DIURNAL MICROHABITAT USE BY AMERICAN WOODCOCK WINTERING IN EAST TEXAS

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Abstract: East Texas is the westernmost extent of the normal winter range of American woodcock (*Scolopax minor*). This study addressed information gaps surrounding diurnal winter habitat used by woodcock in east Texas. We measured 14 different habitat variables, including ground (i.e., bare soil, leaf litter, woody debris, grass, herbaceous, etc.), understory, tree canopy, horizontal, and overhead covers at 239 locations of 60 different radio-marked adults during winter of 2001–2002 and 2002–2003. Because of a shift in use from floodplain to upland habitats, several habitat parameters varied between years ($P \leq 0.05$). Although gross structural habitat cover varied between years, there were general similarities in used and random habitats and in male and female habitats within each year. Moreover, although habitat components changed during each year, microhabitats selected by woodcock remained consistent. Woodcock used habitats with varying amounts of ground cover, as in other studies, but were in locations with much less bare soil than in many previous studies. The woodcock's winter requirements—sparse ground cover and adequate overhead cover—are provided by 3 types of sites in east Texas: 1) early successional forests on upland and floodplain sites; 2) thinned pine sawtimber plantations that are regularly burned; and 3) mixed pine-hardwood sawtimber stands.

Proceedings of the American Woodcock Symposium 10: 63–75

Key words: American woodcock, diurnal winter habitat, *Scolopax minor*, Texas.

The American woodcock (*Scolopax minor*) is a migratory game bird that inhabits the eastern United States. The species has experienced long-term population declines (Kelley and Rau 2006), most likely caused by successional changes and habitat loss (Owen et al. 1977, Dwyer et al. 1983, Dessecker and Pursglove 2000). Early successional habitats are important for woodcock throughout the year because the species is disturbance-dependent (Dessecker and Pursglove 2000); however habitat use varies between diurnal and nocturnal periods. Diurnal habitat in the South has been characterized as dense thickets with sparse ground cover (Boggus and Whiting 1982, Straw et al. 1986) within regenerating clearcuts (Boggus and Whiting 1982, Roberts et al. 1984), intermediate-aged forests (Kroll and Whiting 1977), and mature forests (Horton and Causey 1979). Nocturnal habitat is typically more open because birds use old fields (Glenn et al. 2004) and recently harvested forests (Dyer and Hamilton 1977, Horton and Causey 1979).

During winter in east Texas, woodcock often move between diurnal and nocturnal habitats at dusk and dawn (Glenn et al. 2004, Berry 2006). Both sexes use diurnal habitat for feeding and roosting (Horton and Causey 1979), and starting in late January, some adult females also use diurnal habitats for nesting and then brood rearing (Whiting and Boggus 1982, Whiting et al. 2005). Such nesting activity suggests that there may be differences in diurnal microhabitat use by adult male and female woodcock, particularly during late winter. However, few studies have isolated specific requirements for males and females (Sepik and Derleth 1993) and no

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published studies have described diurnal microhabitat components important to adult male and female woodcock in east Texas. To address this information gap, we compared diurnal microhabitat use between adult male and female woodcock and between woodcock flush sites and associated random sites in east Texas during fall and winter, 2001–2002 and 2002–2003.

METHODS

Study Area

This study was conducted on the Alazan Bayou Wildlife Management Area (ABWMA), the adjacent Stephen F. Austin Experimental Forest (SFAEF), and surrounding private lands in Nacogdoches County, Texas (Figure 1). The 835-ha ABWMA was managed by the Texas Parks and Wildlife Department. Approximately 243 ha of the ABWMA were abandoned upland pastures, and the remainder was bottomland hardwood forests in the Angelina River floodplain. Approximately 308 ha of the SFAEF, a part of the United States Forest Service system, were upland mixed pine-hardwood forests, and approximately 1038 ha of the SFAEF were bottomland hardwood forests in the Angelina River floodplain (Conner et al. 1994). Private lands adjacent to the ABWMA and SFAEF were managed by numerous owners and consisted of improved pastures, mixed pine-hardwood forests, pine plantations, bottomland hardwood forests, and residential areas. However, most of the private lands on which this study took place were comprised of 2 intensively managed pine plantations. One plantation was approximately 5 years old and the other was approximately 25 years old; the latter plantation had been thinned twice.

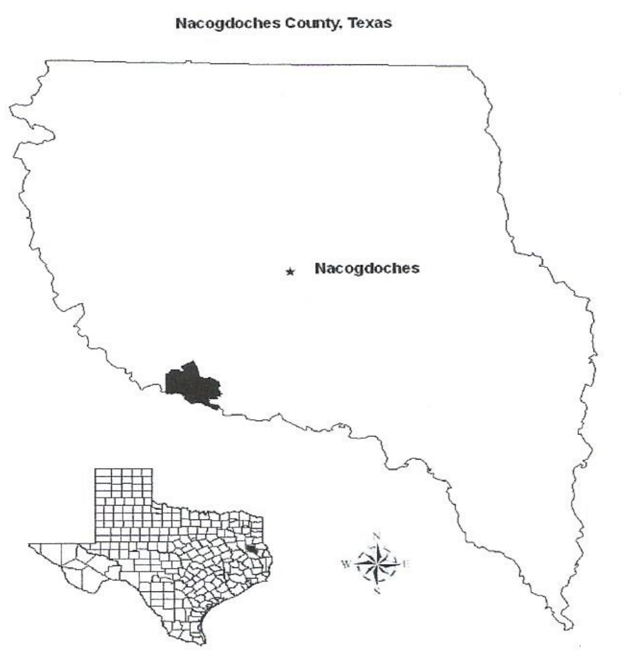


Figure 1. Location of American woodcock study sites at the Stephen F. Austin Experimental Forest and the Alazan Bayou Wildlife Management Area within Nacogdoches County, Texas.

Most upland soils in the area are loams or fine sandy loams in texture on slopes of 0–20%. These soils are deep, moderately to well drained with slow to moderate permeability. Bottomland soils are deep, poorly drained loams with moderate to slow permeability. Bottomland soils contain relatively high proportions of clay and may flood briefly during winter (Dolezel and Fuchs 1980).

