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Wild Turkey habitat use in frequently-burned pine savanna

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ABSTRACT

Managing pine (*Pinus* spp.) savanna through frequent use of prescribed fire and selective harvest of off-site hardwoods in the uplands is appropriate for many declining wildlife species, but may be incompatible with published recommendations for wild turkeys (*Meleagris gallopavo*). Therefore, we investigated breeding season habitat use of radio-tagged wild turkeys ($n = 78$) in a frequently burned pine savanna system in southwest Georgia during 2003–2005. Ground story vegetation structure and composition in pine savannas change rapidly following fire such that categorical (i.e., burned vs. unburned) habitat selection analyses does not depict the fine scaled time-dependent relationships; therefore, we analyzed turkey selection of savanna on a seasonal and continuous scale. From a seasonal standpoint, pine savanna habitat-type were selected by gobblers, but used less than availability by hens. However, selection of pine savanna was influenced by time since fire; hens more likely selected pine savannas burned within 1.4 years whereas gobblers selected pine savannas burned within 1.6 years. Hens also selected hardwood drains whereas gobblers demonstrated proportional use of these habitats. Selection of pine savannas by wild turkeys was dependent on application of prescribed burning <2 years and suggests that previous recommendations for longer burning frequencies are too long to balance turkey habitat needs with those of a suite of declining birds associated with pine savanna ecosystems.

1. Introduction

Numerous habitat use studies have been conducted for the wild turkey (*Meleagris gallopavo*) in almost every part of its distribution (Dickson et al., 1992). However, few studies have investigated habitat use of turkeys on landscapes dominated by pyro-climax pine (*Pinus* spp.) savanna (Sisson et al., 1991). These habitat types are important for many grassland-species of wildlife such as northern bobwhite (hereafter, bobwhite; [*Colinus virginianus*]), Bachman's sparrow (*Aimophila aestivalis*), gopher tortoise (*Gopherus polyphemus*), Henslow's sparrows (*Ammodramus henslowii*), loggerhead shrikes (*Lanius ludovicianus*), among others, which collectively have been declining due to habitat loss (Engstrom et al., 1984; Brennan et al., 1998). In the Southeastern U.S., pine and oak (*Quercus* spp.) savanna were historically a common land cover type maintained by frequent natural and anthropogenic sources of fire (Pyne, 1982; Frost, 1998). Today, approximately 500,000 ha of pine savanna exist on private lands managed for wildlife, principally bobwhites and savanna endemics (Moser et al., 2002), but also wild turkeys. Further, there has been increased attention given to restoration efforts for savannas on public lands such that millions of hectares are being treated with shorter fire frequencies than when fuel reduction was the management goal (e.g., Kabrick et al., 2007; Hedrick, 2007). As such, there is a growing need to understand how wildlife species respond to fire frequency.

Pine savannas, in which there is partial tree canopy and generally a grass-dominated ground cover, have by definition relatively low pine volumes relative to commercially-grown forests (Platt, 1999). On private lands managed for bobwhite, managers typically discourage hardwoods in pine dominated uplands to improve ground cover vigor through reduced water competition and shade suppression, and to support the flammability of the ground cover for prescribed burning (Masters et al., 2007). Management for some pine savanna birds and the appropriate herbaceous-shrub community is maintained through the application of fire on a 1–3 year frequency (Frost, 1998; Huffman, 2006; Glitzenstein et al., 2008, 2012). Conversely, wild turkeys use mast from hardwood tree species, and recommended burning return intervals in upland pine forests for turkeys range from 3 to 5 years in mature pine forests (Stoddard, 1963; Miller et al., 2000) and 3–7 years in commercial pine stands (Miller and Conner, 2007). Longer burn intervals were recommended to develop habitat structure, encourage soft mast from the shrub community, and to provide cover for concealment from predators (Stoddard, 1963; Speake et al., 1975).

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However, food resources may be a secondary concern relative to other key resources.

Prescribed fire frequency is the most important fire characteristic that drives succession in plant communities in pine savanna (Glitzenstein et al., 2003, 2008, 2012). Except on xeric sand hill sites, fire frequencies <3 years are typically needed to sustain herbaceous-dominated groundstories and avoid a shift to a shrub-sapling dominated ground-stories (Gliztzenstein et al., 2008) which can lower the suitability of stands for the target plant and wildlife species (Brennan et al., 1998). This is especially evident on sites in which native ground cover communities (e.g., wiregrass [*Aristida* spp.]) have been replaced by old field species. Recommendations for longer fire-return-intervals for wild turkeys imply there is a conflict in management for turkeys and pine savanna dependent and declining wildlife species. Therefore, we assessed habitat use of wild turkeys in relation to prescribed time-since-fire (i.e., a surrogate for fire frequency) on areas managed to sustain pine savanna habitats. We first conducted a classical habitat use analysis to determine selection of 6 major habitat types associated with the pine savanna system. Second, we determined the relationship in both female (hereafter, hen) and male (hereafter, gobbler) wild turkey use of savanna habitats relative to the time-since-fire.

2. Materials and methods

2.1. Study area

This study was 6100 ha and was located on 7 contiguous private properties located in Grady and Thomas counties, Georgia. However, the core study area was located on Pebble Hill Plantation (30°46′22″N,84°5′35″W) which was managed by Tall Timbers Research Station staff and maintained long-term burn records. These properties are located in a region that has approximately 150,000 ha of land managed for wild bobwhites and their harvest. All study areas were primarily comprised of mature upland pine forests dominated by loblolly (*Pinus taeda*), slash (*Pinus elliotti*) and shortleaf pine (*Pinus echinata*) with associated "old-field" ground cover vegetation dominated by bluestem grasses (*Andropogon* spp. [Carr et al., 2010]).

