following Weigl et al. (1989). Finally, I attached a radiotransmitter collar (Telemetry Solutions, Walnut Creek, Calif.) to a sample of captured adults. All squirrels were released at the capture site after recovery from anesthesia. All trapping and handling followed Animal Care and Use Committee (1998) recommendations as approved by the American Society of Mammalogists. Radio-tagged squirrels were located ≥2 times/week using triangulation from known reference points.

I partitioned a calendar year into 5 seasons based on changes in native food availability and fox squirrel diets (Weigl et al. 1989). I defined early spring (Mar–May) as the period that corresponds with spring green-up. Late spring (Jun–Jul) is a period of low natural food abundance. Longleaf pine seed is an important food item to fox squirrels (Loeb and Moncrief 1993), and seed production peaks

during August–September (Wahlenberg 1946). Therefore, I defined summer as August–September, the period of pine seed production. I defined fall as October–December, corresponding with the period of greatest acorn availability. Finally, I defined winter as January–February, a period marked by a gradual reduction in hard mast availability.

Data Analysis

Because home range estimates are sensitive to number of locations, I restricted composite home range estimates to squirrels with ≥30 locations (Seaman et al. 1999). However, I calculated seasonal home ranges using a minimum of 10 locations, thus seasonal home ranges were only considered an index of relative space use and were not used to determine amount of space required by a squirrel. I used the 95% adaptive kernel method (Worton 1989) in HOME RANGER (Hovey 1999) to estimate composite and seasonal home ranges.

I used a 1-way analysis of variance (ANOVA) on rank transformed data (Conover and Iman 1981) to determine if composite home range sizes differed between sexes. I used a 2-factor ANOVA on rank transformed data (Conover and Iman 1981) to determine if seasonal space use varied as a function of season, sex, or their interaction. I used Student-Newman-Keuls' test to compare seasonal home ranges (Steel and Torrie 1980).

Results

I calculated composite home ranges for 71 (27 M, 44 F) fox squirrels. Male composite home ranges (37.0±3.6 ha; $\bar{x}$ ±SE) were larger ($F_{1,69}=35.84$, $P<0.001$) than female composite home ranges (21.0±6.3 ha).

Although fox squirrels were monitored from early spring 1998 through fall 1999, the number of squirrels monitored during fall 1999 was too few ($N=4$) to warrant statistical analysis. Therefore, seasonal home ranges were only analyzed for 8 seasons

Table 1. Average home range sizes (ha) of fox squirrels and number of squirrels monitored in southwest Georgia between March 1998–September 1999. Standard errors are shown in parentheses.

Season[a]	Male	N	Female	N	Combined
Early spring 1998	45.7 (8.3)	9	29.7 (7.4)	22	34.3 (5.9) A[b]
Late spring 1998	52.1 (16.7)	9	14.8 (1.7)	21	26.0 (5.9) B
Summer 1998	45.9 (13.5)	11	10.5 (1.6)	23	22.0 (5.2) B C
Fall 1998	37.8 (6.0)	11	12.2 (2.6)	22	20.8 (3.3) B C
Winter 1999	10.2 (3.9)	6	4.4 (0.7)	18	5.9 (1.2) D
Early spring 1999	11.9 (3.2)	7	8.5 (1.5)	17	9.5 (1.4) C D
Late spring 1999	18.2 (0.7)	2	12.2 (3.7)	10	13.2 (3.2) B C
Summer 1999	28.8 (10.5)	2	6.8 (1.7)	7	11.7 (3.9) C

a. Early spring = March–May, late spring = June–July, summer = August–September, fall = October–December, and winter = January–February.

b. Means with different letters are significantly different ($P<0.05$).

