Distribution and Habitat Use of Swainson's Warblers in Eastern and Northern Arkansas[1]

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Abstract

Systematic surveys of hardwood forests along the Buffalo National River, the St. Francis Sunken Lands Wildlife Management Area, St. Francis National Forest, Bayou Meto Wildlife Management Area, and the White River National Wildlife Refuge in eastern and northern Arkansas were undertaken between 5 April and 30 June 2000 and 2001 to document current status, distribution, and habitat requirements of Swainson's Warblers (_Limnothlypis swainsonii_) in Arkansas. Swainson's Warblers (SWWAs) were detected at 16 sites in deciduous forests at the Buffalo National River, 11 locations at the St. Francis National Forest, 19 sites at the White River National Wildlife Refuge, and 10 sites in bottomland habitat at the St. Francis Sunken Lands. We measured vegetation characteristics at 48 SWWA detection sites and at 48 randomly located sites. At the Buffalo National River, sites occupied by SWWAs showed a significantly (P < 0.001) greater leaf litter cover ($\bar{x}$ = 59.5 percent) than random sites ($\bar{x}$ = 41.1 percent). When comparing warbler detection sites with random sites at the St. Francis Sunken Lands, there was no significant difference for any variable, which probably reflected the limited sample size. In the St. Francis National Forest, shrub cover (8.9 percent) and shrub stem density (14.1/m^2) were greater at SWWA detection sites than in random plots (1.1 percent and 3.1/m^2, respectively). Several differences were found at the White River National Wildlife Refuge, including greater canopy cover, leaf litter cover and shrub stem density, but lower total green cover and forb cover at sites with SWWAs than at random sites. Based on the pooled data set, SWWA detection sites differed significantly (P < 0.05) from random sites by having greater shrub cover ($\bar{x}$ = 13.3 percent vs. 10 percent), leaf litter cover ($\bar{x}$ = 69.5 percent vs. 51.0 percent), canopy cover ($\bar{x}$ = 89.3 percent vs. 80.9 percent), and stem density ($\bar{x}$ = 10.9/m^2 vs. 5.1/m^2). Using logistic regression, we found stem density and leaf litter cover to be significantly (P < 0.05) associated with the occupancy probability of SWWAs at a specific site. The model correctly assigned detection and random sites for 73 of 96 samples (76 percent). Management suggestions to improve habitat for SWWAs include implementing individual tree and small-group selection cutting in appropriate deciduous habitat and controlled burning in decadent cane stands. To develop effective conservation strategies, further investigation into the demographic patterns (e.g., reproductive success and survival), especially related to different habitat and landscape situations occupied by this species, is critically needed.

Key words: Arkansas, distribution, habitat modeling, _Limnothlypis swainsonii_, management, Swainson's Warbler.

Introduction

Historically a common species in its appropriate habitat (Morse 1989), the Swainson's Warbler (_Limnothlypis swainsonii_) is classified as one of 64 bird taxa having high regional conservation priority in the southeastern U.S. (Hunter et al. 2001). Both the Southeast and Midwest Working Group for Partners in Flight ranked the Swainson's Warbler (SWWA) as of high management concern in these respective regions of the U.S. (Hunter et al. 1993, Thompson et al. 1993). Based on these and other reports, the Swainson's Warbler has been placed on the National Audubon Society Watch-List (Audubon WatchList 2002) and is identified as a species of extremely high priority by the American Bird Conservancy (2001).

Within their breeding range, SWWAs typically inhabit bottomland hardwood forests with cane (_Arundinaria_ spp.) in the Southeast, lowland forests in Maryland (Meanly 1971), rhododendron (_Rhododendron_ spp.) - laurel (_Kalmia latifolia_) thickets in the Appalachian Mountains in West Virginia (Brown and Dixon 1994), and bay swamps and pocosins in the coastal plain of South Carolina (P. Hamel, pers. comm.). In Louisiana, SWWAs also have been found in dense unthinned mid-age pine plantations (A. Bassett, pers. comm.).

An estimated 70 to 84 percent of bottomland hardwood and riparian forests have been lost since European settle-

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ment in the southeastern U.S. (Turner et al. 1981, Mitch and Gosslink 1993, Noss et al. 1995, White et al. 1998). These areas have been converted to farmland, reservoirs, industrial parks, and urban centers. The surviving remnant forests are significantly influenced by levee construction, river channelization, agricultural runoff, cattle grazing, timber extraction, nonindigenous species invasion, and fragmentation (Pashley and Barrow 1992, White et al. 1998, Graves 2001). The loss of southeastern bottomland hardwoods is estimated to be five times greater than the loss of other major hardwood forest types in the U.S. (Abernethy and Turner 1987). This probably has resulted in an even greater reduction in bird populations associated with this habitat due to the effects of fragmentation (Pashley and Barrow 1992) and has contributed to the extinction and extirpation of several species (e.g., Ivory-billed Woodpecker [*Campephilus principalis*], Carolina Parakeet [*Conuropsis carolinensis*], and Bachman's Warbler [*Vermivora bachmanii*]; Remson 1986, White et al. 1998).

Within bottomland forests, cane, the most typical vegetation type associated with SWWA habitat (Thomas 1994) is critically endangered (White et al. 1998). Deforestation of river floodplains for agriculture and livestock production, construction of flood control reservoirs, and fire suppression (Steyermark 1963, Marsh 1977, Thomas 1994, White et al. 1998) have spared only remnant patches of this native "bamboo" in the Southeast (Noss et al. 1995).