2.2. Field methods

Burn records for other properties were gathered from managers at each site and through monthly inspection of sites during the study. In general, pine and mixed savannas were managed with a 1–3 year fire-return-interval. Burns were conducted March through May in patches from 10 to 50 ha. Burns were allowed to burn into bottomland hardwood forests, swamps and hardwood drains that bisected the study area. Habitat types on the study area were delineated from high resolution satellite imagery (i.e., QuickBird) using ArcView® v3.2 (Environmental Systems Research Institute, 1999). We digitized habitat polygons from infrared reflectance imagery at a scale of 1:2500 in the following categories: open, swamp, hardwood drain, roads, pine savanna, planted pine, mixed savanna, and mixed forest. Infrared reflectance in the imagery allowed for distinguishing between coniferous and deciduous vegetation as well as bare ground, grasses, and water. The imagery's high resolution enabled differentiation of overstory (trees) from understory (shrubs) vegetation, which allowed us to categorize forest stands as high-density or low-density. Habitats delineated as swamps were those that held water for the majority of the year and had vegetation indicative of this habitat type (*Taxodium distichum*, *Nyssa sylvatica*, *Nyssa aquatica*, *Cephalanthus occidentalis*, etc.). The hardwood drain habitats were those that had approximately 75% or more of the overstory in deciduous trees. The majority of these areas were bottomland hardwood type forests and a small acreage of associated upland hardwood stands. Likewise, pine savanna and planted pine habitat types each had >75% of their overstory vegetation in pines. Habitats categorized as mixed hardwood-pine savanna and forest were those forested areas that had a mixture of both pine and hardwood trees, and did not fit into the previous hardwood or pine categories. Mixed forest overstories were those with >65% canopy closure and whereas pine and mixed savannas were defined as those with 10–65% canopy closure. Areas with <10% canopy closure were lumped into the "open" category along with pastures, agricultural fields, wildlife food plots, and fallow fields – all of which had similar ground cover conditions on our study area.

We captured wild turkeys during the winter months during 2003–2005 using 3- and 4-projectile rocket nets (Bailey et al., 1980). The rocket net sites were baited with cracked corn, wheat, oats, sorghum, sunflower, or mixes of 2 or more seed types. Upon capture, turkeys were sexed, aged (Pelham and Dickson, 1992) and banded, and fitted with radio transmitters. We fitted turkeys with backpack-style radio transmitters (Advanced Telemetry Systems, Isanti, MN) operating in the 150–151 MHz range with an 8 h mortality delay (i.e., emits a different tone once the animal does not move for 8 h) and 1000 day battery life using elastic bungee harnesses.

We located turkeys using triangulation telemetry techniques (White and Garrott, 1990) and direct observation. We used 138 fixed and roving stations to conduct triangulation telemetry and at least three bearings were taken and recorded for each location. We collected coordinates of roving stations using Global Positioning System (GPS). Telemetry was accomplished using a hand-held, 3-element yagi antenna and Telonics TR-2, Advanced Telemetry Systems R2000, and Wildlife Materials International TRX-2000S telemetry receivers. Additionally, a null-peak system with dual, 7-element yagi antennas mounted on an all-terrain utility vehicle was used in 2004 and 2005 to improve telemetry accuracy. Estimations of locations were calculated by using the triangulation program DogTrac™ (Foresters Inc., Blacksburg, VA). For locations via triangulation, we required azimuths to form angles from 60° to 120°.

The telemetry program LOAS v.3.0.4 (Ecological Software Solutions, 1999) was used to calculate bearing errors for each test bearing. We used *t*-test procedures in SAS (SAS Institute Inc. 2004) to calculate mean bearing errors for our two observers. Telemetry accuracy was also evaluated by using ArcView v.3.2 (Environmental Systems Research Institute, 1999) to calculate distances between the actual location of test transmitters and their estimated location. These "error distances" were used to compute mean error distances and were tested for differences between observers using a t-test in SAS. The mean error distances were used to extrapolate to a mean error area by using the mean error distance as the radius in the $A = \pi r^2$ formula. This allowed visualization of telemetry error in terms of land area.

We assessed cover type classification accuracy by using test transmitters and a blind observer to compare the cover type at the actual transmitter location to the cover type at the estimated transmitter location. This comparison was accomplished using a cover type map in ArcView® v.3.2, and the end result was the percentage of test telemetry locations that were correctly classified.

We examined breeding season habitat selection for gobblers and hens (March 1–October 14), which encompassed mate selection, nesting, and brooding. We constructed 95% fixed kernel home ranges using Hawth's tools (Beyer, 2004) in ArcGIS® v9.1 (Environmental Systems Research Institute, 2004) from turkey locations within each season described above. The minimum number of locations required to build a seasonal home range was set at 10 which was based on the relationship between home range size and number of locations.

The Adehabit package (Calenge, 2006) in *R* was used to perform compositional analysis based on a MANOVA according to Aebischer et al. (1993). This program performs a simultaneous analyses of habitats to determine if habitat use is nonrandom at the $\alpha = 0.05$ level. We used compositional analysis to investigate habitat selection at Johnson's 2nd (home range) to and 3rd orders (use within home range; Johnson, 1980). In order to determine the "available" habitat area for the 2nd order selection, ArcView® v3.2 was used to create a 100% minimum convex polygon (MCP) around all turkey locations (see Mohr (1947) for more info on MCP). This "available" MCP was then buffered by 750 m to encompass the largest area allowed by the land cover imagery. The Animal Movements extension (Hooge and Eichenlaub, 1997) and XTools (DeLaune, 2003) were used within ArcView® v3.2 to calculate the percentage of each habitat type within the study area and within each home range. The composition of home range was used for the "use" habitat in the 2nd order selection analysis; whereas an MCP around all our telemetry locations defined availability for all animals. The home range was used as the "available" habitat to examine the 3rd order selection. The "use" habitat for each home range in the 3rd order selection was defined as the percentage of turkey locations within each habitat type in that home range.