Capturing and Radio-Locating Woodcock

We captured woodcock by night-lighting (Rieffenberger and Kletzly 1967) in the fields within the northernmost portion of the ABWMA during fall and winter, 2001–2002 and 2002–2003 (Figure 2). We sexed, aged (Martin 1964, McAuley et al. 1993), and fitted each captured bird with a United States Geological Survey (USGS) aluminum leg band. We attached radio transmitters weighing <6 g (<4% of bird mass) to adults (>1 year old) backpack style with livestock tag cement and a single-loop cable harness (McAuley et al. 1993) (USGS auxiliary marking authorization permit number 22931). In 2002–2003, the cable harness was replaced with a single thread of Gossamer Floss™. We released each bird at the capture site after transmitter attachment. We attempted to radiomark 15 adult males and 15 adult females each winter.

We allowed radio-marked birds 3 days to resume normal activities. Thereafter, we searched for each bird 1–5 times a week until 1 March 2002 and 2003. When a bird was found dead or was missing for 2 consecutive weeks prior to 1 February 2002 and 13 February 2003, we captured and radiomarked a new adult woodcock of the same sex. After these dates, missing or dead birds were not replaced.

Habitat Data Collection

We randomly located radio-marked birds with traditional telemetry techniques between 0800–1700 hours to ensure birds were found equally throughout the day. Upon locating each bird, we flushed it and the flush point was marked (i.e., the used point). If a bird appeared to move before flushing, we considered the original triangulation the used point. We also marked a point 30 m from the used point in a random direction (i.e., the random point). We chose a 30-m distance for random locations to constrain them 1) to diurnal microhabitat(s) that were potentially used by wood-

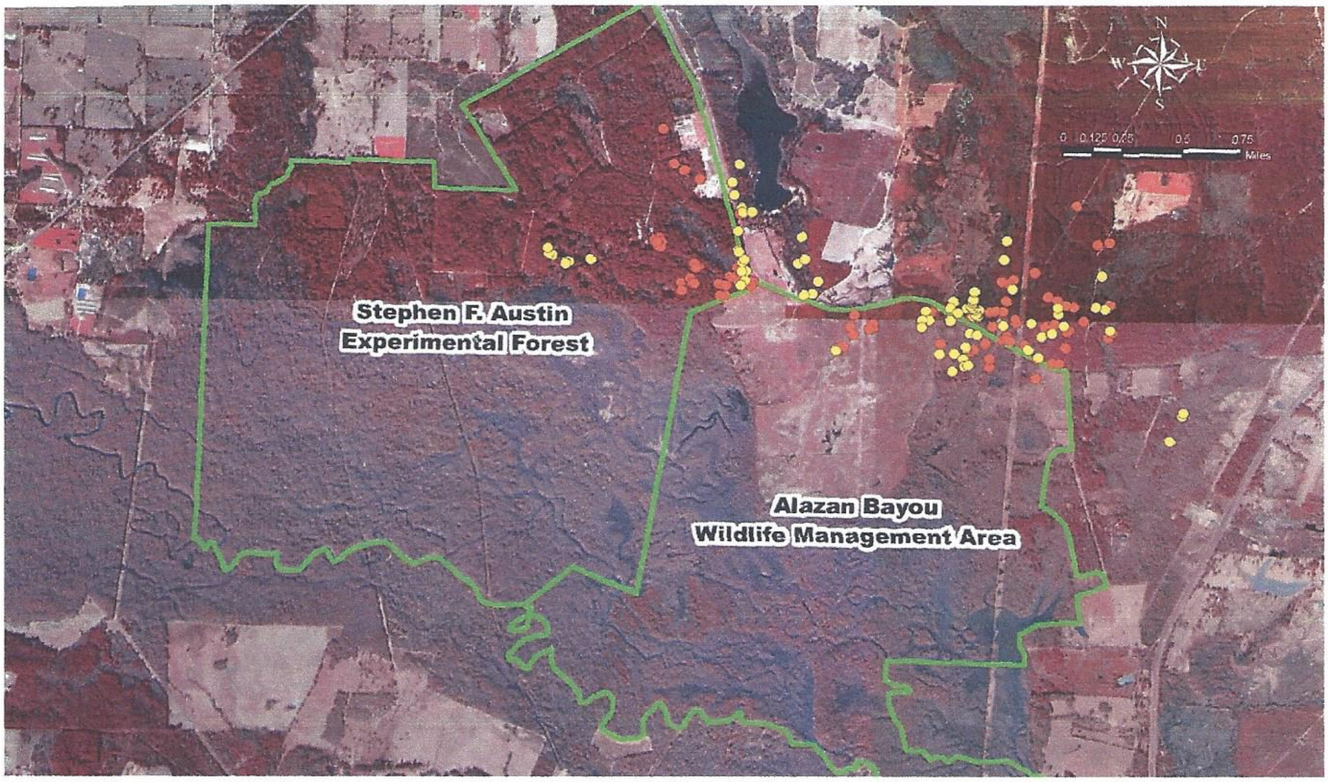


Figure 2. Detailed study area and a subset of American woodcock locations at the Stephen F. Austin Experimental Forest and Alazan Bayou Wildlife Management Area in east Texas, in 2001–2002 (yellow) and 2002–2003 (orange).

