Journal of Field Ornithology

J. Field Ornithol. 79(4):364–370, 2008 DOI: 10.1111/j.1557-9263.2008.00194.x

Density and habitat associations of Henslow's Sparrows wintering in saline soil barrens in southern Arkansas

William C. Holimon,[1,4] C. Theo Witsell,[1] William H. Baltosser,[2] and Catherine W. Rideout[3]

[1]*Arkansas Natural Heritage Commission, 1500 Tower Building, 323 Center Street, Little Rock, Arkansas 72201, USA*
[2]*Biology Department, University of Arkansas at Little Rock, 2801 South University Avenue, Little Rock, Arkansas 72204, USA*
[3]*Arkansas Game and Fish Commission, #2 Natural Resources Drive, Little Rock, Arkansas 72205, USA*

Received 20 December 2007; accepted 1 June 2008

ABSTRACT. Although the habitat requirements of breeding populations of Henslow's Sparrow (*Ammodramus henslowii*) have been examined, less is known about their habitat requirements and ecology during the nonbreeding season. We estimated population densities and quantified habitat associations of Henslow's Sparrows wintering in saline soil barrens in southern Arkansas. Densities of Henslow's Sparrows in the saline soil barrens were similar to those in the Longleaf Pine (*Pinus palustris*) Ecosystem of the southeastern United States, considered by many to be their primary wintering habitat. Henslow's Sparrows were closely associated with open areas with greater cover of *Aristida* spp. and globe beaksedge (*Rhynchospora globularis*), greater stem density at 11–20 cm above ground, more lichens, more herbaceous cover, more bare ground, greater occurrence of little bluestem (*Schizacyrium scoparium*) as the tallest vegetation, less moss, and less shrub cover than randomly selected sites. In contrast to the results of studies conducted in the Longleaf Pine Ecosystem, the presence of Henslow's Sparrows in our study was not correlated with the height of the tallest vegetation. Our results indicate that saline soil barrens of southern Arkansas support a high density of wintering Henslow's Sparrows and do so for longer postdisturbance periods than longleaf pine savanna. We also found that stem density near the ground was similar to that reported from longleaf pine savanna, but only about half that observed on their breeding grounds. Areas used by Henslow's Sparrows had more lichen and less moss cover, suggesting that those areas were drier than random sites within the barrens. Further research is needed to determine if large populations of Henslow's Sparrows winter in other saline soil barrens and if fire influences habitat associations and densities in the barrens.

SINOPSIS. **Densidad y asociación de hábitats en individuos *Ammodramus henslowii* que pasan el invierno en salitrales al sur de Arkansas**

Aunque los requisitos de hábitat para las poblaciones reproductivas de *Ammodramus henslowii* han sido determinadas, se conoce muy poco sobre su ecología y requerimientos de hábitat durante la temporada no-reproductiva. Estimamos la densidad poblacional y cuantificamos el hábitat asociado a Gorrión de Henslow que pasan el invierno en un salitral con suelo empobrecido en el sur de Arkansas. La densidad de las aves en el salitral resultó similar a lo encontrado en Ecosistemas de Pinos (*Pinus palustris*) en el sureste de los EUA, considerado por muchos como el principal hábitat invernal para la especie. Los gorriones estuvieron altamente asociados a áreas abiertas con covertura de *Aristida* spp. y *Rhynchospora globularis*, con mayor densidad de tallos, altura entre 11–20 cm sobre el suelo, mayor cantidad de líquenes, mayor cubierta herbácea, más suelo desnudo, mayor presencia de *Schzacyrium scoparium* (como la vegetación de mayor tamaño), menos musgos, y menos arbustos que localidades seleccionadas al azar. En contraste a los resultados de estudios conducidos en Ecosistemas de Pinos, la presencia del gorrión en nuestra área de estudio no estuvo correlacionada con la altura de la vegetación de mayor tamaño. Nuestros resultados indican que las salinas en Arkansas sostienen una alta densidad de aves invernales, y lo hacen por periodos más largos, después de disturbios, que en las savanas de pinos. También encontramos que la densidad de tallos, cerca del suelo, era similar a la informada en savanas de pinos, pero tan solo la mitad de lo indicado para lugares en donde las aves se reproducen. Las áreas utilizadas tienen más líquenes, pero menos musgos, lo que sugiere que dichas áreas son más secas que lugares con suelo empobrecido muestreados al azar. Se necesitan más trabajos para determinar si otras grandes poblaciones del gorrión de Henslow pasan el invierno en otras salinas con suelos empobrecidos y si eventos como fuegos incluyen en la asociación del hábitat y densidades en los lugares con suelo empobrecido.