(i.e., early spring 1998–summer 1999). The number of squirrels used in seasonal analyses ranged from 9 (2 M, 7 F) during summer 1999 to 34 (11 M, 23 F) during summer 1998 (Table 1). Number of locations/squirrel within a season ranged from 15 during winter 1999 to 21.6 during fall 1998. I did not detect an interaction ($F_{7,181}=1.69$, $P=0.11$) between sex and season effects in the ANOVA. Therefore, I examined main effects of sex and season while averaging the other main effect (Steel and Torrie 1980). Male seasonal home ranges (35.8±4.4 ha) were larger ($F_{1,181}=43.5$, $P<0.001$) than female seasonal home ranges (13.3±1.5 ha). Home range sizes differed ($F_{7,181}=10.91$, $P<0.001$) seasonally. Home ranges (34.4±5.9 ha) were larger ($P<0.05$, SNK multiple range test) during early spring 1998 than during other seasons. Home ranges (5.9±1.2 ha) were smaller ($P<0.05$, SNK multiple range test) during winter 1999 than during other seasons with the exception of early spring 1999.

Discussion

Home range estimates provide a means to determine the amount of space required by an animal to survive and reproduce (Burt 1943). Because home range size is influenced by a variety of factors (e.g., habitat quality, density of the population being studied, behavioral mechanisms, etc; Don 1983), multiple estimates of home range size for a particular species are needed to ensure management decisions are made using the appropriate spatial scale. Fox squirrel home range estimates are rare in the literature, and there are few estimates of fox squirrel home range size in the Southeast (Hilliard 1979, Edwards 1986, Weigl et al. 1989, Kantola and Humphrey 1990). The results of this study are useful for describing a range of "normal" values for fox squirrel home ranges in the Southeast.

Composite home ranges for fox squirrels in southwest Georgia were similar to home ranges reported elsewhere in the South. In Georgia, Hilliard (1979) determined fox squirrel home ranges averaged 15 ha (range=6–31 ha). Fox squirrel home ranges in South Carolina averaged approximately 32 and 19 ha for males and females, respectively (Edwards 1986). In North Carolina, composite home ranges of male fox squirrels averaged 18 ha, whereas female home ranges averaged 3 ha (Weigl et al. 1989). In Florida, Kantola and Humphrey (1990) estimated home ranges of 43 ha and 17 ha for male and female fox squirrels, respectively. Midwestern fox squirrels, however, have much smaller home ranges (Koprowski 1994). For example, Indiana fox squirrel home ranges averaged 3 ha for males and 4 females (Sheperd and Swihart 1995) and Illinois fox squirrel home ranges averaged 2 ha for males and 1 ha for females (Benson 1980).

The patchy, unpredictable, food supply best explains the larger composite home rage size of southeastern fox squirrels relative to midwestern fox squirrels (Weigl et al. 1989, Kantola and Humphrey 1990). Because food availability varies spatially and temporally, southeastern fox squirrels may be required to shift space use to take advantage of temporally available food. Moreover, because food abundance varies temporally, large home ranges may permit southeastern fox squirrels to sample more habitat patches to locate temporally available food.

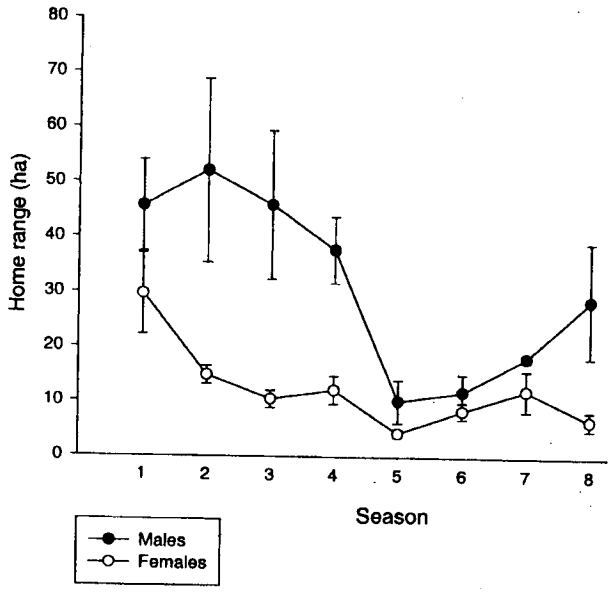

Figure 1. Seasonal home range sizes of fox squirrels monitored in southwest Georgia between March 1998–September 1999. Error bars represent ±1 standard error. Season 1= early spring (Mar–May) 1998, 2= late spring (Jun–Jul) 1998, 3= summer (Aug–Sep) 1998, 4= fall (Oct–Dec) 1998, 5= winter (Jan–Feb) 1999, 6= early spring, 1999, 7= late spring 1999, 8= summer 1999.