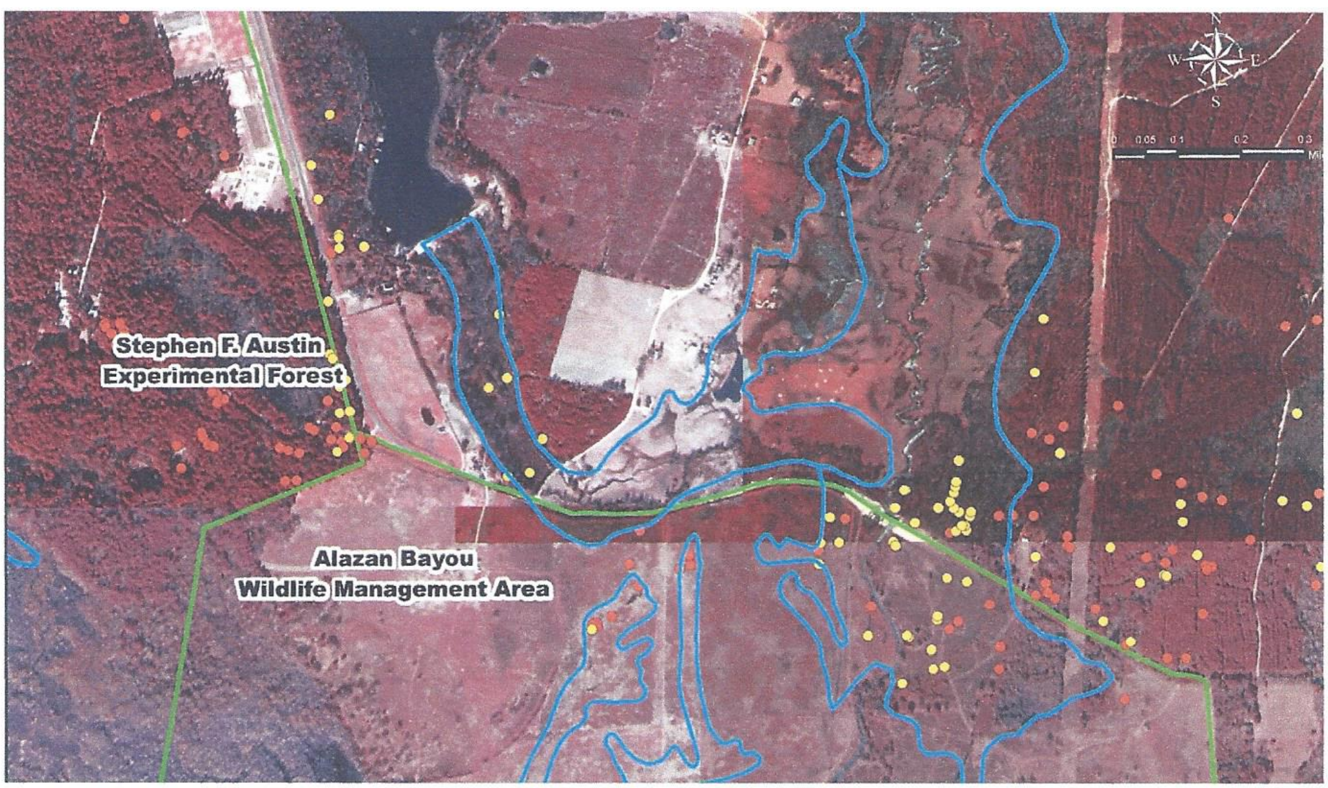


Figure 3. Floodplain soils (blue outline) on the Alazan Bayou Wildlife Management Area overlaid with a subset of American woodcock locations at the Stephen F. Austin Experimental Forest and Alazan Bayou Wildlife Management Area in east Texas, in 2001–2002 (yellow) and 2002–2003 (orange).

cock during this study, 2) from falling in locations in which woodcock would not generally be observed (i.e., roads, open water, etc.), and 3) to focus upon potentially relevant microhabitat features between used and random sites.

Within 1 week of flushing a bird, we collected microhabitat cover data at and around (i.e., used or random location) each used and random point. We recorded vegetative and physiognomic characteristics of the surrounding area. We then ocularly estimated percent ground cover (i.e., 0.0–0.1 m above the ground) in a 0.5 x 1.0-m plot centered on the used or random point for the following categories: water, rock, bare soil, leaf litter, woody debris, and grass, herbaceous, vine, deciduous, or evergreen plant. When green vegetation was above cover lying on the ground (e.g., herbaceous plant above leaf litter), we recorded both categories so that in some instances ground cover totals exceeded 100%. We also estimated the same ground cover categories in 4 additional plots, 1 in each cardinal direction 1 m from each point. We averaged ground cover estimates for the 5 plots by habitat cover category.

We measured understory (i.e., 0.1–6.0 m above the ground) and tree canopy covers (i.e., >6.0 m above the ground) at each location using the line intercept method (Canfield 1941). From each point, we placed a 5-m tape on the ground cover in a cardinal direction and recorded the length of vegetation (cm) directly above the tape for each stratum. We repeated the procedure in the remaining cardinal directions and averaged values for each cover stratum and converted to percentages.

We estimated horizontal vegetation cover in the stratum 0.0–1.5 m above the soil surface at each point. A 0.6 x 1.5-m cover board painted in a black and white checkered pattern of squares, each 15 x 15cm (i.e., 225 cm^2), was placed at each used and random point. We counted only the number of squares ≥50% obscured by vegetation at eye level from a distance of 5 m in each cardinal direction. Squares with <50% coverage were not counted to minimize potential bias towards overestimating horizontal obscurity. We averaged horizontal vegetation cover estimates from cardinal directions and converted the value to a percentage.

We measured overhead vegetation cover using a spherical densiometer with 24 squares (i.e., 96 corners) imprinted on the concave mirror. In an attempt to estimate overhead cover at each point from the perspective of a woodcock, we placed the densiometer on the ground at each used or random point, and then counted the number of corners on the densiometer that reflected vegetation. We performed this procedure while facing each cardinal direction to thoroughly estimate the overhead cover at each point. We averaged the 4 densiometer values and converted that value to a percentage.

Data Analyses

We used multivariate analysis of variance (MANOVA) to examine differences in habitat cover variables (i.e., ground cover by category, understory cover, horizontal vegetation cover, overhead vegetation cover, and tree canopy cover) between years, between used and random locations, between sexes and all interactions. Year was intentionally included as a main effect in initial analyses as yearly variation in habitat was of interest during this study. If interactions ($P < 0.05$) between year and any other main effect occurred, we performed subsequent analyses within each year. To more specifically examine sex-related differences in habitat, we also used MANOVA to examine differences in the same set of habitat variables between years, sexes, and season for used locations only. Each study year was subdivided into early (i.e., November and December) and late (i.e., January, February, and March) seasons in an attempt to examine gender-based habitat use changes within each year. We used MANOVA to maintain overall experiment-wide error rates of 0.05 and Wilks' λ was used as the test criterion because of its conservative power, analogy to univariate F statistics (Johnson and Wichern 2002), resiliency to multivariate non-normality (Olson 1976), and robustness to heterogeneity of variance-covariance matrices (Ito and Schull 1964). If differences ($P < 0.05$) occurred during MANOVA, we performed follow-up analyses of variance (ANOVA) using Type III Sums of Squares. Least squares mean separation was used to examine significant ($P < 0.05$) differences (Zar 1996).

RESULTS

All woodcock captured during each study year were on an upland site or adjacent minor streamside floodplain on the northern portion of ABWMA (Figure 3). In 2001–2002, the first woodcock was radiomarked on 13 December 2001 and the last on 29 January 2002. The first and last radio transmitters fitted in 2002–2003 were on 12 November 2002 and 12 February 2003, respectively.