Key words: *Ammodramus henslowii*, density, edaphic, habitat association, Henslow's Sparrow, saline soil barrens, winter ecology

During the breeding season, Henslow's Sparrows are typically found in large grasslands with tall, dense grass, residual standing dead vegetation, thick litter, and little woody vegetation (Herkert et al. 2002). Until recently, many

[4]Corresponding author. Email: BillH@arkansasheritage.org

investigators assumed that the wintering habitats of these sparrows had similar characteristics (Pruitt 1996, Herkert et al. 2002). However, recent studies suggest that densities of Henslow's Sparrows on their wintering grounds are highest in areas one growing season after fire (Carrie et al. 2002, Tucker and Robinson 2003, Bechtoldt and Stouffer 2005), when litter (Carrie et al. 2002) and vegetation density near the ground (Bechtoldt and Stouffer 2005) is low.

Winter habitat requirements of Henslow's Sparrows are now better understood, but studies to date have focused mainly in the Longleaf Pine (*Pinus palustris*) Ecosystem, considered by many to contain their primary wintering habitat (Bechtoldt 2002, Thatcher 2003, Bechtoldt and Stouffer 2005, Thatcher et al. 2006). Additional studies are needed to identify other wintering areas and to better understand winter habitat requirements (Pruitt 1996).

Henslow's Sparrows winter throughout the southeastern United States, primarily in pine savanna and other open habitats (Bechtoldt 2002, Thatcher 2003, Bechtoldt and Stouffer 2005, Thatcher et al. 2006). These sparrows were considered rare and irregular transient and winter visitors in Arkansas (James and Neal 1986, Pruitt 1996) until Holimon et al. (2004) documented areas in southern Arkansas that regularly support wintering populations of Henslow's Sparrows, primarily in saline soil barrens. However, the densities of and habitat use by sparrows in these populations are poorly understood. Thus, our objectives were to estimate population densities and quantify habitat associations of Henslow's Sparrows wintering in saline soil barrens in southern Arkansas.

METHODS

Study area. Our study was conducted in the saline soil barrens of Warren Prairie Natural Area (WPNA), an 878-ha preserve owned and managed by the Arkansas Natural Heritage Commission and The Nature Conservancy. WPNA is located 11 km southeast of Warren in Bradley and Drew counties in southern Arkansas and consists of a mosaic of open saline soil barrens, Delta post oak (*Quercus similis*) flatwoods, mound upland woodlands, saline marsh, loblolly (*P. taeda*)-shortleaf (*P. echinata*) pine woodlands, and bottomland hardwood forest communities (Arkansas Natural Heritage Commission 2006).

We delineated all saline soil barrens in the WPNA using aerial photographs; barrens area totaled 44.25 ha ($\bar{x} = 0.84 \pm 0.13$ [SE] ha, range = 0.04–3.82 ha, $N = 53$). Vegetation ranged from areas dominated by the perennial grasses little bluestem (*Schizacyrium scoparium*) and long-spike tridens (*Tridens strictus*) in areas of deeper or more productive soils to areas with no vascular plant cover in the most edaphically extreme areas of saline subsoil outcrops. Intermediate areas make up most of the barrens and were dominated by annual grasses and forbs, particularly prairie three-awn (*Aristida oligantha*), lanceleaf ragweed (*Ambrosia bidentata*), rough buttonweed (*Diodia teres*), St. Johns-wort (*Hypericum drummondii*), and perennials such as needleleaf rosette grass (*Dichanthelium aciculare*), rushes (*Juncus* spp.), and globe beaksedge (*Rhynchospora globularis*).

