*Research Article*

# Habitat Selection of Female Turkeys in a Managed Pine Landscape in Mississippi

**DARREN A. MILLER,**[1] *Southern Timberlands Research and Development, Weyerhaeuser Company, P.O. Box 2288, Columbus, MS 39704, USA*
**L. MICHAEL CONNER,** *Joseph W. Jones Ecological Research Center, Route 2, Box 2324, Newton, GA 30602, USA*

**ABSTRACT** Intensive pine (*Pinus* spp.) management is a dominant form of forest management in the southeastern United States. Previous research has shown that managed pine forests provide suitable habitat for eastern wild turkeys (*Meleagris gallopavo silvestris*), but little research has examined seasonal habitat selection for female wild turkeys from a landscape perspective, particularly within managed pine landscapes. Therefore, we used a long-term (1986–1993) data set to describe seasonal habitat selection by female wild turkeys, using an information-theoretic approach from a landscape perspective, on an intensively managed pine landscape. Habitat use patterns during preincubation and autumn–winter were indicative of female wild turkeys moving between a bottomland hardwood–agricultural field complex during autumn–winter and upland managed pine stands during the remainder of the year. During spring and summer, female wild turkeys used landscapes primarily composed of intensively managed pine, including thinned and burned stands and roadsides. Our results confirm results of short-term, stand-based habitat analyses on our study area. We recommend variable fire return intervals of 3 to 7 years to improve habitat conditions for wild turkeys within intensively managed pine forests. Further research is needed to examine management actions, such as thinning, prescribed fire, and herbicide use, within the context of wild turkey use of intensively managed pine landscapes. (JOURNAL OF WILDLIFE MANAGEMENT 71(3):744–751; 2007)

DOI: 10.2193/2005-738

**KEY WORDS** habitat, habitat selection, information-theoretic approach, intensive forest management, landscape metrics, logistic regression, *Meleagris gallopavo silvestris*, Mississippi, pine silviculture, wild turkey.

Eastern wild turkeys (*Meleagris gallopavo silvestris;* hereafter, wild turkeys) are an important recreational resource throughout their range (Tapley et al. 2001). Prior to widespread restoration of this popular game bird, conventional wisdom held that wild turkeys required extensive tracts of older aged forests (Porter 1992) and that intensively managed pine (*Pinus* spp.) landscapes were unsuitable habitat (Mosby 1975). However, as wild turkey populations were successfully restored, they began inhabiting a wide range of habitats (Speake et al. 1975), including intensively managed pine landscapes (Holbrook et al. 1985, Exum et al. 1987). Subsequent research demonstrated that wild turkeys were compatible with intensive pine management, particularly within a sawtimber silvicultural regime that incorporates thinnings and prescribed burning (e.g., Smith et al. 1990, Hurst and Dickson 1992, Miller et al. 1995, Weinstein et al. 1995).

Within the southeastern United States, intensively managed pine forests are a primary forest type, occurring on 12.9 million ha in 1999 (Wear and Greis 2002) and projected to remain an important component of the southern United States landscape (National Commission on Science for Sustainable Forestry 2005). Forestry practices on industrial timberlands in the southern United States continue to change, often becoming more intensive (i.e., shorter rotations, greater vegetation control; Miller and Miller 2004), requiring a basic knowledge of species' ecology within these systems to better understand how changes may affect these species. Past research has documented habitat use by female wild turkeys in managed pine landscapes (Kennamer et al. 1980, Holbrook et al. 1985, Smith and Teitelbaum 1986, Exum et al. 1987), including research on our study area (Burk et al. 1990*a*, *b*; Smith et al. 1990; Stys et al. 1992). These past studies were of short duration and those conducted on our study area did not consider totality of available data. Long-term datasets in studies of wild turkeys are more robust when evaluating annual variations (Leopold et al. 1996, Miller et al. 2001). Further, most prior research in intensively managed pine landscapes used a stand-level approach to examine habitat use, generally in a use–availability context, even though landscape context is likely important to wild turkeys (e.g., Miller et al. 1999, 2000).

Most, if not all, past habitat studies of wild turkeys have used point locations to examine use versus availability and to develop habitat models (e.g., Miller et al. 1999, 2000). Additionally, although use–availability approaches may be useful for stand-level applications (e.g., Thomas and Taylor 1990), criticisms of these approaches (Aebischer et al. 1993, Bingham and Brennan 2004) indicate the need to employ new techniques for examining habitat selection, particularly at the landscape scale. Recently, Katnik and Wielgus (2005) suggested using randomly located home ranges to estimate habitat availability in habitat selection studies. Therefore, our objective was to use a long-term dataset (1987–1993) to examine seasonal habitat selection by female wild turkeys in an intensively managed pine landscape using randomly selected areas to estimate available landscape characteristics.

## STUDY AREA

We conducted our study on about 20,158 ha of mostly contiguous forest in the Interior Flatwoods Resource Area (Pettry 1977) of the East Gulf Coastal Plain, about 6 km southwest of Scooba, Mississippi, USA, in Kemper County.