2.3. Habitat use in relation to prescribed fire

We selected a subsample of telemetry locations that included all locations in pine savannas to explain habitat use for gobblers and hens during the growing season (March 1–October 14). We intersected locations by the total extent that was burned within pine savanna during our study. A buffer was placed around each used location to serve as the available habitat, 331 m radius for hens and 540 m radius for gobblers. The radius of the buffer was determined from a daily movement dataset by calculating average daily movements. Within each buffer, 30 random points were generated and intersected with the GIS map using ArcGIS. The points were spatially joined to the fire history data. A days-since-fire value was calculated for each use and random location (the random locations received the same date as the paired use location) by subtracting the day the location was taken from the day the fire occurred for that patch. Therefore, our response variable was a continuous variable, days-since-fire, for both used locations and random locations.

We avoided the use of classical statistical significant tests, because of our arbitrarily large sample sizes for the random locations (Dunkin et al., 2009). Instead, we used continuous selection functions to describe wild turkey use in relation to prescribed fire similar to the methods described by Kopp et al. (1998). We constructed cumulative distribution functions (CDF) using the mean and standard deviation for days-since-fire values for both used $f(x)$ and random locations $g(x)$ using a truncated normal distribution. The CDFs were scaled and differentiated to produce probability distributions (PDF). A continuous selection function similar to Manly's selection ratio (Guthery, 1997; Manly et al., 1993) was calculated by dividing the used PDF by the random PDF, where

$$u(x) = f(x)/g(x), \quad g(x) > 0$$

where $u(x) > 1$ indicates selection, $u(x) < 1$ indicates avoidance, and $u(x) = 1$ signifies use proportional to availability.

We pooled data from all three years together for each sex for this analysis.

3. Results

A total of 3074 telemetry locations were recorded and used in breeding season home range construction including 62 hens and 16 gobblers. When the cover type at actual test transmitter locations was compared to that of estimated test transmitter locations, the two were in agreement in 59 out of 80 test locations for a cover type classification accuracy rate of 74%. For all data combined, turkeys were most often found in hardwood drains, low-density pine stands, and high density pine stands (Table 1).

Compositional analysis (Aebischer et al., 1993) demonstrated that home range selection by turkey was non-random within the study area (breeding hen: Wilks' $\Lambda = 0.12$, $P = 0.0002$; breeding gobbler: Wilks' $\Lambda = 0.13$, $P = 0.002$). Hens selected home ranges with hardwood drains, and associated mixed savanna and mixed forest habitats (Fig. 1a). Pine savanna was used less than they were available for hen home ranges. Gobblers selected home ranges with pine savanna and mixed savanna habitats and used hardwood drains in proportion to their availability. Gobblers used openings, and pine and mixed forests less than they were available when selecting home ranges (Fig. 1b).

Habitat use within home ranges was non-random for both gobblers (Wilks' $\Lambda = 0.30$, $P = 0.01$) and hens (Wilks's Λ 0.41, $P = 0.002$) as determined using compositional analysis (Aebischer et al., 1993). Within their home ranges, hens selected hardwood drains and avoided pine savannas (Fig. 1a). Hens used all habitats in proportion to their availability (Fig. 1b).

Fire interval influenced turkey use of pine savanna landscapes with greater use sooner after fire than expected relative to random locations. Hens used pine savanna habitats an average of 247 days after fire ($n = 273$, SD = 252.78) whereas random locations were found on average 543 days after fire ($n = 5857$, SD = 406.22; Fig. 2a,b). Gobblers used pine savanna habitat 328 days after fire ($n = 119$, SD = 310.63) whereas random locations were located in patches 430 days after fire ($n = 1534$, SD = 408.34). Based on the $u(x)$ function, hens selected habitat patches that were less than 500 days-since-fire and gobblers selected patches that were less than 600-since-fire (Fig. 3).

4. Discussion

As has been reported in numerous studies, turkey habitat use in pine savanna ecosystems of the Southeast was not random. In the managed ecosystems we studied, a key management tool was fire and it appears that fire frequency impacts habitat use. Even at 2–3 year fire frequencies, turkey selection of pine savannas was sensitive to the time since the last prescribed fire. Both hens and gobblers used savannas that had been burned ca. 18 months and began avoiding stands that had not been burned in the past 2 years. Palmer et al. (1996b) found that hens in a mature pine forest system in Mississippi preferred areas burned that spring and used stands burned within 1–2 years to availability and avoided stands not burned for over 2 years. In open pine savanna, ground

Table 1
Study site land area (ha), turkey telemetry locations and observed turkey nests by overstory cover type, Grady and Thomas Counties, Georgia, 2003–2005.