Bird surveys. We conducted surveys for Henslow's Sparrows from 19 January 2006 to 28 February 2006 by walking transects spaced approximately 5 m apart in all 53 saline soil barrens. We placed a yellow flag where each Henslow's Sparrow first flushed and noted where they landed to minimize double counting. After each barrens was surveyed, we used a Global Positioning System (GPS) to record the coordinates of each flush location. Using ArcView GIS 3.2, a unique polygon for each barrens was generated, the area (ha) determined, and locations where birds flushed were plotted. One to three individuals conducted surveys, with one individual involved with all surveys and responsible for confirming the identification of each Henslow's Sparrow. Tucker and Robinson (2003) found that one person was as effective as four when sampling Henslow's Sparrows in small bogs similar in size to the barrens in our study. Because lower densities tend to be recorded in larger areas (Gaston et al. 1999), we used 2–3 individuals to conduct transects in the largest barrens ($\geq$ 1.25 ha). Each barrens was surveyed once.

Density. We estimated densities of Henslow's Sparrows and examined the pattern of time since last burn on those densities. At the time of our study, WPNA contained three burn units that differed in time since last burn. The North Unit (Year-2 sites; $\bar{x} = 0.98 \pm 0.19$ [SE] ha, range = 0.07–3.51 ha; $N = 27$ barrens) had two growing seasons since the last burn, the East Unit (Year-3 sites;

$\bar{x} = 0.78 \pm 0.13$ [SE], range = 0.16–1.58, $N = 13$) had three growing seasons since the last burn, and the South Unit (Year-≥6 sites; $\bar{x} = 0.59 \pm 0.16$ [SE], range = 0.04–3.82, $N = 13$) had at least six growing seasons since the last burn.

We estimated density (total number of individuals divided by barrens area) for all barrens by calculating mean density within and then across the three units that differed in time since the last burn. We assumed that Henslow's Sparrows were restricted to the barrens where they were observed because of separation of barrens by forests and woodlands and the nearest distance between barrens ($\bar{x} = 70.75 \pm 0.74$ [SE] m). This assumption is supported by recent studies that show Henslow's Sparrows have small winter home ranges, high within-year site fidelity, and exhibit limited, localized movements within a winter (Plentovich et al. 1998, Thatcher 2003, Bechtoldt and Stouffer 2005).

Vegetation sampling. We measured vegetation at the first 30 plots where Henslow's Sparrows initially flushed and at 30 random plots from 19 February 2006 to 15 March 2006. Random plots were selected from randomly generated coordinates located throughout all saline soil barrens within WPNA. We estimated vegetation structure and species composition by sampling vegetation in 5-m-radius plots centered at each vegetation plot. Flush plots were located in 13 barrens ($\bar{x} = 1.57 \pm 0.32$ [SE] ha, range = 0.33–3.82 ha) and random plots in 19 barrens ($\bar{x} = 1.45 \pm 0.27$ [SE], range = 0.13–3.82 ha). Overall, 25 barrens were sampled for vegetation; seven had both flush and random plots and five random points were located in barrens that had no Henslow's Sparrows detected. Flush ($N = 13$ Year-2 plots, $N = 12$ Year-3, and $N = 5$ Year-≥6) and random ($N = 16$ Year-2 plots, $N = 9$ Year-3, and $N = 5$ Year-≥6) plots had similar burn histories. We did not examine the effect of time since last burn on Henslow's Sparrow habitat associations.

We used a modified version of the methods used by Bechtoldt and Stouffer (2005) to measure vegetation structure and species composition. We used a 5-m radius plot instead of 10-m to increase the likelihood that, for flush sites, we were measuring habitat used by Henslow's Sparrows. We used a 2-m pole marked in 10-cm increments to measure vegetation height, species of tallest vegetation, and vegetation density for all flush and random locations. We centered the vegetation plot at a flush or random location and sampled vegetation at the center point and at every 1 m in each of the four cardinal directions for a total of 21 points. We measured vegetation height by placing the 2-m pole at each point and recorded the height and species of the tallest vegetation within 30-cm. We estimated density by placing the 2-m pole at each point and counted the number of contacts with vegetation in each 10-cm increment. We also recorded the presence/absence of moss and lichen within a 30-cm radius of the pole and measured litter depth. For each vegetation plot, we measured the distance to edge, the number of saplings, trees, and shrubs, the most numerous canopy tree and shrub species, and visually estimated the percentage cover of shrubs and trees. We defined edge as forests, woodlands, or gravel road.