[1] *E-mail: darren.miller@weyerhaeuser.com*

Topography was flat with many ephemeral, intermittent, and perennial streams. Dominant overstory tree species included loblolly pine (*Pinus taeda*), oaks (*Quercus* spp.), and hickory (*Carya* spp.). Common midstory species included oaks, hickory, maple (*Acer* spp.), sweetgum (*Liquidambar styraciflua*), and dogwood (*Cornus* spp.). Our study area was composed of intensively managed pine stands (46%), mature pine–hardwood (28%), mature hardwood (15%), and agriculture (11%). Within the intensively managed pine matrix, mature hardwoods primarily occurred in streamside management zones (SMZs). Intensively managed pine stands were primarily owned and managed by Weyerhaeuser Company for production of pine sawtimber and were composed of 76% thinned pine stands, 17% unthinned pine, and 7% pine regeneration. Our core study area, where we captured female wild turkeys (see below), was approximately 9,700 ha and was dominated (84%) by Weyerhaeuser ownership and by intensively managed pine stands (70% of the core area). Approximately 50% of mature hardwood, 60% of mixed pine–hardwood, and 90% of agricultural land was located within the Sucarnochee Creek bottom, located at the southern edge of our study area.

Typical silviculture for intensively managed pine stands on our area included clearcut harvest at about 27–32 years of age followed by site preparation and planting (approx. 1,100 trees/ha), vegetation management, 1 or 2 commercial thinnings (target of 309 trees/ha for first thinning and 150 trees/ha for second thinning), pruning, and fertilization. During our study, prescribed burning was commonly conducted within plantations beginning at 9–10 years of age at intervals of 3–5 years (Smith et al. 1990).

## METHODS

### Capture and Radiotelemetry

We captured wild turkeys by cannon net (Bailey 1976) from the third week of January until the second week of March during 1986–1992 and from late June to mid-August during 1986–1989, using cracked corn for bait. We removed wild turkeys from the net and placed them into cardboard boxes built specifically to accommodate wild turkeys (76.2 × 35.6 × 61 cm). We classified wild turkeys as adults or juveniles (Williams and Austin 1988) and marked them with 2 patagial wing tags (Knowlton et al. 1964) and 2 metal, triple-lock leg bands. We used backpack harnesses to attach 108-g, motion-sensitive radiotransmitters (Wildlife Materials, Carbondale, IL). We released wild turkeys within 10–45 minutes of capture at the site of capture. We operated under Mississippi State University Animal Care and Use Committee Protocol 93-030.

We recorded wild turkey locations using triangulation (Cochran and Lord 1963) from 2 fixed telemetry stations ($n = 144$) if azimuths were <12 minutes apart and angles were between 60° and 120°. We used a hand-held, 3-element, directional Yagi antenna and either a Telonics (Mesa, AZ) or Wildlife Materials receiver for triangulation. We located all female wild turkeys 3 times per day and 3 times per week during spring (Mar–Jun). We located females as often as possible, generally twice daily and twice weekly, during the rest of the year (Weinstein 1994).

### Data Analyses

We delineated biologically meaningful seasons based on the reproductive chronology of turkeys on our study area and previous research (Miller et al. 1997, 1999). For the 7 years of our study, we used median date of nest initiation to define the start of a 1-month spring season, which was intended to include the time most female wild turkeys were nesting. Therefore, we defined spring as 21 April–18 May, summer as 19 May–30 September, autumn–winter as 1 October–28 February, and preincubation as 1 March–20 April.

We estimated seasonal areas of use (SAUs) using a minimum convex polygon home-range estimator (Mohr 1947, Beyer 2004) with animals having ≥10 locations per season. We acknowledge that this is a low number of locations for estimating area of use. However, our purpose was not to define a home range per se but rather to define an area where turkeys were present within a given season (i.e., SAU). This is similar to defining an area for calculation of landscape characteristics associated with capture locations or animal observations (e.g., Kuehl and Clark 2002, Welsh and Lind 2002, Conner and Godbois 2003, Browning et al. 2005). Therefore, we believe using ≥10 locations to define a general area of use to examine habitat attributes of SAUs is justified.

We created a series of habitat layers for each year of the study 1987–1993 from color infrared aerial photographs transferred to 1:24,000 United States Geological Survey topographical maps. We defined 6 habitat types: young pine (recently planted pine, <2 yr old, characterized by a mixture of grasses, forbs, and open ground), sapling pine (pine dominated, 2–15 yr old, characterized by young stands with a thick understory to closed-canopy stands with minimal understory), mature pine (pine dominated, >15 yr old, characterized by an open canopy with a substantial understory, midstory, or both), hardwood forest (>70% hardwood), agriculture, and mixed pine–hardwood (30–70% pine, >30 yr old). The pine habitat classes were primarily under intensive management. We defined pine stands based on general suitability as wild turkey habitat, with sapling pine being the least desirable habitat condition for turkeys (e.g., Miller et al. 1999). We digitized habitat maps for analyses.