Current and historical information on status and distribution of SWWAs in Arkansas is limited. Widmann (1895) found the SWWA as a breeding bird in canebrakes in the St. Francis Sunken Lands of southeastern Missouri and northeastern Arkansas in the late 1800s and early 1900s. Meanly (1971) reported the species in the lower White River bottoms, at the East Moon Lake and Scrubgrass Bayou areas, and along the Arkansas River between the mouth of Bayou Meto and Pendelton Ferry. Observations at White River National Wildlife Refuge in 1980 showed SWWAs to be fairly common in areas dominated with an understory of cane, which was found throughout the refuge (James and Neal 1986). Singing males were found in hardwood timber stands in the Saline River bottoms in Franklin County, in the northwest along the White River, and at Buffalo Point, Buffalo National River (James and Neal 1986).

Recent reports from northeast Arkansas are extremely scarce. Between 1966 and 1998 Breeding Bird Survey (BBS) results for SWWAs showed a nonsignificant annual decline of 17 percent in Arkansas (Sauer et al. 2000). Due to the low abundance of birds and the relatively low number of BBS stops adjacent to streams and rivers, however, this result may not reflect SWWA population trends accurately in Arkansas (see Smith et al. 1993).

Developing management strategies that will successfully reverse declines of this species requires identification of the habitat factors that are associated with viable populations. However, information on SWWA population size, its distribution, habitat requirements, breeding biology, and reproductive success in Arkansas is limited (James and Neal 1986; Graves 1992, 2002; Brown and Dixon 1994; Thomas 1994; Stotz et al. 1996). To begin to identify some of these habitat and population information needs, the aims of this research were (1) to obtain information on the occurrence and extent of SWWA distribution within the Buffalo National River, the St. Francis Sunken Lands Wildlife Management Area, St. Francis National Forest, Bayou Meto Wildlife Management Area, and the White River National Wildlife Refuge in eastern and northern Arkansas; and (2) to collect quantitative information on vegetation structure and characteristics to distinguish SWWA detection sites from randomly-located sites.

Study Areas

Swainson's Warbler surveys were conducted at the Buffalo National River (BNR), St. Francis Sunken Lands (SFSL) Wildlife Management Area (WMA), St. Francis National Forest (SFNF), Bayou Meto Wildlife Management Area (BMWMA), and White River National Wildlife Refuge (WRNWR) in eastern and northern Arkansas from 5 April to 30 June during both 2000 and 2001 (*fig. 1*).

BNR lies primarily in Newton and Searcy counties in northwestern Arkansas, south of Harrison. The area encompasses 38,475 ha of open farmland, oak-hickory forests, bluffs, and box canyons bisected by 217 km of the free-flowing Buffalo River.

SFSL is located in Greene, Craighead, and Poinsett counties in northeastern Arkansas, east of Jonesboro. The area comprises approximately 10,400 ha of Arkansas Game and Fish Commission land, of which the majority lies within the main levees of the St. Francis River. It represents one of the largest contiguous tracts of bottomland hardwood forest remaining in northeastern Arkansas.

SFNF is situated in Lee and Phillips counties in east central Arkansas near the cities of Helena and Marianna. The 8,500 ha of upland and bottomland forest are bordered by the Mississippi and St. Francis Rivers to the east and include Crowley's Ridge to the west.

BMWMA is located in Arkansas and Jefferson counties in east central Arkansas south of Stuttgart and west of DeWitt. The management area encompasses 13,648 ha of bottomland hardwood forest and marshes and is managed by the Arkansas Game and Fish Commission.

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Figure 1— Locations of five survey areas—Buffalo National River (BNR), St. Francis Sunken Lands (SFSL) Wildlife Management Area (WMA), St. Francis National Forest (SFNF), Bayou Meto Wildlife Management Area (BMWMA), and White River National Wildlife Refuge (WRNWR)—and Cut-off Creek Wildlife Management Area, where habitat data at occupied Swainson's Warbler sites were collected in Arkansas in 2000 and 2001.

WRNWR is located in Arkansas, Phillips, and Monroe Counties in eastern Arkansas near the town of St. Charles. The refuge is the largest contiguous bottom-land hardwood forest in the Mississippi Alluvial Valley under one ownership, encompassing 62,775 ha within the floodplain of the lower White River. The Grande Prairie borders the refuge to the west.

During a bird identification workshop with Arkansas Game and Fish Commission personnel, J. Bednarz and workshop participants located one SWWA incidentally in an upland area at Cut-off Creek Wildlife Management Area on 16 May 2000. Cut-off Creek Wildlife Manage-ment Area is located in southeastern Arkansas in Drew County just southwest of Dumas, AR (*fig. 1*). This 3,645 ha management area consists mainly of bottomland hardwood forest with some upland forest. No SWWAs were detected in the bottomland habitats at this site.

Methods

Broadcast surveys for SWWAs were conducted along primitive roads, All Terrain Vehicle (ATV) paths, hiking trails, and along waterways. All broadcast samp-ling along roads and trails was accomplished between sunrise and 12:00 noon. Audio output was set on high so that human observers could hear the broadcast from 50-70 m away on a day with clear atmospheric condi-tions. Along terrestrial survey routes, sampling sites

were spaced approximately 200 m apart. SWWA primary song (cassette tapes prepared from Walton and Lawson 1989) was broadcast from a dual-speaker cassette player (Emerson PD 6509) perpendicular to the trail for 90 s at each sample site. Observations of SWWAs were recorded for 60 s after the broadcast. The cassette player was turned and positioned to the other side of the road or trail and the sequence repeated. In addition to land surveys, sampling along the BNR and the St. Francis River also took place from a canoe between sunrise and 12:00 noon and between 15:00 and 19:00. Broadcasts were directed perpendicu-lar to the river at the shoreline, with sampling sites spaced approximately 400 m apart on both banks of the river.

Coordinates of all SWWA detection sites were recorded with a GPS receiver and their elevation and distance to water measured on DeLorme USA 3-D TopoQuads 3.0 topographic maps (Yarmouth, Maine). Surveyed distances on trails and on water in the BNR area were measured on topographical maps for the west (Trails Illustrated 1999) and east (Trails Illustrated 1997) halves of the BNR. The DeLorme software package was used to measure survey routes on the St. Francis River and in Compartment 22 in SFSL by the use of a digital map wheel. Distance of surveyed trails in SFSL was determined by taking measurements on

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USGS 7.5-minute topographic maps of the Hatchie Coon Quadrangle (SFSL).