Habitat

Habitat was measured at 89 woodcock locations (40 male and 49 female) of 12 males and 14 females between 17 December 2001 and 8 March 2002. Between 19 November 2002 and 16 March 2003, we collected habitat data at 150 woodcock locations (39 male and 111 female) of 12 males and 21 females; 1 male and 2 females were recaptures from the previous year. In 2001–2002, 52% of woodcock locations were in floodplain habitats, whereas in 2002–2003 only 24% of locations were in such habitats (χ^2 = 18.99, df = 2, P < 0.001); use of mature upland pine stands doubled the second year (Table 1, Figure 3).

Habitat varied between years (Wilks' λ = 0.20, df = 14, 461, P < 0.001), between used and random locations (Wilks' λ = 0.91, df = 14, 461, P < 0.001), and there was a year x location interaction (Wilks' λ = 0.87, df = 14, 461, P < 0.001). Subsequent analyses examining habitat between used and random locations were performed within each year. Grass, understory, horizontal, and overhead covers were lower (P < 0.05) at used than random locations in 2001–2002 (Table 2). In 2002–2003, grass, water, and overhead covers were lower (P < 0.05) at used than random locations, but leaf litter, understory, and horizontal covers were higher (P < 0.05) (Table 2).

There was some variation in microhabitat at random locations between years, although grass (F = 0.48, df = 1, 236, P = 0.487), leaf litter (F = 1.98, df = 1, 236, P = 0.161), herbaceous (F = 0.97, df = 1, 236, P = 0.326) and overhead covers (F = 1.08, df = 1, 236, P = 0.300) were similar (Table 2). However, bare ground (F = 6.00, df = 1, 236, P = 0.015), deciduous (F = 74.12, df = 1, 236, P < 0.001), and horizontal covers (F = 38.45, df = 1, 236, P < 0.001) were greater in 2001–2002 than 2002–2003, but understory cover (F = 222.9, df = 1, 236, P < 0.001) was higher in the latter winter (Table 2). Overall habitat at used locations, irrespective of sex, varied (Wilks' λ = 0.14, df = 14, 222, P < 0.001) between years, but was similar between sexes (Wilks' λ = 0.92, df = 14, 222, P = 0.207). Bare soil, woody, deciduous, vine, and tree canopy covers were all higher in 2001–2002 than in 2002–2003, but understory cover was lower in 2001–2002 than in 2002–2003 (Table 3). Few strongly sex-related habitat differences emerged in either year (Table 4). In 2001–2002, habitats used by males and females were similar, whereas in 2002–2003, herbaceous ground cover and overhead canopy cover were higher at male than female locations and female locations had more tree canopy cover (P < 0.05).

Finally, as some previous research indicated that females may begin using diurnal habitat for nesting in January (Whiting et al. 2005), we examined if season (i.e., prior to 1 January or after 1 January) influenced habitat use by sex in either year. As before, used habitat did not vary between sexes in 2001–2002 (Wilks' λ = 0.83, df = 19, 67, P = 0.762), but did in 2002–2003 (Wilks' λ = 0.80, df = 18, 128, P = 0.028). Used habitat varied between early and late seasons in 2001–2002 (Wilks' λ = 0.65, df = 19, 67, P = 0.031) (Table 5) and 2002–2003 (Wilks' λ = 0.79, df = 18, 128, P = 0.018) (Table 6), but there were no season x sex interactions in either year (Wilks' λ = 0.85, df = 19, 67, P = 0.637; 2001–2002) (Wilks' λ = 0.86, df = 18, 128, P = 0.306; 2002–2003), indicating that although habitat changed during winter, males and females selected habitats similarly over time. In both years, the amount of leaf litter declined between periods at used locations. However, in 2001–2002, used locations had more understory and horizontal covers in the early period (Table 5), but those same cover values did not differ over time in 2002–2003 (Table 6). Conversely, in 2001–2002, overhead and tree canopy covers were similar between periods (Table 5) whereas in 2002–2003, overhead cover increased and tree canopy cover decreased over time (Table 6).

Table 1. Number and percent (%) of points, categorized by habitat, from which data were collected for radio-marked adult male and female American woodcock during fall and winter of 2001-2002 and 2002-2003 in Nacogdoches County, Texas.

	2001–2002 (n = 89)		2002–2003 (n = 150)	
Habitat[a]	n	%	n	%
Floodplain				
Early successional hardwood	20	22.5	27	18.0
Early successional pine-hardwood	2	2.3	1	0.7
Early successional pine plantation	14	15.7	3	2.0
Mature hardwood	7	7.9	4	2.6
Mature mixed pine-hardwood	3	3.4	1	0.7
Total	46	51.8	36	24.0
Upland				
Early successional hardwood	1	1.1	0	0.0
Early successional pine hardwood	0	0.0	4	2.7
Early successional pine plantation	6	6.7	29	19.3
Mature hardwood	0	0.0	2	1.3
Mature mixed pine hardwood	22	24.7	28	18.7
Mature pine	14	15.7	51	34.0
Total	43	48.2	114	76.0

[a] Early successional and mature habitats were comprised of seedling-sapling and pole-sawtimber size trees, respectively. Mixed pine-hardwood stands contained both species types in varying proportions.

Table 2. Means, Standard Errors (SE), *F* values, and *P* values resulting from analysis of variance for habitat cover data collected at American woodcock diurnal locations and corresponding random locations during fall and winter of 2001–2002 and 2002–2003 in Nacogdoches County, Texas.