We downloaded road and creek thematic layers from the Mississippi Automated Resource Information System (Jackson, MS; http://www.maris.state.ms.us/) and projected these layers into a state plane coordinate system to match the coordinate system of the habitat layers. We used Weyerhaeuser Company stand data to determine dates of prescribed fire and thinning. We considered a stand as burned if it had been burned within the 3 prior years. We used ≤3 years as this is often a recommended fire interval for wild turkey management in pine stands (Burk et al. 1990*b*, Hurst and Dickson 1992, Palmer et al. 1996*a*, Miller et al. 1999). We considered a stand as having been thinned if it had been thinned prior to year of analysis. On our study

**Table 1.** Variable categories, associated predictor variables, and their definition used in logistic regression models to predict probability of an area being used by a female wild turkeys in east-central Mississippi, USA, 1987–1993.

| Variable class | Variable | Description |
|---|---|---|
| Landcover | Agriculture | % of SAU[a] in agriculture |
| | Hardwood | % of SAU in stands with >70% hardwood |
| | Mature pine | % of SAU in stands with >70% pine >15 yr old |
| | Mixed pine–hardwood | % of SAU in stands with 30–70% pine >15 yr of age |
| | Sapling pine | % of SAU in pine stands 2–14 yr of age |
| | Young pine | % of SAU in pine stands <2 yr of age |
| Landscape | Agriculture density | No. of agricultural fields/100 ha |
| | Hardwood density | No. hardwood stands/100 ha |
| | Mature pine density | No. mature pine stands/100 ha |
| | Mixed pine–hardwood density | No. mixed stands/100 ha |
| | Sapling density | No. sapling stands/100 ha |
| | Young pine density | No. young pine stands/100 ha |
| | Shape | Mean shape index of stands (McGarigal and Marks 1995) |
| | Edge density | m of edge/ha in SAU excluding SAU boundary |
| | Road density | m of road/ha in SAU |
| | Creek density | m of creek/ha in SAU |
| Management | % thin | % of SAU that had been thinned |
| | % of pine thin | % of pine thinned within SAU |
| | % pine mix thin | % of pine and mixed pine–hardwood thinned within SAU |
| | % burn | % of SAU burned within past 3 yr |
| | % pine burn | % of pine burned within SAU |
| | % pine mix burn | % of pine and mixed pine–hardwood burned within SAU |

[a] Seasonal area of use; area defined using the minimum convex polygon method with ≥10 telemetry locations within predefined F wild turkey seasons.

area, pine stands were first thinned between 15–18 years of age. Because of the relatively heavy thinning that was standard silviculture (see above), these stands maintained an open canopy structure until final harvest. Also, frequent burning of these stands maintained relatively consistent understory and midstory characteristics until the end of the rotation.

For each season, we determined number of females monitored and generated an equal number of randomly placed circles within the study area using the buffer tool of ArcMap. To ensure that habitat variables of interest were not influenced by size of SAUs, we generated each circle to match the size of one of the actual SAUs. Therefore, each random circle matched one SAU in size. However, we did not consider these paired observations for analyses. Our approach was similar to that used by Katnik and Wielgus (2005).

To determine habitat attributes within SAUs and random circles, we used ArcMap tools to intersect SAUs and circles with our habitat layers. These intersections produced 22 habitat variables that we used as predictors of habitat selection by wild turkey females. We grouped these variables into one of 3 categories (Table 1): 1) landcover variables, which were percent coverages of each habitat type, 2) landscape variables, which were variables that are often considered landscape metrics (McGarigal and Marks 1995), and 3) management variables, which represented human activity on forest stands (e.g., prescribed fire, thinning).

We used logistic regression (Hosmer and Lemeshow 1989) to develop models to predict whether habitat variables were associated with a SAU or a random circle. We developed one model for each variable ($n = 22$), one model for each variable category (i.e., landcover, landscape, and management; $n = 3$), and models for each combination of 2 variable categories (e.g., landcover + landscape; $n = 3$). Finally, we developed a global model using all variables and a null model using no variables. Thus, we developed 30 a priori candidate models using various combinations of the 22 habitat variables (Table 2).

We used an information-theoretic approach to data analysis (Anderson et al. 2000, Burnham and Anderson 2002). We used the second-order Akaike's Information Criteria ($AIC_c$) and Akaike weights ($w_i$) to identify the most parsimonious of the 30 a priori models and to predict importance of individual variables (Anderson et al. 2000, Burnham and Anderson 2002). We calculated $w_i$ for each model and interpreted $w_i$ as probability of the $i$th model being the best model of the a priori set. We considered the model with the highest $w_i$ as the best approximating model (Burnham and Anderson 2002).

We used model averaging (Burnham and Anderson 2002) to develop parameter estimates and their associated 95% confidence intervals for important predictor variables. We then calculated odds ratios for all parameter estimates whose confidence intervals did not contain zero (Hosmer and Lemeshow 1989). The odds ratio represents the increase in probability of an area being used as a SAU by female wild turkeys for every unit increase in the predictor variable. For example, if creek density had an odds ratio of 1.03 then an area with 1 m/ha more creek than another area would be 1.03 times more likely to be a SAU. We first determined the best model of the competing 30 irrespective of season. We then incorporated a seasonal variable into this overall model to determine if there was evidence supporting a seasonal effect. If so, we then developed seasonal models.

**Table 2.** A priori candidate models used to predict probability of an area being used as a seasonal area of use by female wild turkeys in east-central Mississippi, USA, 1987–1993. Variable descriptions are in Table 1.

| Model name | Variables in model |
|---|---|
| Global | Agriculture, hardwood, mature pine, mixed pine–hardwood, sapling, young pine, agriculture density, hardwood density, mature pine density, mixed pine–hardwood density, sapling density, young pine density, shape, edge density, road density, creek density, % thin, % pine thin, % pine mix thin, % burn, % pine burn, % pine mix burn |
| Null | No predictors |
| Landcover[a] | Agriculture, hardwood, mature pine, mixed pine–hardwood, sapling |
| Management | % thin, % pine thin, % pine mix thin, % burn, % pine burn, % pine mix burn |
| Landscape | Agriculture density, hardwood density, mature pine density, mixed pine–hardwood density, sapling density, young pine density, shape, edge density, road density, creek density |
| Landcover + Management | Landcover and land management variables above |
| Landcover + Landscape | Landcover and landscape variables above |
| Landscape + Management | Land management and landscape variables above |
| Individual variables | 22 models for individual variables included in global model |

[a] Young pine excluded from models containing landcover to avoid unit sum constrain.