To further characterize vegetation structure and species composition, we estimated percent cover in a 1-m^2 grid located at the center point for six variables: bare ground, thatch, herbaceous, moss, lichen, and woody vegetation. We estimated the percentage cover of all grasses and forbs in the 1-m^2 grid and identified them to either species or genus.

Vegetation and statistical analysis. We compared the vegetation characteristics of flush and random plots. For each plot, the five data points from each of the four cardinal directions were averaged, reducing these 20 values to four. These four values and the one value (emphasis placed on site of known occurrence) obtained from the middle of the plot (i.e., the central point from which the four quadrants were established) were then averaged to produce a single value per plot for each variable. Values for 41 variables were thus established for both flush ($N = 30$) and random plots ($N = 30$).

All 41 variables were subjected to Principal Component Analysis (PCA; Proc PRINCOMP, SAS 2003) to assess their usefulness in characterizing and distinguishing random from flush plots. Of 41 variables, 22 were initially deemed to be informative based on their loadings (Pearson Product-Moment Correlation – r_p) with respect to the first three components. These 22 variables were then examined for intercorrelations and those most highly correlated (e.g., the greatest = 0.82) were systematically eliminated

Table 1. Means and loadings of habitat variables on the first three components that best explained differences in vegetation characteristics between flush and random plots*.

	Mean ± SE		Principal components		
Variable	Flush sites	Random sites	I	II	III
Aristida spp. (percent cover)	36.97 ± 5.51	20.13 ± 5.40	**0.4575**	0.1246	−0.1808
Lichen (percent frequency of occurrence)	27.63 ± 4.36	11.70 ± 3.41	**0.4470**	−0.0513	−0.2130
Shrubs (percent cover)	0.17 ± 0.12	1.77 ± 0.54	**−0.4303**	0.3230	0.1239
Density 11–20 cm (number of contacts)	2.22 ± 0.15	1.38 ± 0.12	**0.4186**	0.2545	0.1267
Bare ground (percent cover)	5.33 ± 1.20	9.40 ± 2.54	−0.0494	**−0.5952**	−0.3724
Moss (percent cover)	3.00 ± 0.80	10.97 ± 2.95	−0.3427	**0.4324**	−0.1997
Globe beaksedge (percent cover)	1.37 ± 0.24	0.87 ± 0.22	−0.0812	−0.3024	**0.5480**
Little bluestem (percent frequency of occurrence)	35.38 ± 5.76	22.52 ± 4.91	0.0425	−0.2718	**0.5354**
Herbaceous (percent cover)	83.63 ± 3.27	80.40 ± 4.69	0.3198	0.3259	**0.3537**

* PC1 = 25%, PC2 = 19%, and PC3 = 15%; total variation accounted for = 59%; bold numbers indicate variables that are most strongly correlated with each principal component.

using a reverse step-wise process of deletion. At the completion of this process, only nine of the original 41 variables remained (Table 1). Values are presented as mean ± SE.

RESULTS

Winter density. We detected 73 Henslow's Sparrows in 29 barrens ($\bar{x}$ area = 1.26 ± 0.19 ha, range = 0.13–3.82 ha). Mean densities were 1.43 ± 0.35 individuals/ha for all barrens, 2.30 ± 0.13 individuals/ha for Year-2 sites, 1.71 ± 0.11 individuals/ha for Year-3 sites, and 0.27 ± 0.04 individuals/ha for Year-$\geq$6 sites. We detected Henslow's Sparrows in 23% of the Year-$\geq$6 barrens, compared to 69% of Year-3 sites and 67% of Year-2 sites.