	Used		Random			
Parameter (%)[a]	**Mean**	**SE**	**Mean**	**SE**	***F***	***P***
2001–2002 (*n* = 89)						
Ground cover						
Bare ground	5.13	0.80	5.30 A[b]	1.02	0.10	0.751
Rock	<0.01	<0.01	0.19 A	0.19	0.79	0.375
Leaf litter	90.49	1.24	84.20 A	2.47	3.48	0.064
Woody debris	3.50	0.44	3.63 A	0.51	0.04	0.845
Grass	9.93	1.42	17.20 A	2.39	5.93	0.016
Herbaceous	13.97	1.68	16.47 A	2.20	0.09	0.767
Deciduous	10.14	0.97	7.92 A	0.88	3.39	0.067
Vine	10.95	1.54	9.88 A	1.59	0.76	0.385
Evergreen	1.71	0.46	1.20 A	0.35	0.79	0.376
Water	1.48	0.52	1.98 A	0.71	0.24	0.623
Understory cover	20.05	2.02	33.35 B	2.87	13.11	<0.001
Horizontal cover	35.98	3.04	53.47 A	3.42	14.38	<0.001
Overhead cover	5.57	0.91	11.62 A	1.90	9.75	0.002
Tree canopy cover	68.54	3.57	66.86 A	4.07	0.01	0.909
2002–2003 (*n* = 150)						
Ground cover						
Bare ground	2.27	0.46	2.76 B	0.51	0.19	0.663
Rock	0.00	0.00	0.00 A	0.00	NA	NA
Leaf litter	86.31	1.83	79.13 A	2.44	4.51	0.035
Woody debris	2.76	0.34	3.17 A	0.41	0.49	0.484
Grass	10.65	1.20	15.22 A	1.69	4.08	0.044
Herbaceous	11.24	1.27	13.80A	1.55	1.44	0.232
Deciduous	2.10	0.21	1.76 B	0.17	1.70	0.194
Vine	3.14	0.56	3.76 B	0.69	0.00	0.969
Evergreen	3.10	0.70	1.84 A	0.41	1.80	0.181
Water	0.13	0.67	1.80 A	0.68	6.45	0.012
Understory cover	88.55	1.10	78.69 A	1.63	21.74	<0.001
Horizontal cover	43.08	1.93	30.93 B	1.91	20.04	<0.001
Overhead cover	6.45	0.92	14.40 A	1.69	19.64	<0.001
Tree canopy cover	31.57	2.94	36.44 B	3.13	1.72	0.191

[a] Ground cover, understory cover, and tree canopy cover were evaluated in the stratum 0.0–0.1 m, 0.1–6.0 m, and >6 m above the soil surface, respectively. Horizontal cover was estimated at a distance of 5 m from a density board, and overhead cover was evaluated using a spherical densiometer.

[b] Means of random habitat followed by the same letter within the same column are not different (*P* > 0.05) between years.

Table 3. Means, Standard Errors (SE), *F* values, and *P* values resulting from analysis of variance for habitat cover data collected at American woodcock diurnal locations during fall and winter of 2001–2002 and 2002–2003 in Nacogdoches County, Texas.

	2001–2002 (*n* = 89)		2002–2003 (*n* = 150)			
Parameter (%)[a]	Mean	SE	Mean	SE	*F*[b]	*P*
Ground cover						
Bare ground	5.13	0.80	2.27	0.46	18.28	<0.001
Rock	<0.01	<0.01	0.00	0.00	1.25	0.265
Leaf litter	90.49	1.24	86.31	1.83	0.41	0.523
Woody debris	3.50	0.44	2.76	0.34	6.07	0.015
Grass	9.93	1.42	10.65	1.20	0.26	0.610
Herbaceous	13.97	1.68	11.24	1.27	0.19	0.661
Deciduous	10.14	0.97	2.10	0.21	106.31	<0.001
Vine	10.95	1.54	3.14	0.56	34.71	<0.001
Evergreen	1.71	0.45	3.10	0.70	0.61	0.686
Water	1.48	0.52	0.13	0.07	6.98	0.009
Understory cover	20.05	2.02	88.55	1.10	689.81	<0.001
Horizontal cover	35.98	3.03	43.08	1.92	3.33	0.069
Overhead cover	5.57	0.91	6.45	0.92	1.01	0.316
Tree canopy cover	68.54	3.57	31.57	2.93	78.80	<0.001

[a] Ground cover, understory cover, and tree canopy cover were evaluated in the stratum 0.0–0.1 m, 0.1–6.0 m, and >6 m above the soil surface, respectively. Horizontal cover was estimated at a distance of 5 m from a density board, and overhead cover was evaluated using a spherical densiometer.
[b] Reported *F* and *P* values from Type III Sums of Squares (df = 1, 235).

Table 4. Means, Standard Errors (SE), *F* values, and *P* values resulting from analysis of variance for habitat cover data collected at male and female American woodcock diurnal locations during fall and winter of 2002–2003 in Nacogdoches County, Texas.

	Male (*n* = 39)		Female (*n* = 111)			
Parameter (%)[a]	Mean	SE	Mean	SE	*F*[b]	*P*
Ground cover						
Bare ground	1.44	0.42	2.56	0.60	0.19	0.660
Rock	0.00	0.00	0.00	0.00	NA	NA
Leaf litter	84.20	3.76	87.05	2.10	0.64	0.426
Woody debris	2.99	0.94	2.68	0.32	0.88	0.349
Grass	12.29	2.38	10.07	1.39	0.79	0.376
Herbaceous	16.81	2.72	9.28	1.39	8.57	0.004
Deciduous	2.39	0.58	1.99	0.20	0.12	0.728
Vine	2.50	0.62	3.37	0.72	1.11	0.293
Evergreen	0.69	0.32	3.94	0.92	5.86	0.017
Water	0.23	0.13	0.09	0.07	1.82	0.179
Understory cover	87.53	1.81	88.91	1.34	1.13	0.290
Horizontal cover	39.92	3.64	44.18	2.27	0.85	0.359
Overhead cover	10.27	2.53	5.11	0.84	6.17	0.014
Tree canopy cover	20.19	4.30	35.57	3.60	4.63	0.033

[a] Ground cover, understory cover, and tree canopy cover were evaluated in the stratum 0.0–0.1 m, 0.1–6.0 m, and >6 m above the soil surface, respectively. Horizontal cover was estimated at a distance of 5 m from a density board, and overhead cover was evaluated using a spherical densiometer.
[b] Reported *F* and *P* values from Type III Sums of Squares (df = 1, 146).

Table 5. Means, Standard Errors (SE), *F* values, and *P* values resulting from analysis of variance for habitat cover data collected early (i.e., prior to 1 January) and late (i.e., after 1 January) at American woodcock diurnal locations during fall and winter of 2001–2002 in Nacogdoches County, Texas.