Vegetation characteristics were measured at BNR, SFNL, and WRNWR between 3 and 21 July 2000 and 28 June and 12 July 2001. Following BBIRD Field Protocol procedures (Martin and Conway 1994), quantitative measures of vegetation characteristics were recorded within 5-m and 11.3-m radius plots located at SWWA detection sites and nearby randomly-located sites.

We divided the 5-m radius plot into four quadrants and within each we estimated the percent cover of leaf litter, green grass, shrubs, forbs, bare ground, logs, fern, moss, dead grass, and water. A mean of the four estimates from each quadrant was used in the analysis. Of all the variables measured, moss cover was encountered only at two sites, fern and dead grass cover on one site, and water cover did not occur on any site in 2001. Therefore, these variables were omitted from the analysis. Depth of leaf litter and organic matter was measured at 1 m, 3 m, and 5 m from the center of the plot in each quadrant only in 2001. A small hole was dug down into the soil to where leaf litter was no longer visible and the height of the decomposed material was measured with a ruler positioned vertically.

To assess percent total canopy closure, four densiometer readings were taken, turning 90º between readings. Plot aspect was determined by taking a compass azimuth reading facing downslope from the highest elevation of the 5-m plot. Using a clinometer, the slope was measured in degrees across the 5-m radius plot from the bottom to top of the plot. Woody stems less than 50 cm in height were counted in 1-m^2 plots 3 m from the center of the plot in each of the quadrants. In each quadrant, ocular estimates of the average top heights of shrubs were made (only in 2001) and a mean of the four estimates used in the analysis. The dominant (≥40 percent) and the subdominant shrub species (≥40 percent) were identified to genus.

Within the 11.3-m radius plot, all trees were identified to genus, diameters measured at breast height (dbh), and recorded in size classes (saplings = <2.5 cm in diameter and >30 cm in height; poles = 2.5-8 cm; tree diameter classes = 8-23 cm, 23-38 cm, and >38 cm). The smallest two size classes were classified as understory and the largest three as overstory. The average crown height of trees was estimated and measured with a clinometer (only in 2001). The dominant (≥40 percent) and the sub-dominant (≥40 percent) tree species were identified. Snags >12 cm dbh and taller than 1.4 m were counted.

The vegetation sampling procedure was undertaken at random plots established 0 to 250 m from the detection sites. To locate plots, a random digit between 0 and 9 selected from a random-number table was multiplied by 36. The resulting number represented the azimuth from the detection site. Three random digits between 0 and 250 were selected for the distances from the detection plot.

In addition to SWWAs detected during our fieldwork, Dawn Dumtra (University of Georgia, pers. comm.) reported a singing SWWA in deciduous forest along a secondary road at the WRNWR. Vegetation measurements were taken at this detection site and the data were included in the analysis.

We first checked vegetation variables for normality by plotting the data and using a Kolmogorov-Smirnov test. If data were normally distributed, we then applied two-sample t-test to compare variables between SWWA detection sites and random sites. A Mann-Whitney U-test was used if data were not normally distributed. However, we presented means for all comparisons because we suggest this measure of central tendency may be more biologically meaningful to SWWAs than medians. To adjust for multiple comparisons, we employed a Bonferroni correction and set significance for statistical tests at α = 0.025. A one-way Analysis of Variance (ANOVA) at Tukey's family error rate of 0.05 was used to compare variables between detection and random sites from four different study areas: BNR, SFSL, SFNF, and WRNWR. Because the majority of the variable means were similar between the four study sites, the data were pooled to maximize the sample size. Mean estimates of habitat variables collected at four detection and four random sites at BNR in 2000 were obviously different than estimates based on a larger sample of data collected in 2001. These differences probably reflected unusually high water levels encountered at the BNR in 2000; water levels were relatively normal in 2001. Therefore, 2000 data (4 detection and 4 random sites) from BNR were omitted in the analysis.

A binary logistic regression was performed to predict the probability that SWWAs would use a habitat based on vegetation characteristics. After examination of the data and univariate statistical results, we eliminated all variables that showed a weak relationship (P > 0.1) either with plots used by SWWAs or with random plots. Also, highly correlated vegetation variables (P < 0.05) were removed. We retained the variable that we felt was most meaningful in terms of providing for the habitat needs of the SWWA based on the literature and our knowledge of the species. After we eliminated the correlated variables, we were left with three variables to include in the logistic regression model: leaf litter cover, stem density, and canopy cover. Initial analyses of vegetation data indicated that candidate models developed to predict SWWA occupancy were only moderately successful. Therefore, we decided to pool the entire data set of 96 sites (48 occupied and 48 random

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sites) to develop the best predictive model with the available data. However, in using this approach we could not withhold a sub-sample of the data to test a model developed on another subset of the data. Alternatively, we performed logistic regression analysis on the full model and all subsets of the full model using Minitab. To determine the best habitat model that related habitat variables to occupancy of SWWAs, we calculated Akaike's Information Criterion (AIC) for each model (Christensen 1997). The lowest AIC value should indicate the model that has the best fit with the data.

Results

Distribution

We surveyed 241.9 km of rivers in the Buffalo National River, from Pruitt to Buffalo City, and in the St. Francis Sunken Lands Wildlife Management Area for SWWAs (*table 1*). In addition, we hiked and surveyed with standardized broadcast sampling at locations every 200 m along 230.9 km of primitive roads or trails at our five survey areas (*table 1*). Even though previously-published reports (Widemann 1895, Meanly 1971, James and Neal 1986) indicated that SWWAs were present and relatively common histori-cally at all these study areas, our recent surveys revealed an extremely low frequency of scattered warbler detections (*table 1*).