Habitat	Locations							
	Land area		Hens		Gobblers		Nests	
	Ha	%	*n*	%	*n*	%	*n*	%
Hardwood drain	1510	24.8	758	31	126	19	0	0.0
Planted pine	840	13.8	269	11	40	06	7	31.8
Pine savanna	2389	39.2	536	22	220	34	10	45.5
Mixed forest	316	5.2	141	6	20	3	0	0.0
Mixed savanna	180	2.9	536	22	220	34	2	9.1
Open	647	10.6	137	6	20	3	3	13.6
Swamp	144	2.4	44	2	3	0	0	0.0
Road	69	1.1	4	0	0	0	0	0.0
Total	6095	100	2425	100	649	100	22	100

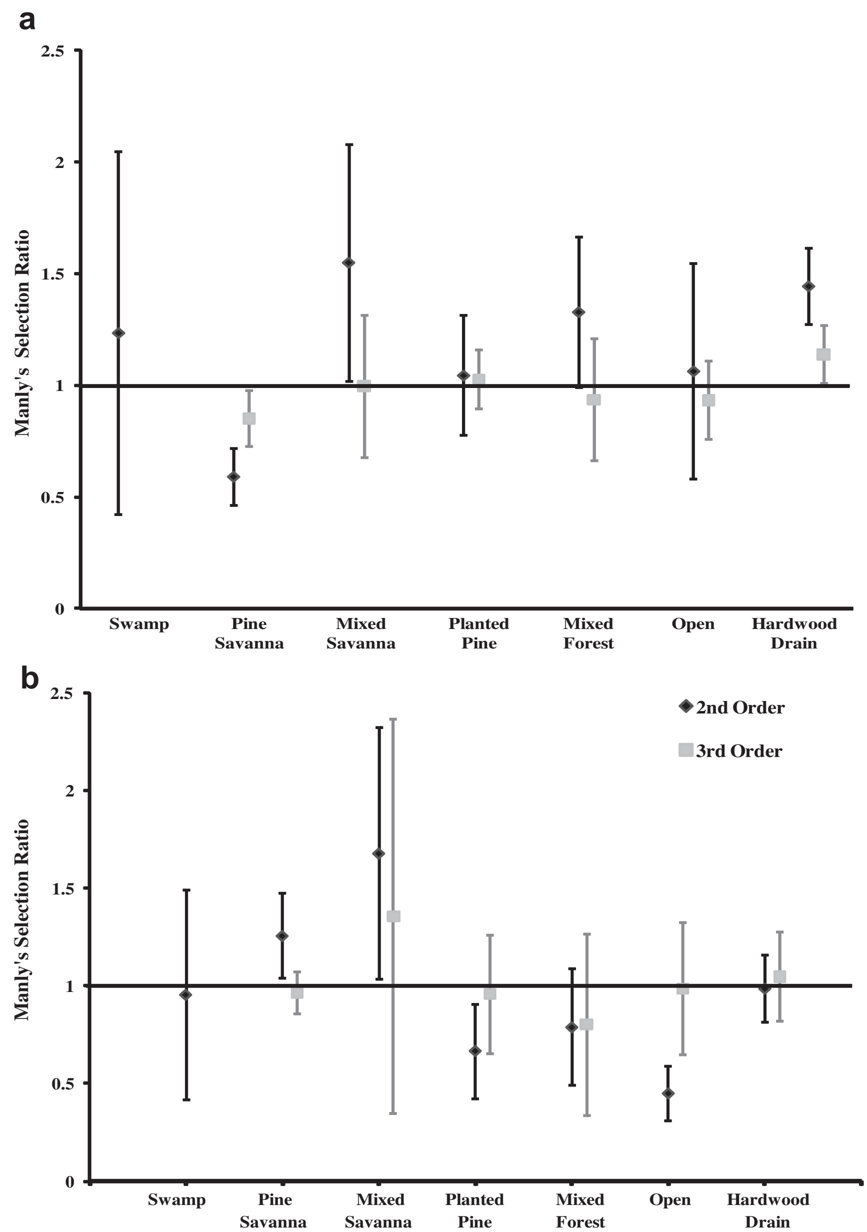

Fig. 1. Manley's selection ratio for Johnson's (1980) 2nd and 3rd order selection of 7 habitats by hen (a) and gobbler and (b) wild turkeys in pine savannas on private hunting lands near Tallahassee, FL, USA.

story conditions change weekly post-fire. Turkeys used burned stands almost immediately after a fire and we suspect they were foraging on food sources made available following the removal of the standing ground vegetation. For weeks following fire turkeys continued to use stands possibly foraging on nutritious young vegetation sprouting after the fire, as well as insects (Kennamer et al., 1980; Smith et al., 1990; Godfrey and Norman, 1999). At some point, the ability for hens to find food resources may decline as ground story vegetation becomes too rank to forage effectively; on our study areas about 500 days post-fire. Unlike hens, gobblers selected for pine savannas and had a broader tolerance for fire return interval than hens as indicated by the flatter frequency distribution. In Mississippi, gobblers selected mature pine stands during summer and used stands burned <2 years according to availability and older burns less than they were available (Godwin et al., 1992). We suspect that differences in the life history and physical stature of gobblers and hens, including differing risk to specific predators, may play a role in habitat use differences.

Many studies have recommended longer burn intervals for turkey management in pine forests. Stoddard (1963) recommended fire frequencies of 3–5 years on areas managed for wild turkeys. In Mississippi, Miller et al. (2000) recommended burning rotations of 3 to 4 years for wild turkeys in mature pine forests. In densely planted commercial pine stands, Miller and Conner (2007) recommended 3–7 year fire frequencies to improve habitat conditions for turkeys. Speake (1975) recommended 2–4 year burn rotations to ensure some soft fruit production for turkeys. Longer fire intervals may suffice in intensively planted pine plantations or in pine forests where denser canopies limit the amount of ground cover. However, in pine savanna habitats, longer burn intervals would not only reduce habitat for turkeys in the short-term, but threaten sustaining the pine savanna system. If fire frequency is not maintained at 1–3 years, the groundstory plant community begins to shift from a herbaceous grass/forb-dominated community to a hardwood-shrub-sapling community (Glitzenstein et al., 2008, 2012), and as such, the suitability of the habitat for turkeys and