## RESULTS

We used 535 SAUs (128 individual F) that met our criteria for inclusion in analyses. This included 117 SAUs during autumn–winter ($\bar{x} = 16.7$/yr), 156 SAUs during preincubation ($\bar{x} = 26$/yr), 110 during spring ($\bar{x} = 18.3$/yr), and 152 during summer ($\bar{x} = 25.3$/yr). Number of radiolocations per female averaged 37.9 during autumn–winter (range of 10–108), 26.3 during preincubation (range of 10–69), 16.9 during spring (range of 10–41), and 47.2 during summer (range of 10–168).

For models irrespective of season, the global model ($K = 22$, $AIC_c = 1{,}024.81$, $w_i = 1$) was the best of the 30 a priori candidate models with the second best model ($K = 16$, $AIC_c = 1{,}056.14$, $w_i = 0$) being 31.3 $AIC_c$ units from the global model, suggesting that there was essentially no support for any other model. When we assessed weight of evidence for a season effect given the global model, there was strong evidence for a season effect with the global model containing seasons ($K = 25$, $AIC_c = 1{,}010.24$, $w_i = 1.0$) being 14.7 $AIC_c$ units less than the global model without season. Therefore, we partitioned data into seasons and used the information-theoretic approach to assess seasonal importance of variables. We then used model averaging to develop parameter estimates, 95% confidence intervals for parameter estimates, and odds ratios.

**Table 3.** A priori models, number of variables ($K$), second-order Akaike's Information Criterion ($AIC_c$), distance from the lowest $AIC_c$ ($\Delta AIC_c$) and model weight ($w_i$) for models used to predict presence of seasonal area of use of female wild turkeys in east-central Mississippi, USA, during spring (SP), summer (SU), autumn–winter (FW), and preincubation (PRE), 1987–1993. We present only models with $\Delta AIC_c \leq 10$; we present models in order of likelihood of being the best model within seasons ($w_i$).

| Season[a] | Model | $K$ | $AIC_c$ | $\Delta AIC_c$ | $w_i$[b] |
|---|---|---|---|---|---|
| SP | Landscape + management | 17 | 209.003 | 0 | 0.496 |
| | Global | 22 | 210.806 | 1.803 | 0.201 |
| | Landcover + landscape | 16 | 211.399 | 2.39 | 0.149 |
| | Mature pine | 2 | 212.334 | 3.332 | 0.094 |
| | Landcover + management | 12 | 214.117 | 5.114 | 0.038 |
| | Landcover | 6 | 215.340 | 6.337 | 0.021 |
| SU | Global | 22 | 280.79 | 0 | 0.958 |
| | Landcover + landscape | 16 | 288.164 | 7.36 | 0.024 |
| | Landcover + management | 12 | 288.842 | 8.048 | 0.017 |
| FW | Landcover + landscape | 16 | 231.085 | 0 | 0.837 |
| | Global | 22 | 234.353 | 3.268 | 0.163 |
| PRE | Global | 22 | 276.799 | 0 | 0.992 |

[a] SP: 21 Apr–18 May, SU: 19 May–30 Sep, FW: 1 Oct–28 Feb, and PRE: 1 Mar–20 Apr.

[b] Probability that model is the best of the a priori models.

During spring, there was a 0.496 probability that the landscape and management model was the best model. However, the global, landcover and landscape, percent mature pine, landcover and management, and landcover models were all within 10 $AIC_c$ units of the landscape and management model (Table 3). When we used model averaging to estimate parameters, there were 4 variables (road density, creek density, density of sapling pine, and % young pine) with parameter estimates that differed from zero (Table 4). Parameter estimates and odds ratios suggested a positive relationship between road density, creek density, and sapling density on probability of use by female wild turkeys. Percent young pine was negatively associated with probability of use.

During summer, there was a 0.958 probability that the global model was the best candidate model. However, the landcover and landscape and landcover and management models were both within 10 $AIC_c$ units of the global model (Table 3). When we used model averaging to estimate parameters, there were 3 variables (road density, agriculture density, and % pine burn) with parameter estimates that differed from zero (Table 4). Parameter estimates and odds ratios suggested a positive relationship between each of these variables and probability of use by female wild turkeys.

During autumn–winter, there was a 0.837 probability that the landcover and landscape model was the best of the a priori models, with the global model being the second most likely best model (Table 3). When we used model averaging to estimate parameters, 11 variables (hardwood density, agriculture density, mature pine density, mixed pine–hardwood density, sapling density, road density, agriculture, hardwood, mature pine, percent thin, and percent pine mix thin) had parameter estimates that differed from zero (Table 4). Parameter estimates and odds ratios suggested a positive relationship between each of these variables and probability

**Table 4.** Model-averaged parameter estimates, lower (LCI) and upper (UCI) 95% confidence intervals, and log-odds ratios for variables used in logistic regression models within 10 second-order Akaike's Information Criterion ($AIC_c$) units of the best candidate model predicting seasonal area of use of female wild turkeys in east-central Mississippi, USA, during spring (SP), summer (SU), autumn–winter (FW), and preincubation (PRE), 1987–1993. We include only those variables with parameter estimates that differ from zero.