In the BNR area, 16 SWWAs were detected: 12 detec-tions were in deciduous forest with cane understory, three in deciduous habitat without cane association, and one bird was found in red cedar (*Juniperus* sp.) stands. In SFSL, SWWAs responded at ten sites, seven of which were located in hardwood forests on Hatchie Coon Island. Three detection sites were situated in hardwood-cypress forests near Hatchie Coon Lake on the east side of Hatchie Coon Island. On three occa-sions in May before fledglings should have been present, when two SWWAs were sighted together, we assumed them to be mated. Each pair exchanged soft "chip" calls and were observed feeding in leaf litter next to each other. Presumed females (not singing) were difficult to follow and we often lost view of them quickly after they were detected. Males, on the other hand, were often observed flying to a perch where they sang, sometimes repeatedly.

We detected 11 SWWAs in the SFNF, all in bottom-land forest habitat, with no cane present. No SWWAs responded during our survey of BMWMA. In the WRNWR, we detected 18 SWWAs, 13 in bottomland forest and 5 in canebrakes. On the refuge, the mean elevation of occupied sites ($\bar{x}$ = 49.2 m, se = 0.30, N = 18) was significantly higher (P < 0.001) than random sites ($\bar{x}$ = 47.1, se = 0.30, N = 40).

Habitat and Vegetation Characteristics

Vegetation characteristic differences between detection sites and randomly-located sites at the BNR (*table 2*) were only significant (P < 0.025) for leaf litter cover ($\bar{x}$ = 59.5 percent at detection sites vs. $\bar{x}$ = 41.1 percent at random sites). We detected no significant differences when comparing other vegetation variables, but some trends were apparent (*table 2*). Limited sample size may have precluded statistical significance in some cases.

In the SFSL, measured characteristics between detec-tion sites and random sites did not show statistically-significant differences (*table 3*). Again, we attribute the lack of statistical trends to small sample sizes.

Two differences were observed in the vegetation char-acteristics that were measured at SFNF between warb-ler and random sites. Specifically, shrub cover ($\bar{x}$ = 8.9 percent) and shrub stem density ($\bar{x}$ = 14.1/m^2) were significantly greater at sites with SWWAs compared to random locations (*table 4*).

Table 1— *Distances surveyed and number of detections of Swainson's Warblers within selected study areas in Arkansas.*

Study area	Distance of trails surveyed (km)	Distance of river surveyed (km)	Number of Swainson's Warbler detections
Buffalo National River (BNR)	51.7	226.6	16
St. Francis Sunken Lands Wildlife Management Area (SFSL)	45.2	15.3	10
St. Francis National Forest (SFNF)	13.4	0	11
Bayou Meto Wildlife Management Area (BMWMA)	22.5	0	0
White River National Wildlife Refuge (WRNWR)	98.1	0	18
Cut-off Creek Wildlife Management Area	0	0	1

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Table 2— *Mean vegetation characteristics measured at Swainson's Warbler detection sites and random sites at the Buffalo National River, Arkansas in 2001.*

| Characteristics | Detection sites (N = 12) | | Random sites (N = 12) | | | |
	Mean	se	Mean	se	P-values	Test[a]
Green cover (%)	47.6	8.5	47.8	7.5	0.986	t
Shrub cover (%)	15.6	2.5	19.3	4.2	0.470	t
Grass cover (%)	12.1	4.7	11.4	3.2	0.665	MW
Forb cover (%)	19.9	4.9	16.7	4.5	0.633	t
Leaf litter cover (%)	59.5	8.5	41.1	10.0	<0.001[*]	MW
Bare ground cover (%)	7.7	2.3	17.5	6.1	0.158	t
Downed log cover (%)	5.6	1.5	5.4	1.7	0.928	t
Canopy cover (%)	90.9	3.3	84.9	5.2	0.073	MW
Leaf litter depth (mm)	21.5	4.7	15.3	4.9	0.298	MW
Stem density (m^2)	8.3	3.4	7.2	2.2	0.840	MW
Understory tree density (ha)	780	231	785	175	0.986	t
Overstory tree density (ha)	584	76	814	126	0.135	t
Snag density (ha)	12.9	6.0	7.8	5.6	0.534	t
Mean shrub height (m)	2.4	0.3	3.2	1.7	0.124	MW
Mean tree height (m)	9.1	0.8	10.5	1.2	0.348	t

[*]Indicates a significant difference of (P ≤ 0.025).
[a] t = Two sample t-test, MW = Mann-Whitney U-test.

Table 3— *Mean vegetation characteristics measured at Swainson's Warbler detection sites and random sites in the St. Francis Sunken Lands Wildlife Management Area, Arkansas in 2001.*

| Characteristics | Detection sites (N = 10) | | Random sites (N = 10) | | | |
	Mean	se	Mean	se	P-values	Test[a]
Green cover (%)	20.6	3.4	24.8	6.5	0.969	MW
Shrub cover (%)	15.3	3.5	17.9	4.8	0.663	t
Grass cover (%)	2.5	0.8	2.9	1.8	0.410	MW
Forb cover (%)	2.9	0.7	4.0	2.2	0.672	MW
Leaf litter cover (%)	82.6	3.7	77.0	5.8	0.427	t
Bare ground cover (%)	2.9	2.1	5.0	2.6	0.871	MW
Downed log cover (%)	7.8	1.0	8.0	1.6	0.897	t
Canopy cover (%)	95.5	0.5	96.0	0.8	0.643	t
Leaf litter depth (mm)	40.3	3.0	33.9	4.0	0.140	MW
Stem density (m^2)	10.6	3.8	4.7	1.2	0.198	MW
Understory tree density (ha)	1135	210	1032	276	0.772	t
Overstory tree density (ha)	784	136	911	159	0.623	MW
Snag density (ha)	12.4	5.1	6.2	4.1	0.473	MW
Mean shrub height (m)	1.6	0.1	1.3	0.2	0.299	t
Mean tree height (m)	13.5	1.7	11.3	1.2	0.345	MW

[a] t = Two sample t-test, MW = Mann-Whitney U-test.