Male composite home ranges were nearly twice the size of female home ranges, and male seasonal home ranges were nearly 3 times larger than female seasonal home ranges. Others (Weigl et al. 1989, Kantola and Humphrey 1990) have observed similar differences in home range size between sexes. Because there is little sexual dimorphism in fox squirrels, body size does not explain sex-specific differences in home range size. Behavioral mechanisms (e.g., males searching for mating opportunities, females caring for young, etc.) are likely responsible for the difference in home range size between sexes.

Male seasonal home ranges were largest from early spring–fall 1998 (Fig. 1). Weigl et al. (1989) suggested that male fox squirrels wander over relatively large areas during breeding season in search of females. Peak breeding in fox squirrels generally occurs during late winter/early spring, and a second breeding season often occurs during summer/fall (Loeb and Moncrief 1993). Fox squirrel reproduction is linked to food availability (Weigl et al. 1989, Loeb and Moncrief 1993), and there was an excellent acorn crop during the fall prior to this study (i.e., fall 1997). This mast crop may have initiated breeding activity that led to large male home ranges during the early portion of this study.

The patchy yet locally abundant distribution of mature oaks may have been responsible for smaller fox squirrel home ranges during winter. Acorn production

peaked during late November and early December (unpubl. data), and fox squirrels concentrated their activity around oaks during this period, resulting in smaller winter home ranges.

Management Recommendations and Future Research

Southeastern fox squirrels maintain larger home ranges than midwestern fox squirrels. Managers should take large home range requirements and variability of native foods into consideration when managing for fox squirrels. Acorns and pine seeds are both seasonally important to fox squirrels (Weigl et al. 1989, Loeb and Moncrief 1993). Integrated forest/wildlife management should focus on the interspersion of hard mast producers within pine matrix. Pure stands of either hardwoods or pines should be avoided in favor of mixed pine/hardwood forest, and special attention should be paid to the juxtaposition of mature pine and hardwood habitats.

Future research should explore the relationship between fox squirrel home range size and habitat quality. Because spatial and temporal food availability is thought to affect southeastern fox squirrel home range size (Weigl et al. 1989, Kantola and Humphrey 1990), supplemental feeding experiments should be used to better understand the relationship between fox squirrel home range size and food abundance.

Literature Cited

Animal Care and Use Committee. 1998. Guidelines for the capture, handling, and care of mammals as approved by the American Society of Mammalogists. J. Mammal. 79:1416–1431.

Baumgartner, L. L. 1940. Trapping, handling, and marking fox squirrels. J. Wildl. Manage. 4:444–450.

Benson, B. N. 1980. Dominance relationships, mating behavior and scent marking in fox squirrels *(Sciurus niger)*. Mammalogy 44:143–160.

Burt, W. H. 1943. Territoriality and home range concepts applied to mammals. J. Mammal. 24:346–352.

Conner, L. M., J. L. Landers, and W. K. Michener. 1999. Fox and gray squirrel density, habitat and interspecific association within minimally distrubed longleaf pine forest. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 53:364–374.

Conover, W. J. and R. L. Iman. 1981. Rank transformations as a bridge between parametric and nonparametric statistics. Am. Sta. 35:124–129.

Don, B. A. C. 1983. Home range characteristics and correlates in tree squirrels. Mammal Rev. 13:123–132.

Edwards, J. W. 1986. Habitat utilization by southern fox squirrel in coastal South Carolina. M.S. Thesis, Clemson University, Clemson, S.C. 52pp.

Hilliard, T. H. 1979. Radiotelemetry of fox squirrels in the Georgia coastal plain. M.S. Thesis, Univ. Ga., Athens. 121pp.

Hovey, F. W. 1999. The Home Ranger. Ursus software. Revelstake, British Columbia, Can.

Kantola, A. T. and S. R. Humphrey. 1990. Habitat use by Sherman's fox squirrel *(Sciurus niger shermani)* in Florida. J. Mammal. 71:411–419.

Koprowski, J. L. 1994. Mammalian species *Sciurus niger*. Am. Soc. Mammal. 479:1–9.