We found a significant, but weak, inverse relationship between time since burn and density of Henslow's Sparrows ($r_p = -0.36$, $P = 0.008$). We also found a significant positive correlation between barrens area and Henslow's Sparrow abundance ($r_p = 0.76$, $P < 0.001$). Further, in areas burned within 3 yrs, we were least likely to detect at least one Henslow's Sparrow in barrens $\leq$0.2 ha, whereas at least one Henslow's Sparrow was detected in all barrens >1.25 ha (Fig. 1).

Vegetation structure and species composition. The first three components of PCA accounted for 59% of the variation between flush and random sampling plots (Table 1, Fig. 2). Approximately 25% of the variation was due to flush plots having greater percent cover of *Aristida* spp., greater stem density between the height of 11–20 cm, greater occurrence of lichen, and fewer shrubs. Flush sites had more bare ground and less ground cover by moss than random plots, explaining an additional 19% of the variation. PC3 accounted for 15% of the variation, with flush sites having more little bluestem as the tallest vegetation and greater cover of globe beaksedge. Although more little bluestem as the tallest vegetation was important in separating sites, the mean height of little bluestem did not differ between flush ($\bar{x}$ = 82.07 ± 0.39 cm) and random ($\bar{x}$ = 81.97 ± 0.72 cm) sites. Flush ($\bar{x}$ = 67.26 ± 0.48 cm)

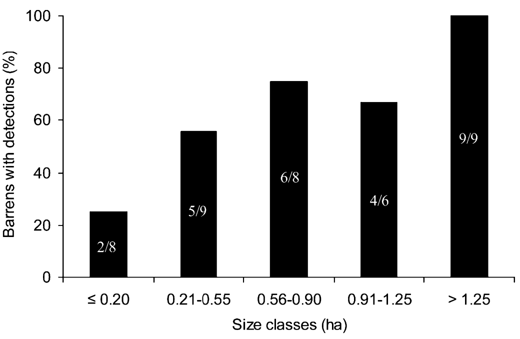

Fig. 1. The likelihood of detecting at least one Henslow's Sparrow in barrens burned within 3 yrs was greater for barrens larger than 0.20 ha.

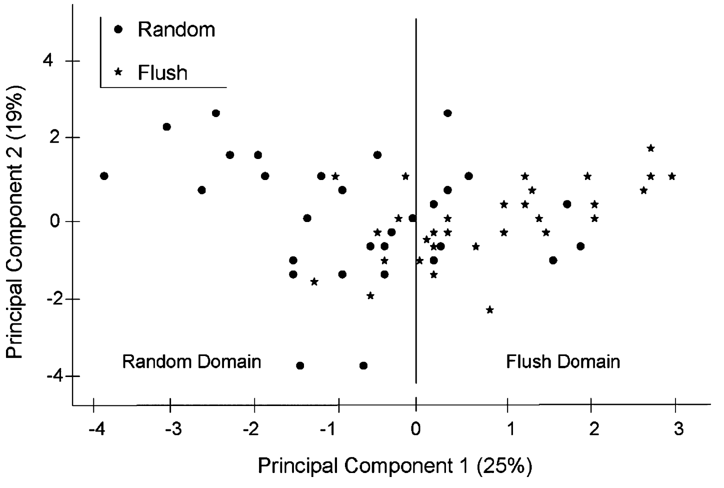

Fig. 2. Scatter plot of PCA scores for flush and random locations. Flush plots had greater cover of *Aristida* spp. and globe beaksedge, higher stem density in the 11–20 cm height strata, and less shrub cover with respect to PC1 than random plots. Flush plots had more bare ground and less moss than random plots with respect to PC2.

and random ($\bar{x}$ = 63.75 ± 0.44 cm) sites also did not differ in the mean height of the tallest vegetation. Litter depth did not differ between flush ($\bar{x}$ = 0.83 ± 0.1 cm) and random ($\bar{x}$ = 1.07 ± 0.13 cm) sites.