| Season[a] | Variable | Parameter estimate | LCI | UCI | Odds ratio[b] |
|---|---|---|---|---|---|
| SP | Road density | 0.065 | 0.017 | 0.112 | 1.067 |
| | Creek density | 0.098 | 0.023 | 0.166 | 1.105 |
| | Sapling density | 0.732 | 0.176 | 1.288 | 2.079 |
| | Young pine | −0.027 | −0.049 | −0.004 | 0.973 |
| SU | Road density | 0.059 | 0.008 | 0.109 | 1.061 |
| | Agriculture density | 0.425 | 0.031 | 0.819 | 1.529 |
| | % pine burn | 0.027 | 0.005 | 0.049 | 1.028 |
| FW | Hardwood density | 2.464 | 1.305 | 3.622 | 11.749 |
| | Agriculture density | −2.551 | −3.984 | −1.118 | 0.078 |
| | Mature pine density | −0.869 | −1.608 | −0.132 | 0.419 |
| | Mixed pine–hardwood density | −0.867 | −1.598 | −0.135 | 0.420 |
| | Sapling density | 2.978 | 0.739 | 5.217 | 19.646 |
| | Road density | 0.125 | 0.039 | 0.211 | 1.133 |
| | Agriculture | 0.101 | 0.033 | 0.169 | 1.106 |
| | Hardwood | 0.096 | 0.038 | 0.155 | 1.101 |
| | Mature pine | 0.092 | 0.033 | 0.151 | 1.096 |
| | % thin | −0.212 | −0.381 | −0.044 | 0.809 |
| | % pine mix thin | 0.187 | 0.031 | 0.343 | 1.206 |
| PRE | Road density | 0.0837 | 0.018 | 0.149 | 1.087 |
| | Creek density | 0.165 | 0.094 | 0.235 | 1.18 |
| | Hardwood density | 0.754 | 0.197 | 1.311 | 2.13 |
| | Mature pine density | −0.606 | −1.078 | −0.133 | 0.555 |
| | % thin | −0.076 | −0.145 | −0.007 | 0.927 |
| | % pine burn | 0.0315 | 0.006 | 0.056 | 1.032 |
| | % pine mix thin | 0.0655 | 0.001 | 0.129 | 1.068 |
| | Mature pine | 0.104 | 0.043 | 0.164 | 1.109 |
| | Agriculture | 0.069 | 0.001 | 0.139 | 1.072 |
| | Mixed pine–hardwood | 0.074 | 0.008 | 0.140 | 1.077 |
| | Sapling | 0.094 | 0.008 | 0.179 | 1.098 |
| | Young pine | −0.036 | −0.056 | −0.009 | 0.968 |

[a] SP: 21 Apr–18 May, SU: 19 May–30 Sep, FW: 1 Oct–28 Feb, and PRE: 1 Mar–20 Apr.

[b] Increase in probability of use as a seasonal area of use by F wild turkeys/unit increase in variable.

of use by wild female wild turkeys, with exception of agriculture density, mature pine density, mixed pine–hardwood density, and percent thin, which had a negative relationship with probability of use.

During preincubation, the global model was the best candidate model ($w_i = 0.99$) with no other models coming within 10 $AIC_c$ units of the global model (Table 3). When we used model averaging to estimate parameters, 12 variables (road density, creek density, hardwood density, mature pine density, percent thin, percent pine burn, percent pine mix thin, mature pine, agriculture, mixed pine–hardwood, sapling, and young pine) had parameter estimates that differed from zero (Table 4). Parameter estimates and odds ratios suggested a positive relationship between each of these variables and probability of use by female wild turkeys, with the exception of mature pine density, percent thin, and young pine, which had a negative relationship with probability of use.

## DISCUSSION

Our results confirmed the results of previous, short-term, stand-based habitat selection studies and indicate that female wild turkeys on our study area had consistent habitat use across the 8 years of our study, in spite of annual variations in habitat, weather, and population parameters. Past studies on our area found that during 1987–1990, 16–64% of radiotagged females ($\bar{x} = 42.5\%$/yr ) moved from upland, intensively managed pine forests to the large bottomland hardwood–soybean field complex (Sucarnochee Creek bottom) during the autumn–winter, returning to the intensively managed pine forests during flock breakup in the spring (Stys 1992). This movement was likely associated with differential resource availability (Porter 1977, Exum et al. 1987, Godwin et al. 1996), particularly availability of hard mast in the bottomland hardwood stands and availability of desired nesting and brood habitat in intensively managed pine stands (Smith et al. 1990, Stys et al. 1992, Miller and Conner 2005). Our results for preincubation and autumn–winter models reflected these transitional stages, indicating that female wild turkeys were associated with landscapes characteristic of both hardwood stands with adjacent fields and intensively managed pine stands (Table 4). Also, our models describing habitat composition of SAUs had more variables with nonzero coefficients during preincubation and autumn–winter (11 variables each) than either spring (4) or summer (3). This further indicates the wider range of habitat conditions used by females during these 2 transitional seasons. The positive association with road density in both models was because of high road density within the managed pine matrix (Smith et al. 1990).