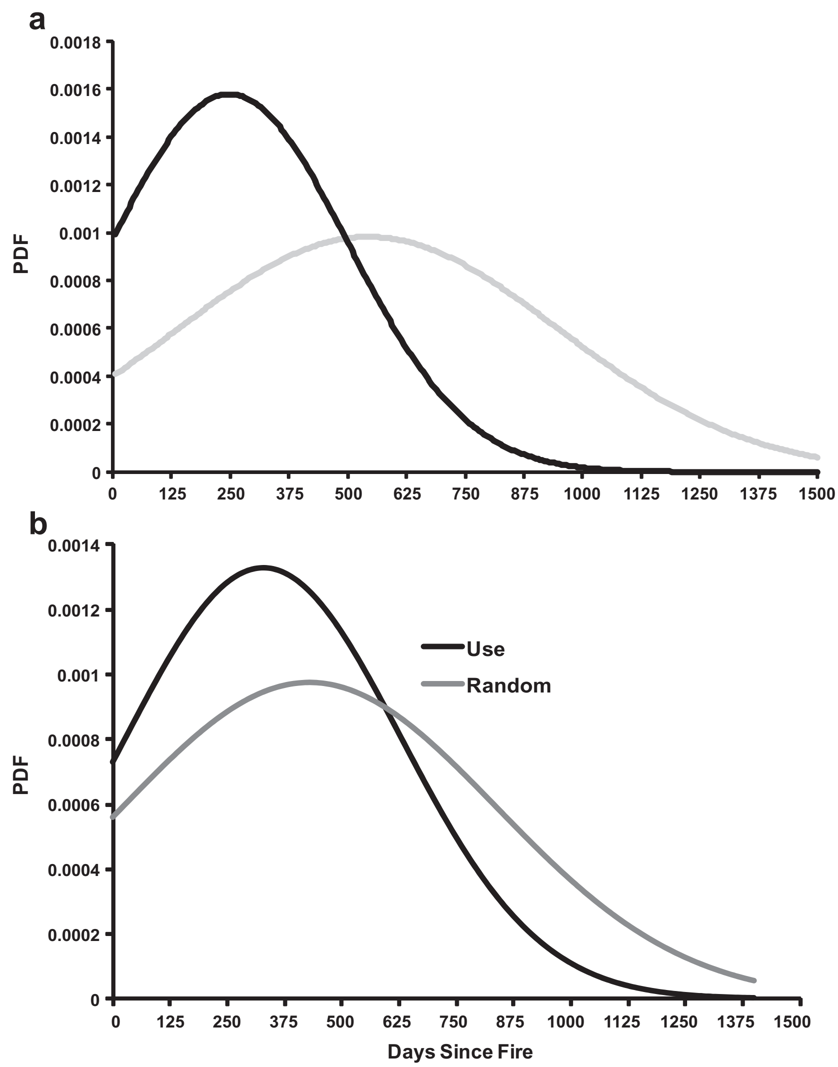

Fig. 2. Probability distribution function (PDF) for random versus used locations following fire in pine savanna habitats by hen (a) and gobbler and (b) wild turkeys.

other wildlife is reduced (Palmer et al., 1996a; Brennan et al., 1998). Even when fires occur on a more frequent basis, it is rare that coverage of fires are complete, such that the argument that longer burning regimes are needed to produce soft mast is likely oversimplified.

Why then have so many studies recommended longer burn intervals for turkeys? Plant communities are a function of the long-term fire regime, with frequency being an important variable in pine systems for sustaining a diverse herbaceous community (Platt, 1999; Huffman, 2006; Glitzenstein, 2012). We suspect that weak evidence for turkey selection for burned stands in some studies may be a reflection of the long-term burning (or lack thereof) regime and its effects on the groundstory plant community (Miller et al., 1999, 2000). In previous studies on wild turkey habitat use in pine forests (Exum et al., 1987; Palmer et al., 1996b; Miller et al., 2000; Miller and Conner, 2007; Palmer and Hurst, 1998), fire intervals were too long (3–7 years) to sustain a grass/forb-dominated ground cover rather than a hardwood-shrub community. Longer burn regimes and shrub-sapling groundstory communities likely reduced the overall suitability of pine forests and savannas for wild turkeys; Palmer et al. (1996b) found that hen's selected for grass-forb dominated ground cover communities versus woody-vine ground cover. Further, longer burn interval regimes may limit the difference in habitat suitability among burn classes (e.g., 0, 1, 2, etc. years post-fire) because changes to the vegetation are primarily to the stature of a less suitable hardwood-shrub community. For example, a resprouting herbaceous groundstory community found in a frequent fire savanna likely provides more nutritious forage for turkeys than resprouting perennial shrub communities found in longer-burn rotations. Therefore, our current study provides an important exception to studies conducted on landscapes with longer burn intervals and demonstrates how important recent burns are for turkeys and how ephemeral their habitat selection is in pine savannas. Other species also show dramatic differences in selection across fire return intervals, such that in some systems a matter of months can influence habitat selection (Brennan et al., 1998; Widener and Cox, 2008).