At WRNWR, both green cover ($\bar{x}$ = 31.0 percent) and forb cover ($\bar{x}$ = 49.7 percent) were significantly less at sites with SWWAs than measured in random plots (57.1 percent and 19.6 percent, respectively). Conversely, leaf litter cover (70.0 percent vs. 50.4 percent), canopy cover (88.3 percent vs. 72.0 percent), and shrub stem density (9.6/m^2 vs. 4.7/m^2) were greater at sites with warblers compared to random locations (*table 5*).

Comparison of vegetation characteristics at BNR detection sites with SFSL sites (*table 6*) revealed percent green cover ($\bar{x}$ = 47.6 percent) and percent forb cover ($\bar{x}$ = 19.9 percent) at the BNR were significantly higher than at the SFSL sites ($\bar{x}$ green cover = 20.6 percent and $\bar{x}$ forb cover = 2.9 percent). Also, leaf litter depth ($\bar{x}$ = 21.5 mm, se = 4.7) was significantly lower at BNR detection sites compared with sites at SFSL ($\bar{x}$ = 40.3 mm, se =3.0).

Percent leaf litter cover ($\bar{x}$ = 59.5 percent at BNR vs. $\bar{x}$ = 82.6 percent at SFSL) showed a trend towards statistical significance (P = 0.026; t-test) as did percent

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Table 4— *Mean vegetation characteristics measured at Swainson's Warbler detection sites and random sites in the St. Francis National Forest, Arkansas in 2000.*

	Detection sites (N = 10)		Random sites (N = 10)			
Characteristics	**Mean**	**se**	**Mean**	**se**	**P-values**	**Test[a]**
Green cover (%)	31.7	5.2	42.1	8.1	0.299	t
Shrub cover (%)	8.9	2.5	1.1	1.1	0.006[*]	MW
Grass cover (%)	2.4	1.2	6.6	1.7	0.264	t
Forb cover (%)	21.9	5.7	33.5	7.1	0.222	t
Leaf litter cover (%)	67.1	5.2	43.6	11.1	0.078	t
Bare ground cover (%)	8.8	2.9	25.9	10.2	0.137	t
Downed log cover (%)	2.7	0.7	3.5	2.2	0.741	t
Canopy cover (%)	85.5	2.2	80.6	3.5	0.309	t
Leaf litter depth (mm)	40.3	3.0	33.9	4.0	0.140	MW
Stem density (m^2)	14.1	2.6	3.1	0.7	0.002[*]	t
Understory tree density (ha)	338	78	262	53	0.484	t
Overstory tree density (ha)	364	31	476	59	0.143	t
Snag density (ha)	5.0	5.0	7.5	5.3	0.448	MW

[*]Indicates a significant difference of ($P \leq 0.025$).
[a] t = Two sample t-test, MW = Mann-Whitney U-test.

Table 5— *Mean vegetation characteristics measured at Swainson's Warbler detection sites and random sites in the White River National Wildlife Refuge, Arkansas in 2000.*

	Detection sites (N = 14)		Random sites (N = 14)			
Characteristics	**Mean**	**se**	**Mean**	**se**	**P-values**	**Test[a]**
Green cover (%)	31.0	3.9	57.1	5.8	0.005[*]	MW
Shrub cover (%)	9.2	3.5	3.5	2.4	0.195	t
Grass cover (%)	2.5	1.2	4.1	1.7	0.472	t
Forb cover (%)	19.6	3.5	49.7	5.3	<0.001[*]	MW
Leaf litter cover (%)	70.0	2.8	50.4	5.2	0.003[*]	MW
Bare ground cover (%)	3.2	1.0	4.2	1.4	0.574	t
Downed log cover (%)	4.6	1.8	1.6	0.4	0.128	t
Canopy cover (%)	88.3	2.2	72.0	3.5	0.003[*]	MW
Stem density (m^2)	9.6	1.1	4.7	0.9	0.001[*]	MW
Understory tree density (ha)	310	70	159	41	0.102	MW
Overstory tree density (ha)	278	31	347	30	0.124	t
Snag density (ha)	14.2	6.2	17.8	4.8	0.448	MW

[*]Indicates a significant difference of ($P \leq 0.025$).
[a] t = Two sample t-test, MW = Mann-Whitney U-test.

grass cover ($\bar{x}$ = 12.1 percent at BNR vs. $\bar{x}$ = 2.5 percent at SFSL) with P = 0.031 (t-test). When comparing random sites, we found the percent green cover ($\bar{x}$ = 47.8 percent), grass cover ($\bar{x}$ = 11.4 percent), and percent forb cover ($\bar{x}$ = 16.7 percent) were significantly higher (P < 0.025) at BNR sites than at SFSL sites ($\bar{x}$ green cover = 24.8 percent, $\bar{x}$ grass cover = 2.9 percent, and $\bar{x}$ forb cover = 4.0 percent). Percent leaf litter cover ($\bar{x}$ = 41.1 percent), canopy cover ($\bar{x}$ = 84.9 percent), and leaf litter depth ($\bar{x}$ = 15.3 mm) were significantly (P < 0.025) lower at BNR sites than at SFSL sites ($\bar{x}$ leaf litter cover = 77.0 percent, $\bar{x}$ canopy cover = 96.0 percent, and $\bar{x}$ leaf litter depth = 33.9 mm). The mean shrub height was higher at BNR

sites ($\bar{x}$ = 2.4 m) than at SFSL ($\bar{x}$ = 1.6 m; P = 0.033). The mean tree height was lower at BNR ($\bar{x}$ = 9.1 m) than at SFSL ($\bar{x}$ = 13.5 m; P = 0.036).