DISCUSSION

Winter density. Densities of Henslow's Sparrows in the saline soil barrens at WPNA in southern Arkansas were similar to those in longleaf pine savanna habitat in the southeastern United States (Bechtoldt 2002, Bechtoldt and Stouffer 2005), considered by several investigators to be their primary wintering habitat (Bechtoldt 2002, Thatcher 2003, Bechtoldt and Stouffer 2005, Thatcher et al. 2006). The mean density of Henslow's Sparrows in the saline soil barrens was similar to that in pine savanna habitat of southeastern Louisiana ($\bar{x}$ = 1.17 ± 0.32 (SE) individuals/ha; Bechtoldt and Stouffer 2005). Consistent with prior investigations (Carrie et al. 2002, Tucker and Robinson 2003, Bechtoldt and Stouffer 2005), densities in our study were highest in the most recently burned sites. However, the weak relationship we observed between time since burn and densities of Henslow's Sparrows may be more attributable to site differences. Additional studies that quantify and control for site differences are needed to better assess this relationship.

Densities of Henslow's Sparrows in barrens with two growing seasons since the last burn were similar to those in longleaf pine savanna with only one growing season since the last burn. In addition, densities in barrens with three growing seasons since the last burn were nearly twice as high as those in longleaf pine savanna with only two growing seasons since the last burn. Differences in edaphic conditions may help explain this pattern. Grasses and forbs grow slower and with less vigor in the saline soil barrens than in less saline soils (Horn 1962, U.S. Fish and Wildlife Service 1993), such as those in longleaf pine savanna. Edaphic conditions may thus maintain suitable habitat for longer periods and support high densities of Henslow's Sparrows for longer postdisturbance periods.

We detected more Henslow's Sparrows in larger barrens. In areas with two or three growing seasons since the last burn, the likelihood of detecting at least one Henslow's Sparrow was greater for barrens larger than 0.2 ha. Similarly, Tucker and Robinson (2003) found a greater percentage of bogs larger than 0.25 ha were occupied by Henslow's Sparrows. In addition, we detected at least one Henslow's Sparrow in all barrens >1.25 ha with two or three growing seasons since last burn.

Habitat structure and composition. Wintering Henslow's Sparrows in our study were associated with a matrix of open saline soil barrens within a forested complex. Henslow's Sparrows were found in areas of the barrens with greater cover of *Aristida* spp. and globe beaksedge, greater cover of the overall herbaceous layer, greater stem density at 11–20 cm heights, more little bluestem as the tallest vegetation, and less shrub cover than randomly selected sites. Areas where sparrows were detected also had more lichens, more bare ground, and less moss. Although Henslow's Sparrows occurred in areas with greater stem density near the ground than random sites, those densities were about one-half that reported in their breeding habitat (Reinking et al. 2000). Bechtoldt and Stouffer (2005) also found that wintering Henslow's Sparrows were most abundant in areas with low vegetation density near (<30 cm) the ground, and the stem densities they reported were similar to ours.

More little bluestem as the tallest vegetation was important in predicting Henslow's Sparrow presence in the barrens. The presence of tall grass was also an important predictor of Henslow's Sparrow presence in longleaf pine savanna (Bechtoldt and Stouffer 2005). However, we found that flush and random sites did not differ in the mean height of the tallest vegetation. In addition, in contrast to Carrie et al. (2002), we found no difference between flush and random sites in litter depth. However, there is generally little litter in the barrens and edaphic conditions may result in less litter for longer periods than in longleaf pine savanna. We did find a positive correlation between the amount of bare ground and the presence of Henslow's Sparrows. Similarly, Carrie et al. (2002) suggested that more open substrates with little or no litter were important for Henslow's Sparrows searching for seeds on the ground and their preference for walking or running rather than flying.

We found that Henslow's Sparrow flush sites had more cover of *Aristida* spp. and globe beaksedge. Studies in longleaf pine savanna habitat have revealed that *Aristida* spp. and toothache grass (*Ctenium aromaticum*) often dominated sites where wintering Henslow's Sparrows were observed (Fuller 2004, Bechtoldt and Stouffer 2005, DiMiceli 2006, Thatcher et al. 2006). Henslow's Sparrows winter in other saline soil barrens in southern and eastern Arkansas and at two airports in central Arkansas with large patches of *Aristida* spp (Holimon et al. 2004, WCH and CWR, unpubl. data). Fuller (2004) suggested that *Aristida* spp. is likely more important in providing habitat structure because *Aristida* spp. seeds comprised a small part of the winter diet of Henslow's Sparrows in southern Mississippi. However, in southeast Louisiana, DiMiceli (2006) found that *Aristida* spp. seeds were frequently consumed. Globe beaksedge seeds were found to be a common food item for Henslow's Sparrows in southern Mississippi (Fuller 2004), but not southeast Louisiana (DiMiceli 2006).