Turkeys used savanna habitats, open areas and planted pines for nesting. Other studies have identified the importance of unburned "roughs" for nesting sites (Sisson et al., 1991). On our study areas, patch burning at small fire sizes (<50 ha) provided each turkey with habitat use options, from recent burns to older roughs. The value of the diversity of habitats provided by patchy burns has not been adequately studied for most wildlife species, including turkeys, yet fire scale (size and extent), as well as season and frequency, define a fire regime on a landscape. Additional research

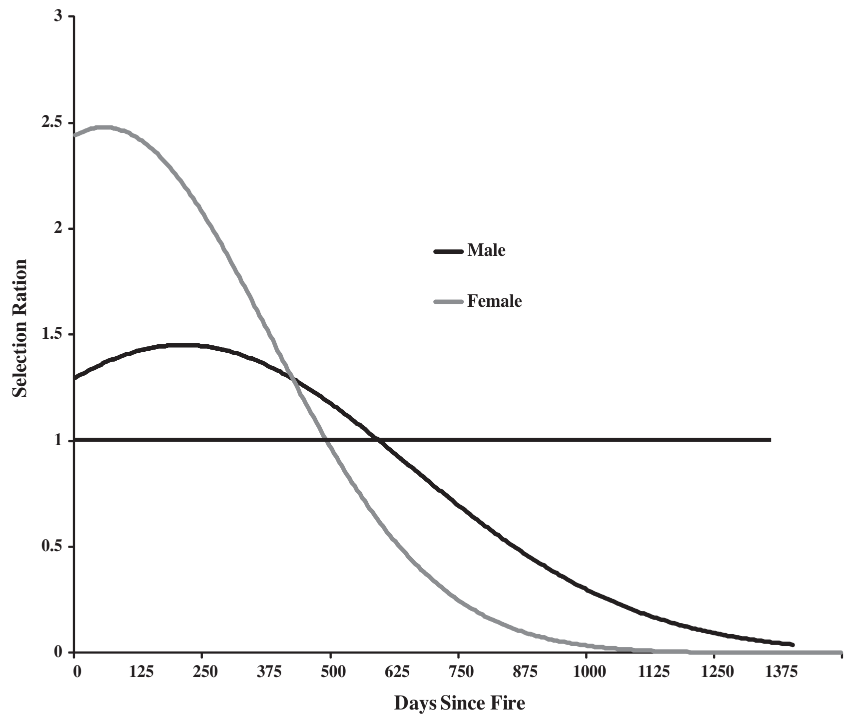

Fig. 3. Manley's selection ratio for continuous days-since-fire habitat by hen and gobbler turkeys in pine savannas on private hunting lands near Tallahassee, FL, USA.

is needed on how turkeys respond to higher burn frequencies when scales (both in grain and extent) of fire are larger, such as commonly applied on large public landscapes.

Hen home ranges included hardwood drains more than were available and hens also selected this habitat within their home ranges. Drains provided travel corridors, and likely a diversity of food resources and reduced exposure to solar radiation. Almost all drainage systems on the properties were associated with managed uplands, therefore, juxtaposed with other important habitat types. Studies in Mississippi have also shown the importance of hardwood drains to hen turkeys, especially in locations where this habitat type is reduced or the surrounding habitat is poor (Phalen and Hurst, 1993; Burke et al., 1990; Palmer and Hurst, 1995; Miller et al., 1999). Drains were also important for roosting habitat (Chamberlain et al., 2000) increasing the chances our telemetry data found turkeys in this habitat with movements to and from the roost.

Management of hardwood drains on our study areas likely contributed to their selection by turkey hens. Hardwood drains were for the most part protected from timber harvest to maintain a mature overstory, but these forests were not protected from prescribed fire. Fires used to manage upland pine savanna were allowed to burn into drains on a regular basis and particularly during droughty periods when fuel moistures were such that low-intensity fires sweep throughout bottomlands. Fire was once a natural disturbance in southeastern lowlands and an important force shaping plant communities in bottomland forests (Komarek, 1974; Gagnan, 2008). Fire management as applied on our study areas helped to maintain hardwood drains and bottomlands in an open "park-like" condition with an herbaceous-dominated groundstory preferred by turkeys (Burke et al., 1990).

Open habitats were ranked last or next-to-last in nearly all seasons. Although many studies have emphasized the value of well dispersed openings (Speake et al., 1975; Healy, 1985), turkeys on this study site may have had their need for open areas met in the abundance of frequently-burned pine and mixed pine-hardwood savanna. Miller et al. (1999) previously noted that turkeys may not use openings when mature pine forests provide a diversity of food resources and the appropriate vegetation structure for turkeys. It is also possible that the small size of some fields on this study site made it more difficult to correctly categorize turkey locations within these small openings. No hens tracked during this study were known to be rearing broods. Peoples et al. (1995) and Sisson et al. (1991) have previously documented the importance of fields and openings for brood rearing purposes in this area. Within many of the forested stands bobwhite management activities such as frequent prescribed fire, roller-drum chopping, mowing, and herbicide use allow grasses, forbs, and young shrubs to dominate the understory. This, perhaps, provides similar vegetative conditions found in 2- or 3-year fallow fields or openings (Swanson et al., 1995). Zwank et al. (1988) reported that hens in Louisiana used fallow fields and wheat fields less following a 47% basal area reduction of timber in surrounding forests, citing increases in diversity and cover of understory vegetation as a major factor.

5. Conclusions

The inherent nature of southeastern coastal plain landscape provides hardwood drains or similar features in most management units negating the need to purposely create such features. Data is lacking on the expected outcomes of wild turkey populations if these features were absent. The wild turkey population under study was thriving under current management conditions and hunting pressure. Ostensibly, the combination of frequently burned uplands and available hardwood drains is an appropriate landscape for wild turkeys.

This study demonstrates that fire regimes developed to restore or sustain pine savanna habitats are within the suitable bounds for wild turkeys. Longer burn intervals which threaten the diverse composition of pine savannas are not necessary to encompass habitat needs of wild turkeys. We would argue that turkeys evolved with the pine savanna ecosystem which likely burned every 1–3 years and are suited to a management style designed to maintain pine savanna as the climax vegetation community. Hen and gobbler avoidance of older burns, except for nesting by hens, suggest that longer burn rotations would be unsuitable turkeys as well as many declining wildlife and plant species. In addition, extending fire return intervals past 3 years over much of the historic pine savanna range would reduce the effectives of fire itself as a tool to manage these systems.