Several variables were found to differ among study areas sampled in 2000 and 2001. Vegetation characteristics with mean values that most frequently differed among sites included the percent green foliage cover, canopy cover, understory tree density, and overstory tree density for both SWWA detection sites (*table 6*) and random sites (data not shown). However, we only noted consistent patterns among sites for three variables. Specifically, grass cover tended to be greater at BNR ($\bar{x}$ = 12.1 percent) compared to other sites, densities of understory trees (>700 trees/ha) and overstory trees (>550

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trees/ha) were greater at BNR and SFSL than at SFNF and WRNWR (means <300 and 450 trees/ha, respectively; *table 6*). Data are not shown for random sites, but patterns were very similar. None of these variables seemed to be related statistically to the presence or absence of SWWAs at a particular habitat. Moreover, we observed none of the mean estimates measured to vary consistently between the two years that we collected vegetation data. Therefore, we suggest that some differences among the different study sites were to be expected and there were no systematic measurement biases among the data collected at the different study areas. We believe the lack of consistent biases in the habitat data among sites and between years allows us to pool the data to look for general patterns.

To maximize the sample size and to identify common characteristics at SWWA detection sites, we pooled the 2001 data (BNR, SFSL, and WRNWR) with the data collected in 2000 (Cut-off Creek Wildlife Management Area, SFNF, and WRNWR). Using the pooled data set, we found significantly greater (P < 0.05) percent of shrub cover ($\bar{x}$ = 13.3 percent), leaf litter cover ($\bar{x}$ = 69.5 percent), canopy cover ($\bar{x}$ = 89.3 percent), and stem density ($\bar{x}$ = 10.9/m^2) at SWWA detection sites than at random sites ($\bar{x}$ shrub cover = 10.0%; $\bar{x}$ leaf litter cover = 51.0%; $\bar{x}$ canopy cover = 80.9%; $\bar{x}$ stem density = 5.1/m^2; *table 7*). The mean distance of SWWA detection sites to water was 227 m (se = 56, N = 12) for BNR and 321 m (se = 80, N = 10) for SFSL. The mean elevation of

warbler locations was 203.3 m (se = 18, N =12) for BNR and 67.3 m (se = 0.4, N = 10) for SFSL.

Binary Logistic Regression

We evaluated all variables for potential inclusion in a logistic regression model. However, we only retained three uncorrelated variables (see Methods) that based on the literature and our knowledge of the species, were likely important to SWWA habitat selection: leaf litter cover, shrub stem density, and canopy cover. Of all possible model variations with these three variables, the full model including stem density, leaf litter cover, and canopy cover had the lowest AIC value (4.0). This model was significant (G^2 = 106.64, P < 0.001; *table 8*) and predicted SWWA occupied and random sites correctly in 76.04% of the cases. The Hosmer-Lemeshow lack-of-fit test (Chi-square = 9.63, df = 8, P = 0.292) indicated that the data did not significantly deviate from the model and the Goodman-Kruskal statistic (0.61) revealed a reasonable association between the actual and predicted classification of the 96 samples. The two-variable model that performed almost as well (AIC = 4.8) as the full model included stem density and leaf litter (G^2 = 109.43, P < 0.001; *table 8*). The Hosmer-Lemeshow lack-of-fit test (Chi-square = 11.24, df = 8, P = 0.189) indicated a more questionable fit between the data and the model, but the association between the actual and predicted classification of sites was relatively good (Goodman-Kruskal statistic = 0.58).

Table 6— *Mean vegetation characteristics measured at Swainson's Warbler detection sites at the Buffalo National River and the St. Francis Sunken Land Wildlife Management Areas, Arkansas in 2001, and in the St. Francis National Forest and the White River National Wildlife Refuge, Arkansas in 2000. Locations with the same letters did not differ significantly (P < 0.05) from each other.*

Characteristics	Buffalo National River (N = 12) Mean		St. Francis National Forest (N = 10) Mean		St. Francis Sunken Lands (N = 10) Mean		White River National Wildlife Refuge (N = 14) Mean	
Green cover (%)	47.6	a	31.7	b	20.6	c	31.0	b, c
Shrub cover (%)	15.6	a	8.9	a	15.3	a	9.2	a
Grass cover (%)	12.1	a	2.4	b	2.5	b	2.5	b
Forb cover (%)	19.9	a	21.9	a	2.9	b	19.6	a
Fern cover (%)	0	a	0.6	a	0	a	0	a
Leaf litter cover (%)	59.5	a	67.1	a	82.6	a	70.0	a
Bare ground cover (%)	7.7	a	8.8	a	2.9	a	3.2	a
Downed log cover (%)	5.6	a	2.7	a	7.8	a	4.6	a
Water cover (%)	0	a	0	a	0	a	0.8	a
Canopy cover (%)	90.9	a	85.0	b	95.5	c	88.3	a
Stem density (m^2)	8.3	a	14.1	a	10.6	a	9.6	a
Understory tree density (ha)	780	a	264	b	1135	c	310	b
Overstory tree density (ha)	584	a, b	339	a, c	784	b	278	c
Snag density (ha)	12.9	a	5.0	a	12.4	a	14.2	a

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Table 7— *Mean vegetation characteristics measured at Swainson's Warbler detection sites and random sites combined for the Buffalo National River, the St. Francis Sunken Lands Wildlife Management Area, and the White River National Wildlife Refuge, Arkansas in 2001, and for the Cut-off Creek Wildlife Management Area, the St. Francis National Forest and the White River National Wildlife Refuge, Arkansas in 2000.*