	Early (n = 15)		Late (n = 74)			
Parameter (%)[a]	**Mean**	**SE**	**Mean**	**SE**	F^{b}	P
Ground cover						
Bare ground	1.72	0.60	5.83	0.94	3.92	0.051
Rock	0.00	0.00	0.00	0.00	0.16	0.687
Leaf litter	96.49	0.92	89.27	1.44	4.79	0.031
Woody debris	4.31	0.82	3.34	0.49	0.86	0.355
Grass	5.92	1.78	10.75	1.65	1.22	0.272
Herbaceous	6.62	3.00	15.46	1.89	3.81	0.054
Deciduous	7.17	1.09	10.74	1.13	2.01	0.159
Vine	7.61	1.77	11.62	1.80	1.55	0.216
Evergreen	0.13	0.13	2.03	0.54	2.18	0.144
Water	0.00	0.00	1.78	0.62	1.54	0.218
Understory cover	30.25	5.51	17.97	2.09	5.89	0.017
Horizontal cover	62.58	6.70	30.59	3.03	22.46	<0.001
Overhead cover	4.87	1.86	5.71	1.02	0.01	0.906
Tree canopy cover	52.68	7.04	71.76	3.97	3.94	0.050

[a] Ground cover, understory cover, and tree canopy cover were evaluated in the stratum 0.0–0.1 m, 0.1–6.0 m, and >6 m above the soil surface, respectively. Horizontal cover was estimated at a distance of 5 m from a density board, and overhead cover was evaluated using a spherical densiometer.
[b] Reported *F* and *P* values from Type III Sums of Squares (df = 1, 85).

Table 6. Means, Standard Errors (SE), *F* values, and *P* values resulting from analysis of variance for habitat cover data collected early (i.e., prior to 1 January) and late (i.e., after 1 January) at American woodcock diurnal locations during fall and winter of 2002–2003 in Nacogdoches County, Texas.

	Early (n = 69)		Late (n = 81)			
Parameter (%)[a]	**Mean**	**SE**	**Mean**	**SE**	F^{b}	P
Ground cover						
Bare ground	1.49	0.48	2.93	0.74	0.84	0.361
Rock	NA	NA	NA	NA	NA	NA
Leaf litter	90.37	2.43	82.85	2.64	6.55	0.012
Woody debris	2.98	0.33	2.57	0.56	0.02	0.899
Grass	8.82	1.86	12.22	1.54	2.32	0.130
Herbaceous	8.83	1.74	13.29	1.81	3.27	0.073
Deciduous	2.53	0.32	1.73	0.28	3.29	0.072
Vine	4.10	1.14	2.33	0.36	0.94	0.333
Evergreen	6.01	1.43	0.62	0.17	5.62	0.019
Water	0.04	0.04	0.21	0.12	0.86	0.355
Understory cover	86.51	1.73	90.29	1.38	0.08	0.772
Horizontal cover	41.55	2.62	44.38	2.79	0.06	0.806
Overhead cover	4.31	1.24	8.28	1.30	6.41	0.012
Tree canopy cover	48.08	4.55	17.51	3.06	18.32	< 0.001

[a] Ground cover, understory cover, and tree canopy cover were evaluated in the stratum 0.0–0.1 m, 0.1–6.0 m, and >6 m above the soil surface, respectively. Horizontal cover was estimated at a distance of 5 m from a density board, and overhead cover was evaluated using a spherical densiometer.
[b] Reported *F* and *P* values from Type III Sums of Squares (df = 1, 145).

DISCUSSION

Yearly Habitat Variation

The magnitude of overall habitat differences between years drove many of the analyses within this study, and likely influenced differences between used and random habitats and between male and female habitat use patterns. For example, habitat varied more between study years than between used and random locations or male and female locations within years. However, yearly differences in used and random locations were generally related to understory, horizontal, and tree canopy covers, not specific ground cover components, which were quite similar in both years (see Table 2). Moreover, these non-ground cover components were undoubtedly related to the general distribution of woodcock between years on the study site. For example, during 2001–2002, woodcock locations were evenly distributed between floodplain and upland habitats, but in 2002–2003, 75% of all the birds were located on upland sites. As expected, understory and horizontal cover patterns mirrored more open floodplain habitats in 2001–2002 and more dense upland habitats in 2002–2003. However, beyond gross differences in generalized habitat structure, we hypothesize that this dramatic shift from floodplains to uplands between years may be due to differences in moisture regimes.

Precipitation in Lufkin, Texas, prior to and during the study period of 2002–2003 was higher than that of either 2001–2002 or the 30-year average (Table 7). More precipitation in 2002–2003 may have increased both soil moisture and suitability of well-drained upland habitats by increasing earthworm availability (Rabe et al. 1983, Owen and Galbraith 1989). The habitat shift observed during this study mirrors woodcock habitat shifts in Alabama, where woodcock used mixed pine-hardwood uplands during wet periods, and hardwood floodplains during dry periods (Horton and Causey 1974). As such, variation in precipitation levels among years may promote facultative habitat shifts by woodcock in response to improved soil moisture conditions, allowing them to periodically occupy upland areas with soils that are too well drained to provide adequate soil moisture conditions in some years.

Differences Between Used and Random Locations

Despite yearly variation in gross structural cover, soil type, and distribution of woodcock in this study, there was little variation in habitats selected by woodcock within years. Likewise, although gross structural cover values varied, woodcock habitat selection patterns were similar between years. For example, most ground cover values were similar between random and used locations within each year, and although not statistically significant in many instances, the direction of most comparisons was similar between years. Conversely, the direction that understory and horizontal cover values changed for used and random locations differed between years, again reflecting the variation in distribution of woodcock on the study site.

Often, the availability of bare soil will partially explain woodcock selection patterns. However, in this study, bare soil proportions were similar between used and random locations within each year and our values (range 2.3–5.1%) are lower than those of other studies. Glenn et al. (2004), working on the ABWMA during winter, reported bare soil values of 14–23 % at nocturnal woodcock locations and 6–15% at random locations. Studies in other geographic regions have reported more bare ground at woodcock locations, even in habitats described as poor or avoided altogether. For example, Wishart and Bider (1976) found that good habitat in Quebec averaged 87% bare ground, whereas poor habitat averaged 56%. Woodcock in Pennsylvania selected areas of 12–17% bare ground and avoided areas with <2% bare ground (Straw et al. 1986). In Alabama, Horton and Causey (1979) found that woodcock activity centers had 53% open ground cover (i.e., void of standing

Table 7. Precipitation (cm) records (NOAA 2006) during fall and winter of 2001–2002 and 2002–2003 in Lufkin, Angelina County, Texas.