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References

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

Bailey, W., Dennett, D., Gore, H., Pack, J., Simpson, R., Wright, G., 1980. Basic considerations and general recommendations for trapping the wild turkey. Proc. Natl. Wild Turkey Symp. 4, 10–23.

Beyer, H.L., 2004. Hawth's Analysis Tools for ArcGIS®. <http://www.spatialecology.com/htools>.

Brennan, L.A., Engstrom, R.T., Palmer, W.E., Herman, S.M., Hurst, G.A.L., Burger, W., Hardy, C.L., 1998. Whither wildlife without fire? Trans. North Am. Wild Natl. Res. Con. 63, 402–414.

Burke, J.D., Hurst, G.A., Smith, G.R., Leopold, B.D., Dickson, J.G., 1990. Wild turkey use of streamside management zones in loblolly pine plantations. Proc. Natl. Wild Turkey Symp. 6, 84–89.

Calenge, C., 2006. The package "adehabitat" for the R software: a tool for the analysis of space and habitat use by animals. Ecol. Model 197, 516–519.

Carr, S.C., Robertson, K.M., Peet, R.K., 2010. A vegetation classification of fire-dependent Pinelands of Florida. Castanea 75, 153–189.

Chamberlin, M.J., Leopold, B.D., Burger, L.W., 2000. Characteristics of roost sites of adult wild Turkey females. J. Wildlife Manage. 64, 1025–1032.

DeLaune, M.G., 2003. Guide to XTools Extension. Version September, 2003. Oregon Department of Forestry, Salem, OR.

Dickson, J.G., 1992. The Wild Turkey: Biology and Management. Stackpole, Harrisburg, PA.

Dunkin, S.W., Guthery, F.S., Demaso, S.J., Peoples, A.D., Parry, E.S., 2009. Influence of anthropogenic structures on northern bobwhite space use in western Oklahoma. J. Wildlife Manage. 73, 253–259.

Ecological Software Solutions, 1999. LOAS User's Guide. <http://www.ecostats.com/software/loas/loas.htm>.

Environmental Systems Research Institute, 1999. Using ArcView® GIS, version 3.2. Environmental Systems Research Institute, Redlands, California, USA.

Environmental Systems Research Institute, 2004. Using ArcGIS®, version 9.1. Environmental Systems Research Institute, Redlands, California, USA.

Engstrom, R.T., Crawford, R.L., Baker, W.W., 1984. Breeding bird populations in relation to changing forest structure following fire exclusion: a 15-year study. Wilson Bull. 96, 437–450.

Exum, J.H., McGlincy, J.A., Speake, D.W., Buckner, J.L., Stanley, F.M., 1987. Ecology of the eastern wild turkey in an intensively managed pine forest in southern Alabama. Tall Timbers Research Station Bulletin No. 23, Tallahassee, FL, 70pp.

Frost, C.C., 1998. Presettlement fire frequency regimes of the United States: a first approximation. In: Pruden, Teresa L., Brennan, Leonard.A. (Eds.), Fire in ecosystem management: Shifting The Paradigm From Suppression To Prescription, Proceedings of The 20th Tall Timbers Fire Ecology Conference. Tall Timbers Research, Inc., Tallahassee, Florida, pp. 70–81.

Gagnon, P.R., 2008. Fire in floodplain forests in the southeastern USA: insights from disturbance ecology and native bamboo. Wetlands 29, 520–526.

Glitzenstein, J.S., Streng, D.R., Wade, D.D., 2003. Fire frequency effects on longleaf pine (*Pinus palustris* P. Miller) vegetation in South Carolina and Northeast Florida,USA. Nat. Areas J. 23, 22–37.

Glitzenstein, J.S., Streng, D.R., Masters, R.E., Platt, W.J., 2008. Clarifying long-term impacts of fire frequency in southeastern pine savannas. Eastern Native Grass Symp. 6, 14–25.

Glitzenstein, J.S., Streng, D.R., Masters, R.E., Robertson, K.M., Herman, S.M., 2012. Fire frequency effects on vegetation in North Florida pinelands: another look at long-term Stoddard fire plots at tall timbers research station. Forest Ecol. Manage. 264, 197–209.

Godfrey, C.L., Norman, G.W., 1999. Effect of habitat and movement on wild Turkey poult survival. Proc. Annu. Conf. Southeast Assoc. Fish Wildlife Agencies 53, 330–339.

Godwin, K.D., Hurst, G.A., Leopold, B.D., Randall, L Kelley, 1992. Habitat use of wild turkey gobblers on Tallahala wildlife management area, Mississippi. Proc. Annu. Conf. Southeast. Assoc. Fish Wildlife Agencies 46, 249–259.

Guthery, F.S., 1997. A philosophy of habitat management for northern bobwhites. J. Wildlife Manage. 61, 291–301.

Healy, W.M., 1985. Turkey poult feeding activity, invertebrate abundance, and vegetation structure. J. Wildlife Manage. 49, 466–472.

Hooge, P.N., Eichenlaub, B., 1997. Animal Movement Extension to ArcView®. v. 1.1. Alaska Science Center – Biological Science Office, U.S. Geological Survey, Anchorage, AK, USA.

Hedrick, L.D., Bukenhofer, G.A., Montague, W.G., Pell, W.F., Gudlin, J.M., 2007. Shortleaf pine-bluestem restoration in the Ouachita National Forest. In: Shortleaf Pine Restoration and Ecology in the Ozarks. USDA Forest Service General Technical Report NRS-P-15, pp. 206–213.

Huffman, J.M., 2006. Historical Fire Regimes in Southeastern Pine Savannas. Ph Dissertation, Louisian State University, Baton Rouge, LA 71pp.

Johnson, D.H., 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61, 65–71.