Characteristics	Detection sites (N = 48) Mean	se	Random sites (N = 48) Mean	se	P-values	Test[a]
Green cover (%)	34.6	3.2	43.3	3.7	0.093	MW
Shrub cover (%)	13.3	1.7	10.0	2.0	0.022[*]	MW
Grass cover (%)	5.0	1.4	6.2	1.3	0.359	MW
Forb cover (%)	16.7	2.2	26.9	3.5	0.085	MW
Fern cover (%)	0.1	0.1	0.3	0.2	0.696	MW
Leaf litter cover (%)	69.5	2.8	51.0	4.4	0.005[*]	MW
Bare ground cover (%)	5.3	1.0	14.3	3.2	0.281	MW
Downed log cover (%)	5.1	0.7	4.6	0.8	0.430	MW
Water cover (%)	0	0	0.2	0.2	0.356	t
Canopy cover (%)	89.3	1.4	80.9	2.9	0.024[*]	MW
Stem density (m^2)	10.9	1.3	5.1	0.7	<0.001[*]	MW
Understory tree density (ha)	578	93	530	93	0.764	MW
Overstory tree density (ha)	482	47	612	61	0.079	MW
Snag density (ha)	10.4	2.7	9.9	2.6	0.890	t

[*]Indicates a significant difference of ($P \leq 0.05$).
[a] t = Two sample t-test, MW = Mann-Whitney U-test.

Table 8— *Results of logistic regression model comparing 48 sites occupied with Swainson's Warblers to 48 randomly-selected sites in eastern and northern Arkansas (2000-2001).*

Parameter	Coefficient	se	P–value	Odds ratio
Full model				
Constant	4.800	1.799	0.008	
Stem density	-0.122	0.045	0.007	0.89
Leaf litter cover	-0.022	0.010	0.027	0.98
Canopy cover	-0.300	0.020	0.138	0.97
Two-variable Model				
Constant	2.460	0.709	0.001	
Stem density	-0.122	0.044	0.005	0.89
Leaf litter cover	-0.025	0.010	0.010	0.98

Discussion

During this study, the entire length of the BNR from Steel Creek to Buffalo City was surveyed at a time when SWWAs should have been active on their breeding grounds. We detected only 16 birds in this large survey area, and the majority of them were concentrated on the downstream portion (between Gilbert, AR and the confluence with the White River) of BNR. Twelve of these 16 birds were located in deciduous forested habitat with a mostly cane understory. Canebrake is considered the primary and "classic" habitat of SWWAs in the river floodplain forests and swamps of the Coastal Plain by many authors (e.g., Meanly 1971; Graves 2001, 2002). Historical records indicate that cane was formerly very abundant in the southeastern U.S. and extended northward as far as Pennsylvania (Marsh 1977). In Arkansas, cane was a

conspicuous part of bottomland and riverine landscapes during the 1800s. Early travelers reported an immense quantity in the river bottoms between the St. Francis and Mississippi Rivers (Stoddard 1812) and abundant cane in the areas around Batesville and Helena, AR (Jewell 1892). Stands of cane were described as lining the shores of the Arkansas River for hundreds of miles (Stoddard 1812) and poles reaching tree heights up to 10 m were frequently encountered (e.g., Featherstonhaugh 1844). Since then, loss of canebrakes has been dramatic in the Southeast and the canebrake habitat type is now classified as an endangered ecosystem with less than 2 percent of the original stands remaining (White et al. 1998). The loss of cane habitat might be one of the contributing factors to the current decline of SWWAs. This suggestion is supported by the fact that the present geographic ranges of cane and SWWA coincide very closely (Marsh 1977).

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Although SWWAs seem to exhibit a close affinity or as Wheeler (1924:136) states, "cling tenaciously" to cane, they are able to occupy sites with undergrowth structurally similar to "bamboo." These warblers have been found to inhabit forests with understory consisting of sweet pepperbush (*Clethra alnifolia*) in the northern part of the Atlantic Coastal Plain and scrub palmetto (*Sabal minor*) in the southern parts of the Coastal Plain. In the Appalachians, where cane is probably limited by low temperatures (Marsh 1977), SWWAs are associated with rhododendron on the moist slopes in Maryland and rhododendron, mountain laurel, hemlock (*Tsuga canadensis*), and American holly (*Ilex opaca*) in Virginia (Brown and Dixon 1994). Moreover, Graves (2002) argued that the presence of a relatively high density of SWWAs in the Whiskey Bay Pilot Channel in Louisiana, where giant cane is absent, represents strong evidence refuting cane-SWWA association hypothesis.

Mean shrub stem densities (83,000-141,000/ha) in habitats where SWWAs were found in Arkansas were extremely high, whether habitats consisted of understory shrub thickets or cane stands. This is somewhat similar to relatively high stem densities found by Graves (2002) at five locations occupied by SWWAs throughout the Southeastern U.S. However, the maximum count of understory woody stems that he recorded in a core SWWA territory was 104,710 stems/ha and median values from different study areas varied from 31,592-48,281 stems/ha (Graves 2002). Based on these data, Graves (2002) suggested that a relatively narrow range of stem densities (ca. 30,000-50,000 stems/ha) seemed to provide high-quality cover for nesting and foraging SWWAs throughout the Southeast. We suggest that the reason our stem densities are generally greater than those reported by Graves, in part, could be related to different methodology. Specifically, we counted stems in four 1-m^2 plots, whereas Graves (2002) tallied stems in single 12.6-m^2 circular plots, and these larger plots may have included more micro patches with relatively sparse shrub growth. Importantly, more work is required to determine what range of shrub stem densities support populations that are breeding and surviving successfully. Neither our study in Arkansas, or the work reported by Graves related demographic performance to habitat characteristics.