Month	Average 1971–72 to 2000–01	2001–2002	2002–2003
October	8.41	10.03	21.44
November	9.78	8.79	21.34
December	9.96	14.20	23.93
January	11.30	10.87	1.65
February	8.05	5.54	14.68
March	8.97	18.97	8.66
Total	56.46	68.40	91.69

vegetation). Beyond sampling differences among these studies, low values of bare ground and low grass cover values observed in this study may reflect the woodcock's propensity to select relatively open ground-level diurnal habitat with relatively high amounts of understory and horizontal covers (*sensu* Boggus and Whiting 1982).

Like bare ground cover, amounts of leaf litter, grass, and herbaceous cover did not vary between used and random locations. Although leaf litter cover values were relatively high in both years and similar to those reported in Glenn et al. (2004), our results are inconclusive and generally support Morgenweck's (1977) conclusion that woodcock use sites with varying levels of litter. During this study, woodcock locations had less grass cover (approx. 10%) than random locations (approx. 15%). These values are slightly lower than those of Glenn et al. (2004), although dissimilarities between these studies may reflect differential habitat use diurnally (this study) and nocturnally (Glenn et al. 2004). However, relatively high grass cover hinders woodcock movement (Boggus and Whiting 1982) and reduces available foraging substrate (Berdeen and Krementz 1998), whereas such grass cover may provide protection from nocturnal predators.

Understory and horizontal cover values were lower at woodcock locations than random locations in 2001–2002, but were higher and lower, respectively, in 2002–2003, reflecting a shift from floodplain to upland sites between years. Floodplain stands were dominated by early hardwood successional vegetation whereas upland stands were dominated by pines, thus the variation in these metrics. Conversely, overhead cover was lower at woodcock locations than random locations in both years; this was the only consistent variation in inter-year structural cover. Despite numerous inconsistencies between years, it appears that woodcock select habitats with little direct overhead cover and with varying amounts of both structural and ground cover. Such habitats may be more reflective of stand structure, residual litter, and vegetative characteristics within the stands than specific features that woodcock seek. As such, woodcock appear to select diurnal habitats based upon the entire vegetation profile and structure as well as the presence of near-ground openings. However, their occupancy or presence in a particular habitat may be facultative based upon soil moisture and precipitation conditions prior to and during winter in east Texas.

Habitat Use Between Sexes and Seasons

As with used versus random comparisons, there were few differences in habitat use between males and females in either year. These results are similar to Krementz and Pendleton (1994), who also found gross similarities between male and female habitat use in winter in Georgia, South Carolina, and Virginia. Although these similarities exist, evidence of female nesting activities initiating in January in east Texas (Whiting et al. 2005) may alter comparisons of habitat use between sexes in late winter and early spring. Although understory and horizontal covers declined at woodcock locations over time during this study, there were no sex x season interactions, indicating that woodcock did not change microhabitat selection during late winter and early spring. This is relevant as we demonstrated that male and female woodcock generally selected microhabitat similarly throughout the late winter and early spring even as habitat conditions changed.

MANAGEMENT IMPLICATIONS

East Texas forested habitats are important for wintering American woodcock (Kroll and Whiting 1977, Boggus and Whiting 1982, Whiting and Boggus 1982). In this study, different moisture regimes allowed for a facultative shift from floodplain habitats to upland habitats between years. Although gross structural habitat changed between years, as reflected in the general distribution of woodcock, early successional ground cover vegetation types were consistent microhabitat features of used habitat in both years. Moreover, although seasonal changes in microhabitats occurred, male and female woodcock selected habitats similarly over time, indicating that structural habitat management for woodcock can be accomplished without consideration of sex during winter. Subtle differences occurred between 1) male and female microhabitats and 2) used and random microhabitats, but dramatic changes in precipitation and subsequent soil moisture conditions between years likely drove the habitat use patterns observed in this study.

From a management perspective, suitable soil moisture conditions are dependent upon precipitation prior to and during winter. However, managers can provide the early successional structure by encouraging frequent disturbance in order to create and maintain woodcock habitat in almost every seral stage of forest. Creation and maintenance of pioneer communities (e.g., young pine plantations, abandoned pastures) permits development of suitable vegetative structure, where mowing, prescribed fire, and other techniques can be used to maintain less-dense areas for access and escape routes. Timber harvesting activities disturb understory vegetation and simultaneously reduce overhead cover, allowing more sunlight to reach the forest floor. Interspersing thinned and completely harvested stands will result in habitat variety suitable for woodcock during winter. Future research on diurnal habitat of American woodcock in east Texas should examine woodcock use of different habitat types as directly related to precipitation, soil moisture variability, and earthworm availability.

ACKNOWLEDGMENTS

J. Broussard, J. R. Glenn, J. LaRue, J. T. Steele, A. E. Thomas, M. A. Watson, K. K. Webb, and J. R. Williamson provided field and laboratory assistance. S. E. Richardson and L. A. Whiting assisted with manuscript preparation. Funding was provided by the Arthur Temple College of Forestry and Agriculture at Stephen F. Austin State University and the U.S. Fish and Wildlife Service.

LITERATURE CITED

Berdeen, J. B., and D. G. Krementz. 1998. The use of fields at night by wintering American woodcock. Journal of Wildlife Management 62: 939–947.

Berry, C. B. 2006. Characteristics of diurnal microhabitat used by adult American woodcock in east Texas. Thesis, Stephen F. Austin State University, Nacogdoches, Texas, USA.

Boggus, T. G., and R. M. Whiting, Jr. 1982. Effects of habitat variables on foraging of American woodcock wintering in east Texas. Pages 148–153 *in* T. J. Dwyer and G. L. Storm, editors. Woodcock ecology and management. U.S. Fish and Wildlife Service, Wildlife Research Report 14.

Canfield, R. H. 1941. Application of the line interception method in sampling range vegetation. Journal of Forestry 39: 388–394.

Conner, R. N., S. D. Jones, and G. D. Jones. 1994. Snag condition and woodpecker foraging ecology in a bottomland hardwood forest. Wilson Bulletin 106: 242–257.

Dessecker, D. R., and S. R. Pursglove, Jr. 2000. Current population status and likely future trends for American woodcock. Pages 3–8 *in* D. G. McAuley, J. G. Bruggink, and G. F. Sepik, editors. Proceedings of the Ninth American Woodcock Symposium. U.S. Geological Survey, Biological Resources Division Information and Technology Report USGS/BRD/ITR-2000-0009, Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Dolezel, R., and C. Fuchs. 1980. Soil survey of Nacogdoches County, Texas. U.S. Department of Agriculture, Soil Conservation Service and Forest Service, in cooperation with the Texas Agricultural Experiment Station, College Station, Texas, USA.