Kabrick, J.M., Dey, D.C., Gwaze, D., 2007. Shortleaf Pine Restoration and Ecology in the Ozarks In: Proceedings of a Symposium, November 7–9, 2006, Springfield, MO. USDA Forest Service, Northern Research Station.

Kennamer, J.E., Gwaltney, J.R., Sims, K.R., 1980. Food habits of the eastern wild turkey on an area intensively managed for pine in Alabama. Proc. Natl. Wild Turkey Symp. 4, 246–250.

Komarek, 1974. Effects of fire on temperate forests and related ecosystems: southeastern United States. In: Kozlowski, T.T., Algren, C.E. (Eds.), Fire and Ecosystems. Academic Press, New York, NY, USA, p. 1–272.

Kopp, S.D., Guthery, F.S., Forrester, N.D., Cohen, W.E., 1998. Habitat selection modeling for northern bobwhites on subtropical rangeland. J. Wildlife Manage. 62, 884–895.

Manly, B.F., McDonald, L.L., Thomas, D.L., 1993. Resource Selection by Animals. Chapman and Hall, London, UK.

Masters, R.E., Robertson, K.M., Palmer, W.E., Cox, J., Green, L., Ambrose, C., 2007. Red hills stewardship guide. In: Tall Timbers Research Station and Conservancy. Tall Timbers Research, Inc. Tallahassee, FL, USA (miscellaneous publication).

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

Miller, D.A., Conner, L.M., 2007. Habitat selection of female turkeys in a managed pine landscape in Mississippi. J. Wildlife Manage. 71, 744–751.

Miller, D.A., Leopold, B.D., Hurst, G.A., Gerard, P.D., 2000. Habitat selection models for eastern wild turkeys in central Mississippi. J. Wildlife Manage. 64, 765–776.

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

Moser, W.K., Jackson, S.M., Podrazsky, V., Larsen, D.R., 2002. Examination of stand structure on bobwhite plantations in the red hills region of Georgia and Florida managed by the Stoddard–Neel system: an example for forest managers. Forestry 75, 443–449.

Palmer, W.E., Hurst, G.A., 1995. Drainage systems as minimum habitat management units for wild turkey hens. Proc. Natl. Wild Turkey Symp. 7, 96–101.

Palmer, W.E., Hurst, G.A., Godwin, K.D., Miller, D.A., 1996a. Effects of prescribed burning on wild turkeys. Trans. North Am. Wildlife Natl. Resour. Conf. 61, 228–236.

Palmer, W.E., Hurst, G.A., Leopold, B.D., 1996b. Preincubation habitat use by wild turkey hens in central Mississippi. Proc. Annu. Conf. Southeast. Assoc. Fish Wildlife Agencies 50, 417–427.

Palmer, W.E., Hurst, G.A., 1998. Prescribed burning effects on wild turkey hens during preincubation. Tall Timbers Fire Ecol. Proc. 20, 102–106.

Pelham, P.H., Dickson, J.G., 1992. Physical characteristics. In: Dickson, J.G. (Ed.), The Wild Turkey: Biology and Management. Stackpole Books, Mechanicsburg, PA, pp. 32–45.

Peoples, J.C., Sisson, D.C., Speake, D.W., 1995. Wild turkey brood habitat use and characteristics in coastal plain pine forests. Proc. Natl. Wild Turkey Symp. 7, 89–96.

Phalen, P.S., Hurst, G.A., 1993. Reproductive effort and success in a declining wild turkey population. Proc. Annu. Conf. Southeast. Assoc. Fish Wildlife Agencies, 138–147.

Platt, W.J., 1999. Southeastern pine savannas. In: Anderson, R.C., Fralish, J.S., Baskin, J.M. (Eds.), Savannas, Barrens, and Rock Outcrop Plant Communities of North America. Cambridge University Press, Cambridge, England, pp. 23–51.

Pyne, S.J., 1982. Fire in America: A Cultural History of Wildland and Rural Fire. University of Washington Press, Seattle, USA.

Sisson, D.C., Speake, D.W., Landers, J.L., 1991. Wild turkey brood habitat use in fire-type pine forests. Proc. Annu. Conf. Southeast Assoc. Fish Wildlife Agencies 45, 49–57.

Smith, D.R., Hurst, G.A., Burke, J.D., Leopold, B.D., Melchiors, M.A., 1990. Use of loblolly pine plantations by wild turkey hens in east-central Mississippi. Proc. Natl. Wild Turkey Symp. 6, 61–66.

Speake, D.W., Lynch, T.E., Fleming, W.J., Wright, G.A., Hamrick, W.J., 1975. Habitat use and seasonal movements of wild turkeys in the southeast. Proc. Natl. Wild Turkey Symp. 3, 122–130.

Stoddard, H.L., 1963. Maintenance and increase of the eastern wild turkey on private lands of the coastal plain of the deep southeast. Tall Timbers Research Station Bulletin No. 3, Tallahassee, FL, 49pp.

Swanson, D.A., Pack, J.C., Taylor, C.I., Samuel, D.E., Brown, P.W., 1995. Selective timber harvesting and wild turkey reproduction in West Virginia. Proc. Natl. Wild Turkey Symp. 7, 81–88.

Widener, B., Cox, J., 2008. Lightning-season burning: friend or foe of breeding birds? Miscellaneous publication Tall Timbers Research Station and Conservancy, Tallahassee, FL, USA.

White, G.C., Garrott, R.A., 1990. Analysis of Wildlife Radio-Tracking Data. Academic Press, New York.

Zwank, P.J., White Jr, T.H., Kimmel, F.G., 1988. Female turkey habitat use in Mississippi River Batture. J. Wildlife Manage. 52, 253–260.