Also during preincubation, habitat characteristics of upland stands indicated female wild turkeys were more likely to use areas that contained burned and thinned stands. Past research has indicated female wild turkeys prefer open, herbaceous understory vegetation during preincubation (Phalen et al. 1986, Palmer et al. 1996*b*), conditions available in managed pine stands subjected to thinning and burning. Additionally, female wild turkeys may be sampling potential nesting habitat during preincubation (Badyaev et al. 1996, Miller et al. 1999). Given most nests were located in thinned and burned plantations (Stys et al. 1992; see below) this may also be the case on our study area.

Greater variation in our spring model was probably a result of differences in selectivity among nesting, nonnesting, and brood-rearing female wild turkeys monitored simultaneously during this season. This is reflected in that the probability that the final model was the best of the competing models was only 0.495. On our study area, >90% of nests (1987–1990) were in thinned and burned plantations that were ≥15 years old (Stys et al. 1992), possibly influencing the negative association with young pine. A positive relationship with number of sapling (2–14 yr old) stands and road density may have resulted from the general association of females with plantation habitats during spring.

Importance of creek density during spring was likely due

to habitat preferences of nonnesting females as nests never occurred in hardwood stands or SMZs. Female wild turkeys with broods have been documented using hardwood habitats (Phalen et al. 1986, Exum et al. 1987, Palmer et al. 1996*b*), and some females had broods during our generally defined spring. However, 95% of all broods used managed pine stands on our study area (Smith et al. 1990), making use of SMZs on our area by broods infrequent and probably a minor contribution to our results. But wild turkeys on our study area used SMZs for travel and foraging throughout the year (Burk et al. 1990*a*) and a study in central Mississippi found female wild turkeys associated with hardwood forests during spring (Miller et al. 1999, 2000). Similar to preincubation season, road density was likely an artifact of female wild turkeys being in managed pines during spring but may also have been the result of females and broods foraging along roads. Within heavily forested landscapes, roadsides of gated roads (most common type within our study area) can serve as a surrogate for open habitat and are often used by wild turkeys in intensively managed pine landscapes (Smith et al. 1990, Hurst and Dickson 1992).

During summer, female wild turkeys were positively associated with increased road density, agriculture density, and percent of pine stands that had been burned. This model fits well with what we know of wild turkey ecology during summer. Use of roads was influenced by high density of roads in upland pine stands and because female wild turkeys and broods often foraged along roads (Smith et al. 1990). During summer, females prefer using areas with low, abundant herbaceous vegetation for availability of food and preferred cover (Speake et al. 1975, Hurst 1981, Hurst and Dickson 1992). This is especially true of females with broods (Phalen et al. 1986, Hurst and Dickson 1992, Porter 1992). On our study area, and in similar landscapes, these habitat conditions can be found in fields, thinned and burned pine stands, and SMZs (Smith et al. 1990, Stys et al. 1992). Although wild turkeys on our study area used SMZs throughout the year (Burk et al. 1990*a*), most female observations were associated with plantations (Smith et al. 1990), thus explaining the positive association between female wild turkey use and percent of pine stands burned. Females also used agriculture fields during the summer, as indicated by density of agriculture being an important variable.

We conducted this study on an unreplicated, intensively managed forested landscape. As such, caution should be used when extrapolating these results to other, albeit similar, landscapes. Our study area was dominated by >15-year-old thinned pine stands and contained a relatively high proportion of SMZs, and wild turkeys had access to a large bottomland hardwood complex. Additionally, Weyerhaeuser's standard silvicultural practices include heavy thinnings (approx. 350 trees/ha for first thins and 150 trees/ha for second thins) and low stocking density (approx. 1,000 trees/ha at planting). Such heavy thinnings provide an open canopied forest with abundant herbaceous vegetation (Wilson and Watts 2000, Miller et al. 2004), which is likely conducive to wild turkey habitat.

Hurst (1981) noted that a link between prescribed burning and turkey demographic processes had yet to be quantified. Additionally, the trend in intensively managed forests in the southeastern United States is away from use of prescribed fire and towards increased reliance of herbicides for vegetation management (Haines et al. 2001). Therefore, we suggest that further research on wild turkeys in managed pine landscapes is needed to document magnitude of habitat improvement due to prescribed fire and examine management actions (e.g., thinning, prescribed fire, and herbicide use) within the context of wild turkey use of intensively managed pine landscapes.

## MANAGEMENT IMPLICATIONS

As documented by others (e.g., Smith et al. 1990, Hurst and Dickson 1992, Stys et al. 1992), our long-term data indicate burning improves habitat conditions for female wild turkeys during late winter to early autumn in intensively managed pine landscapes. We suggest implementing a range of fire return intervals, from 3 years to 7 years, may be of greatest benefit to female wild turkeys in intensively managed pine landscapes. Managers should also be aware of the location and availability of seasonally important resources, such as hard mast, when considering wild turkey habitat management on intensively managed pine landscapes.

## ACKNOWLEDGMENTS

This paper is a contribution to the Mississippi Cooperative Wild Turkey Research Project funded by Weyerhaeuser Company, Weyerhaeuser Company Foundation, National Wild Turkey Federation, United States Department of Agriculture Forest Service, Gulf States Paper Company, East Mississippi Sportsmen Association, and the Mississippi Agricultural and Forestry Experiment Station. We thank J. Burk, J. T. Forbes, D. Smith, J. Stys, and M. Weinstein for their efforts as graduate students on this project. The Joseph W. Jones Ecological Research Center provided support for M. Conner during manuscript preparation. Special thanks to G. A. Hurst, B. D. Leopold, and the Forest and Wildlife Research Center at Mississippi State University. M. J. Chamberlain and 2 anonymous reviewers provided valuable comments on an earlier draft of this manuscript.