Dwyer, T. J., D. G. McAuley, and E. L. Derleth. 1983. Woodcock singing-ground counts and habitat changes in the northeastern United States. Journal of Wildlife Management 47: 772–779.

Dyer, J. M., and R. B. Hamilton. 1977. Analyses of several site components of diurnal woodcock habitat in southern Louisiana. Pages 51–62 *in* D. M. Keppie and R. B. Owen, Jr., editors. Proceedings of the Sixth Woodcock Symposium. Fredericton, New Brunswick, Canada.

Glenn, J. R., R. M. Whiting, Jr., and J. P. Duguay. 2004. Microhabitat characteristics of nocturnal roost sites of American woodcock in east Texas. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 58: 302–311.

Horton, G. I., and M. K. Causey. 1974. Telemetric studies of woodcock in east central Alabama. Pages 1–12 *in* Proceedings of the Fifth Woodcock Workshop. Athens, Georgia, USA.

Horton, G. I., and M. K. Causey. 1979. Woodcock movements and habitat utilization in central Alabama. Journal of Wildlife Management 43: 414–420.

Ito, K., and W. Schull. 1964. On the robustness of the T^2 test in multivariate analysis of variance when variance-covariance matrices are not equal. Biometrika 51: 71–82.

Johnson, R. A., and D. W. Wichern. 2002. Applied multivariate statistical analysis. Prentice-Hall, Upper Saddle River, New Jersey, USA.

Kelley, J. R., Jr., and R. D. Rau. 2006. American woodcock population status, 2006. U.S. Fish and Wildlife Service, Laurel, Maryland, USA.

Krementz, D. G., and G. W. Pendleton. 1994. Diurnal habitat use of American woodcock wintering along the Atlantic Coast. Canadian Journal of Zoology 72: 1945–1950.

Kroll, J. C., and R. M. Whiting. 1977. Discriminant function analysis of woodcock winter habitat in east Texas. Pages 63–72 *in* D. M. Keppie and R. B. Owen, Jr., editors. Proceedings of the Sixth Woodcock Symposium. Fredericton, New Brunswick, Canada.

Martin, F. W. 1964. Woodcock age and sex determination from wings. Journal of Wildlife Management 28: 287–293.

McAuley, D. G., J. R. Longcore, and G. F. Sepik. 1993. Techniques for research into woodcocks: experiences and recommendations. Pages 5–11 *in* J. R. Longcore and G. F. Sepik, editors. Proceedings of the Eighth American Woodcock Symposium. U.S. Fish and Wildlife Service Biological Report 16. Washington, D.C., USA.

Morgenweck, R. O. 1977. Diurnal high use areas of hatching-year female American woodcock. Pages 155–160 *in* D. M. Keppie and R. B. Owen, Jr., editors. Proceedings of the Sixth Woodcock Symposium. Fredericton, New Brunswick, Canada.

Olson, C. L. 1976. On choosing a test statistic in multivariate analysis of variance. Psychology Bulletin 83: 579–586.

Owen, R. B., Jr., J. M. Anderson, J. W. Artmann, E. R. Clark, T. G. Dilworth, L. E. Gregg, F. W. Martin, J. D. Newsom, and S. R. Pursglove. 1977. American woodcock (*Philohela minor* = *Scolopax minor* of Edwards 1974). Pages 149–186 *in* G. C. Sanderson, editor. Management of migratory shore and upland game birds in North America. International Association of Fish and Wildlife Agencies, Washington D.C., USA.

Owen, R. B., and W. J. Galbraith. 1989. Earthworm biomass in relation to forest types, soil, and land use: implications for woodcock management. Wildlife Society Bulletin 17: 130–136.

Rabe, D. L., H. H. Prince, and E. D. Goodman. 1983. The effect of weather on bioenergetics of breeding American woodcock. Journal of Wildlife Management 47: 762–771.

Rieffenberger, J. C., and R. C. Kletzly. 1967. Woodcock night-lighting techniques and equipment. U.S. Bureau of Sport Fisheries and Wildlife, Special Science Report-Wildlife, Number 101.

Roberts, T. H., E. P. Hill, and E. A. Gluesing. 1984. Woodcock utilization of bottomland hardwoods in the Mississippi Delta. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 38: 137–141.

Sepik, G. F., and E. L. Derleth. 1993. Habitat use, home range size, and patterns of moves of the American woodcock in Maine. Pages 41–49 *in* J. R. Longcore and G. F. Sepik, editors. Proceedings of the Eighth American Woodcock Symposium. U.S. Fish and Wildlife Service Biological Report 16. Washington, D.C., USA.

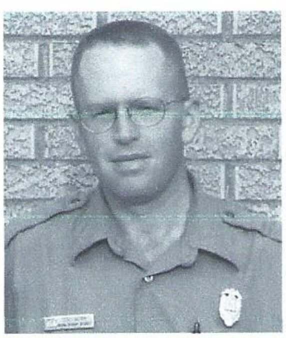
Straw, J. A., Jr., J. S. Wakeley, and J. E. Hudgins. 1986. A model for management of diurnal habitat for American woodcock in Pennsylvania. Journal of Wildlife Management 50: 378–383.

Whiting, R. M., Jr., and T. G. Boggus. 1982. Breeding biology of American woodcock in east Texas. Pages 132–138 *in* T. J. Dwyer and G. L. Storm, editors. Woodcock ecology and management. U.S. Fish and Wildlife Service, Wildlife Research Report 14.

Whiting, R. M., Jr., D. A. Haukos, and L. M. Smith. 2005. Factors affecting January reproduction of American woodcock in Texas. Southeastern Naturalist 4: 639–646.

Wishart, R. A., and J. R. Bider. 1976. Habitat preferences of woodcock in southwestern Quebec. Journal of Wildlife Management 40: 523–531.

Zar, J. H. 1996. Biostatistical analysis. Prentice-Hall, Upper Saddle River, New Jersey, USA.



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Not Pictured

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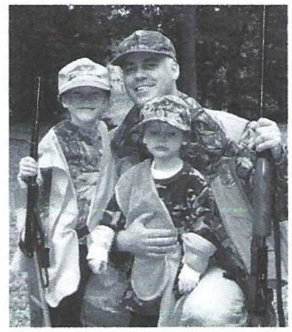

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