In Arkansas, we found SWWAs primarily inhabiting swampy tangles and shrub thickets along the interface between floodplains and upland forests in the SFNF and the WRNWR. Also, SWWA detection sites in the SFSL were concentrated on the slightly elevated ($\bar{x}$ = 67 m) Hatchie Coon Island, a tract of 13-16 yr old deciduous forest that in most years is not inundated during the spring flood period (C. Wilcoxson, Arkansas Game and Fish Commission, pers. comm.). Such

elevated sites in close vicinity to a permanent water source might be a critical factor to the reproductive success of SWWAs (Brown and Dixon 1994). Altered hydrology in many bottomland batture systems in Arkansas and in the southeastern U.S. results in deeper and longer flooding than under natural conditions. Thus, current hydrological conditions probably adversely impact species, including the SWWA, that nest in low vegetation (Brown and Dixon 1994). Importantly, at the higher-elevation locations within bottomland forests, broods are less likely to be destroyed by rising water in the spring or early summer (Graves 2001). In the SFSL, the nearest water to SWWA detection sites was a mean distance of 320 m. Eddlemann (1978) and Thomas (1994) found SWWAs within 200-400 m of water.

In our study, warbler detection sites were characterized by dense shrub cover, high stem density, closed canopy, and well-developed leaf litter cover relative to available random sites (*table 7*). These findings are consistent with reports that SWWAs tend to nest in the densest, darkest areas of their habitat (Meanly 1971, Graves 2001). A canopy cover of 50 percent was regarded as the minimum requirement for SWWA habitat by Eddlemann (1978), with an optimum of 80 percent or higher. Also, Thomas (1994) found warblers at sites with a mean canopy cover of 85 percent. In our study, the mean canopy cover was 89.3 percent (*table 7*). This combination of dense shrub understory and closed canopy contributes to the abundant leaf litter cover measured, that probably supports a rich invertebrate fauna. Morphologically specialized to feeding on subsurface prey, SWWA express a stereotyped method of manipulating leaf litter in search for beetles and spiders (Graves 1998, Strong 2000). Unfortunately, we only began measuring the depth of leaf litter during the second year of this study (2001) and our sample size was very limited for this variable. The data collected, however, did suggest a possible trend of a deeper layer of litter at sites where we detected SWWAs compared to random sites, albeit this pattern was not significant (*tables 2, 3*).

Habitats with deep leaf litter cover are confined to sites with a dense thicket of shrubs. Also natural flooding action in bottomland sites may contribute to the build up of dense leaf litter. In the tropics, leaf litter cover is reduced through increased desiccation resulting from forest fragmentation (Kapos 1989) or from increased radiation reaching leaf litter in early successional habitats (Lee 1989). Desiccation of SWWA habitats due to hydrological alteration in the southeastern U.S. (White et al. 1998) ultimately reducing available invertebrate prey may be another factor contributing to the species' decline. High shrub stem density and leaf litter cover were both important vegetation characteristics in our habitat model (*table 8*). Graves (2001,

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2002) also found that extensive understory thickets, greenbriar (*Similax* spp.) tangles, deep shade, including a variety of and an abundance of leaf litter typified SWWA territories in several locations of the southeastern U.S.

Despite the fact that cane shows broad ecological amplitude and can potentially occur in many different community types, including a variety of successional and some climax communities (Marsh 1977), it is increasingly rare and sizeable remaining patches are worthy of protection and in need of management. Frost (1995) has shown fire is a major factor in maintaining canebrakes throughout the southeastern U.S. Thus, carefully-controlled burning may be used to renovate decadent stands. However, Hughes (1957) reported that a completely killed-out canebrake would not restock naturally for several generations, probably due to its rhizomatous vegetative propagation. A reduction in fire frequency leads to the establishment of successional species, such as shrubs and saplings, eventually overwhelming the canebrake. Although this habitat type may not be required by SWWAs (Graves 2002, this study), the historical loss of large cane patches undoubtedly contributed to the decline of this species in the Southeast.

Management Implications

Based on our observations and findings, we propose initiation of small group selection cuts (<0.5 ha) to open up the canopy in combination with prescribed low-heat burns to regenerate remnant cane stands to reestablish potential SWWA habitat. In deciduous habitat, SWWAs have been reported to respond positively to selective cutting as long as cut areas are not excessive in size (Pashley and Barrow 1992). Graves (2002) reported that small clear cuts (as small as 0.25 ha) at a density of 25 clearcuts/km^2 may foster the establishment of SWWAs in marginal habitats in Virginia. The size of a timber harvest that may be too large and would adversely impact the SWWA population is unknown. Although Graves (2002) has suggested that clearcuts as large as 20 ha on a staggered 25-yr cutting rotation could support populations of SWWAs on agroforestry lands. At this point, we suggest that tree harvest operations on SWWA breeding grounds in bottomland hardwood habitats should be limited to individual tree or small group-selection cuts because this method more closely resembles natural disturbances and treefalls (Graves 2001). These light gap areas should promote the development of dense understory vegetation that provides critically important nesting habitat for SWWAs. To prevent direct disturbance of nesting SWWAs, timber cutting should be limited to the non-breeding season (1 October-1 April).

Larger cuts could be detrimental as this approach would enlarge forest gaps probably increasing the risk of nest predation and/or brood parasitism (Robinson et al. 1995). This could especially be important for management of forested tracts surrounded by agricultural lands and this situation is characteristic of the bottomland forest remnants throughout the Mississippi Alluvial Valley (e.g., SFNF, SFSL, and WRNWR). Meanly (1971) reported substantial brood parasitism on SWWAs by Brown-headed Cowbirds (*Molothrus ater*) at Pendelton Ferry, Arkansas in 1967. We found a single nest in the SFNF that fledged one cowbird and no warblers. We also observed cowbirds being attracted to SWWAs' primary song on a few occasions in the SFSL, but because we only located one nest, we cannot assess what the impact of cowbird parasitism is on the reproductive success of extant SWWA populations in Arkansas. Although we and others (e.g., Graves 2002) have documented the use of both understory thickets and cane habitats by SWWAs in a variety of circumstances (fragmented patches to contiguous forests), few data are available on what landscape and vegetative structural characteristics support viable vs. sink populations. Therefore, documenting demographic performance (reproductive success and survival) in differing habitat and landscape situations is vital to the development of effective management strategies and conservation policies to avoid further declines in this species.

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