Loeb, S. C. and N. D. Moncrief. 1993. The biology of fox squirrels in the Southeast: a review. Pages 1–20 *in* N. D. Moncrief, J. W. Edwards, and P. A. Tappe, eds. Proceedings of the second symposium of Southeastern fox squirrels, *Sciurus niger.* Va. Mus. Nat. History Spec. Publ. 1. 84pp.

Seaman, D. E., J. J. Millspaugh, B. J. Kernohan, G. C. Brundige, K. J. Raedeke, and R. A. Gitzen. 1999. Effects of sample size on kernel home range estimates. J. Wildl. Manage. 63:739–747.

Sheperd, B. F. and R. K. Swihart. 1995. Spatial dynamics of fox squirrels *(Sciurus niger)* in fragmented landscapes. Can. J. Zool. 73:2098–2105.

Steel, R. G. D. amd J. H. Torrie. 1980. Principles and precedures of statistics: a biometrical approach. 2nd ed. McGraw-Hill, New York. 633pp.

Tappe, P. A. and D. C. Guynn. 1998. Southeastern fox squirrels r- or k-selected? Implications for management. Pages 239–249 *in* M. A. Steele, J. F. Merritt, and D. A. Zegers, eds. Ecology and evolutionary biology of tree squirrels. Spec. Publ. Va. Mus. Nat. History 6. 320pp.

Wahlenberg, W. G. 1946. Longleaf pine: its use, ecology, regeneration, protection, growth, and management. Charles Lathrop Pack For. Found. Washington, D.C. 429pp.

Weigle, P. D., M. A. Steele, L. J. Sherman, and J. C. Ha. 19889. The ecology of the fox squirrel *(Sciurus niger)* in North Carolina: implications for survival in the Southeast. Tall Timbers Res. Sta. Bull. 24. 93pp.

Worton, B. J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70:164–168.

Distribution and Status of the Swamp Rabbit in South Carolina

Steven G. Platt,[1] *Department of Biological Sciences, 132 Long Hall, Clemson University, Clemson, SC 296334–1903*

Mary Bunch, *Wildlife Diversity, South Carolina Department of Natural Resources, 153 Hopewell Road, Pendleton, SC 29670*

Abstract: We conducted a survey from 1990 to 1995 to determine the distribution and status of the swamp rabbit *(Sylvilagus aquaticus)* in South Carolina. Populations appear largely confined to 3 counties in the Savannah river watershed of northwestern South Carolina. We found little evidence that a significant change in distribution has occurred in South Carolina since the species was first reported in the late 1930s. Swamp rabbits are restricted to bottomlands, but were found in a variety of successional habitats ranging from old-fields to mature hardwood forests.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 54:408–414

The swamp rabbit has been reported from 14 states in the Gulf Coastal Plain and lower Mississippi River Valley (Chapman and Feldhamer 1981). This distribution extends from the Gulf of Mexico, north to Illinois and Indiana, westward to eastern Texas, Oklahoma, and Kansas, and east to Georgia and South Carolina (Chapman and Feldhamer 1981). Swamp rabbits occur in swamps, river bottoms, and other wetland habitats (Allen 1985). The swamp rabbit is the least studied species of *Sylvilagus* (Chapman and Feldhamer 1981), and its current range and status throughout much of the southeastern United States is largely unknown (Dailey et al. 1993). Population declines attributable to habitat loss have been reported in Arkansas (Sealander and Heidt 1990), Indiana (Harrison and Hicke 1931, Terrel 1972, Whitaker and Abrell 1986), Kentucky (Sole 1994), and Missouri (Korte and Fredrickson 1977, Dailey et al. 1993). Habitat loss is primarily due to conversion of bottomlands to extensive row-crop agricultural fields (Allen 1985). Surveys of swamp rabbit distribution and status have been accorded high priority because of widespread population declines and continuing habitat loss (Korte and Frederickson 1977, Dailey et al. 1993, Sole 1994).

The current distribution and status of the swamp rabbit in South Carolina has received little attention. Sherman (1930) first reported the swamp rabbit in the state on

1. Present address: Wildlife Conservation Society, P.O. Box 9345, Siem Reap, Cambodia.