## LITERATURE CITED

Aebischer, N. J., P. A. Robertson, and R. E. Kenward. 1993. Compositional analysis of habitat use from animal radio-tracking data. Ecology 74: 1313–1325.

Anderson, D. R., K. P. Burnham, and W. L. Thompson. 2000. Null hypothesis testing: problems, prevalence, and an alternative. Journal of Wildlife Management 64:912–923.

Badyaev, A. V., T. E. Martin, and W. J. Etges. 1996. Habitat sampling and habitat selection by female wild turkeys: ecological correlates and reproductive consequences. Auk 113:636–646.

Bailey, R. W. 1976. Live-trapping wild turkeys in North Carolina. North Carolina Wildlife Resources Commission Publication, Raleigh, USA.

Beyer, H. L. 2004. Hawth's analysis tools for ArcGIS. <http://www.spatialecology.com/htools>. Accessed 9 Nov 2006.

Bingham, R. L., and L. A. Brennan. 2004. Comparison of Type I error rates for statistical analyses of resource selection. Journal of Wildlife Management 68:206–212.

Browning, D. M., S. J. Beaupré, and L. Duncan. 2005. Using partitioned Mahalanobus D2(k) to formulate a GIS-based model of timber rattlesnake hibernacula. Journal of Wildlife Management 69:33–44.

Burk, J. D., G. A. Hurst, D. R. Smith, B. D. Leopold, and J. G. Dickson. 1990*a*. Wild turkey use of streamside management zones in loblolly pine plantations. Proceedings of the National Wild Turkey Symposium 6:84–89.

Burk, J. D., D. R. Smith, G. A. Hurst, B. D. Leopold, and M. A. Melchiors. 1990*b*. Wild turkey use of loblolly pine plantations for nesting and brood rearing. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 44:163–170.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference. Second edition. Springer-Verlag, New York, New York, USA.

Cochran, W. W., and R. D. Lord. 1963. A radio-tracking system for wild animals. Journal of Wildlife Management 27:9–24.

Conner, L. M., and I. A. Godbois. 2003. Habitat associated with daytime refugia of fox squirrels in a longleaf pine forest. American Midland Naturalist 150:123–129.

Exum, J. H., J. A. McGlincy, D. W. Speake, J. L. Buckner, and F. M. Stanley. 1987. Ecology of the eastern wild turkey in an intensively managed pine forest in southern Alabama. Tall Timbers Research Station Bulletin 23, Tallahassee, Florida, USA.

Godwin, K. D., G. A. Hurst, and B. D. Leopold. 1996. Size and percent overlap of gobbler home ranges in central Mississippi. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 45:218–226.

Haines, T. K., R. L. Busby, and D. A. Cleaves. 2001. Prescribed burning in the south: trends, purpose, and barriers. Southern Journal of Applied Forestry 25:149–153.

Holbrook, H. T., M. R. Vaughan, and P. T. Bromley. 1985. Wild turkey management on domesticated pine forests. Proceedings of the National Wild Turkey Symposium 5:253–258.

Hosmer, D. W., and S. Lemeshow. 1989. Applied logistic regression. John Wiley and Sons, New York, New York, USA.

Hurst, G. A. 1981. Effects of prescribed burning on the eastern wild turkey. Pages 81–88 *in* G. W. Wood, editor. Prescribed fire and wildlife and wildlife in southern forests. Belle W. Baruch Forest Science Institute, Georgetown, South Carolina, USA.

Hurst, G. A., and J. G. Dickson. 1992. Eastern turkey in Midwestern oak–hickory forests. Pages 265–285 *in* J. Dickson, editor. The wild turkey: biology and management. Stackpole, Harrisburg, Pennsylvania, USA.

Katnik, D. D., and R. B. Wielgus. 2005. Landscape proportions versus Monte Carlo simulated home ranges for estimating habitat availability. Journal of Wildlife Management 69:20–32.

Kennamer, J. E., J. R. Gwaltney, and K. R. Sims. 1980. Habitat preferences of eastern wild turkeys on an area intensively managed for pine in Alabama. Proceedings of the National Wild Turkey Symposium 4:240–245.

Knowlton, F. F., E. D. Michael, and W. C. Glazener. 1964. A marking technique for the field recognition of individual turkeys and deer. Journal of Wildlife Management 28:167–170.

Kuehl, A. K., and W. R. Clark. 2002. Predator activity related to landscape features in northern Iowa. Journal of Wildlife Management 66:1224–1234.

Leopold, B. D., G. A. Hurst, and D. A. Miller. 1996. Long- versus short-term research and effective management: a case study using the wild turkey. North American Wildlife and Natural Resources Conference 61: 477–487.

McGarigal, K., and B. J. Marks. 1995. FRAGSTATS: spatial pattern analysis program for quantifying landscape structure. U.S. Forest Service General Technical Report PNW-351, Portland, Oregon, USA.

Miller, D. A., M. J. Chamberlain, B. D. Leopold, and G. A. Hurst. 2001. Lessons from Tallahala: what have we learned for turkey management into the 21st Century? Proceedings of the National Wild Turkey Symposium 8:23–33.

Miller, D. A., and L. M. Conner. 2005. Seasonal and annual home ranges of eastern wild turkey hens in a managed pine landscape in Mississippi. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 59:89–99.

Miller, D. A., G. A. Hurst, and B. D. Leopold. 1999. Habitat use of eastern wild turkeys in central Mississippi. Journal of Wildlife Management 63:210–222.

Miller, D. A., B. D. Leopold, and G. A. Hurst. 1997. Seasonal home ranges of wild turkeys in central Mississippi. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 51:414–425.

Miller, D. A., B. D. Leopold, G. A. Hurst, and P. D. Gerard. 2000. Habitat selection models for eastern wild turkeys in central Mississippi. Journal of Wildlife Management 64:765–776.

Miller, D. A., R. E. Thill, M. A. Melchiors, T. B. Wigley, and P. A. Tappe. 2004. Small mammal communities of streamside management zones in intensively managed pine forests of Arkansas. Forest Ecology and Management 203:381–393.

Miller, D. A., M. Weinstein, S. R. Priest, B. D. Leopold, and G. A. Hurst. 1995. Wild turkey reproductive parameters from two different forest ecosystems in central Mississippi. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 49:466–475.

Miller, K. V., and J. H. Miller. 2004. Forestry herbicide influences on biodiversity and wildlife habitat in southern forests. Wildlife Society Bulletin 32:1049–1060.

Mohr, C. O. 1947. Table of equivalent populations of North American small mammals. American Midland Naturalist 37:223–249.

Mosby, H. S. 1975. The status of the wild turkey in 1974. Proceedings of the National Wild Turkey Symposium 3:22–26.

National Commission on Science for Sustainable Forestry. 2005. Global Markets Forum: summary report of the National Commission on Science for Sustainable Forestry. <http://www.ncseonline.org/NCSSF/>. Accessed 30 Jan 2006.

Palmer, W. E., G. A. Hurst, K. D. Godwin, and D. A. Miller. 1996*a*. Effects of prescribed burning on wild turkeys. Transactions of the North American Wildlife and Natural Resources Conference 61:228–236.

Palmer, W. E., G. A. Hurst, and B. D. Leopold. 1996*b*. Preincubation habitat use by wild turkey hens in central Mississippi. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 50:417–427.

Pettry, D. E. 1977. Soil resource areas of Mississippi. Mississippi Agricultural and Forestry Experiment Station Information Sheet 1278, Mississippi State, USA.

Phalen, P. S., G. A. Hurst, and W. J. Hamrick. 1986. Brood habitat use and preference by wild turkeys in central Mississippi. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Resources 40:397–404.

Porter, W. F. 1977. Utilization of agricultural habitats by wild turkeys in southeastern Minnesota. Dissertation, University of Minnesota, Minneapolis, USA.

Porter, W. F. 1992. Habitat requirements. Pages 202–213 *in* J. Dickson, editor. The wild turkey: biology and management. Stackpole, Harrisburg, Pennsylvania, USA.

Smith, D. R., G. A. Hurst, J. D. Burk, B. D. Leopold, and M. A. Melchiors. 1990. Use of loblolly pine plantations by wild turkey hens in east-central Mississippi. Proceedings of the National Wild Turkey Symposium 6:61–66.

Smith, W. P., and R. D. Teitelbaum. 1986. Habitat use by eastern wild turkey hens in southeastern Louisiana. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 40:405–415.

Speake, D. W., T. E. Lynch, W. J. Fleming, G. A. Wright, and W. J. Hamrick. 1975. Habitat use and seasonal movements of wild turkeys in the Southeast. Proceedings of the National Wild Turkey Symposium 3: 122–130.

Stys, J. E. 1992. Vegetative characteristics of wild turkey hen use of control-burned loblolly pine plantations. Thesis, Mississippi State University, Mississippi State, USA.

Stys, J. E., G. A. Hurst, B. D. Leopold, and M. A. Melchiors. 1992. Wild turkey use of control-burned loblolly pine plantations. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 46:37–45.

Tapley, J. L., W. H. Healy, R. K. Abernathy, and J. E. Kennamer. 2001. Status of wild turkey hunting in North America. Proceedings of the National Wild Turkey Symposium 8:257–268.

Thomas, D. L., and E. J. Taylor. 1990. Study designs and tests for comparing resource use and availability. Journal of Wildlife Management 54:322–330.

Wear, D. N., and J. G. Greis. 2002. Southern forest resource assessment: summary report. U.S. Forest Service General Technical Report SRS-54, Asheville, North Carolina, USA.

Weinstein, M. D. 1994. Experimental designs for estimating wild turkey population size and reproduction using bait site counts and radiotelemetry. Thesis, Mississippi State University, Mississippi State, USA.

Weinstein, M. D., B. D. Leopold, and G. A. Hurst. 1995. Evaluation of wild turkey population estimation methods. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 49:476–487.

Welsh, H. H., and A. J. Lind. 2002. Multiscale habitat relationships of stream amphibians in the Klamath–Siskiyou region of California and Oregon. Journal of Wildlife Management 66:581–602.

Williams, L. E., Jr., and D. H. Austin. 1988. Studies of the wild turkey in Florida. Florida Game and Freshwater Fish Commission, Technical Bulletin 10, Gainesville, USA.

Wilson, M. D., and B. D. Watts. 2000. Breeding bird communities in pine plantations on the coastal plain of North Carolina. Chat 64:1–14.

*Associate Editor: Morrison.*