The hydroxeric, saline soils of the barrens favor annuals and drought-tolerant perennials. For example, rough buttonweed and the three species of *Aristida* (*A. dichotoma*, *A. longespica*, and *A. oligantha*) that occur in the saline soil barrens are annuals (Diggs et al. 1999). In contrast, forbs and grasses in longleaf pine savanna habitat are primarily perennials (Kirkman et al. 2001) and likely either dependent on or benefit from fire for seed production (Christensen 1977, Clewell 1989, Fuller 2004). In saline soil barrens, *Aristida* spp. and rough buttonweed produce seed crops annually regardless of fire history, and edaphic conditions maintain low-density vegetation for longer periods between fires, reducing competition that could limit seed production by some perennials. Seed production and habitat structure in the saline soil barrens are thus not as dependent on disturbance and may be more constant over time than in longleaf pine savanna.

Our results indicate that saline soil barrens of southern Arkansas support a high density of wintering Henslow's Sparrows and do so for longer postdisturbance periods than longleaf pine savanna. We also found that stem density near the ground was similar to that reported from longleaf pine savanna but only about one-half that observed on their breeding ground. Percent cover of *Aristida* spp. was the most important factor predicting Henslow's Sparrow presence in the barrens whereas tallest vegetation height, unlike other investigations, was not an important characteristic. We observed Henslow's Sparrows in areas with more lichen and less moss, which suggests they were drier than randomly selected sites. Further research is needed to determine if large populations of

Henslow's Sparrows winter in other saline soil barrens and if fire influences habitat associations and densities within the barrens.

ACKNOWLEDGMENTS

We thank D. Reinking, D. Wiedenfeld, D. Wolfe, R. Rohrbaugh, Jr, and the G.M. Sutton Avian Research Center for sharing data from a breeding season habitat study conducted in northeast Oklahoma. We thank H. Ford for randomizing vegetation plots and C. Osborne and S. Winningham for assistance in spatial analyses. The manuscript benefited from reviews by P. Stouffer, two anonymous reviewers, and the editor (G. Ritchison). This research was supported by U.S. Fish and Wildlife Service State Wildlife Grant T-16.

LITERATURE CITED

ARKANSAS NATURAL HERITAGE COMMISSION. 2006. Arkansas Natural Heritage Commission Annual Report 2006. Little Rock, AR.

BECHTOLDT, C. L. 2002. Habitat use by wintering Henslow's Sparrows *(Ammodramus henslowii)* in relation to fire management. M.S. thesis, Southeastern Louisiana University, Hammond, LA.

———, AND P. C. STOUFFER. 2005. Home-range size, response to fire, and habitat preferences of wintering Henslow's Sparrows. Wilson Bulletin 117: 211–225.

CARRIE, N. R., R. O. WAGNER, K. R. MOORE, J. C. SPARKS, E. L. KEITH, AND C. A. MELDER. 2002. Winter abundance of and habitat use by Henslow's Sparrows in Louisiana. Wilson Bulletin 114: 221–226.

CHRISTENSEN, N. L. 1977. Fire and soil-plant nutrient relations in a pine-wiregrass savanna on the coastal plain of North Carolina. Oecologia 31: 27–44.

CLEWELL, A. F. 1989. Natural history of wiregrass (*Aristida stricta* Michx., Gramineae). Natural Areas Journal 9: 223–233.

DIGGS, G. M., JR, B. L. LIPSCOMB, AND R. J. O'KENNON. 1999. Illustrated flora of north central Texas. Botanical Research Institute of Texas, Fort Worth, TX.

DIMICELI, J. K. 2006. Winter diet, seed preferences and foraging behavior of Henslow's Sparrows (*Ammodramus henslowii*) in southeastern Louisiana. M.S. thesis, Louisiana State University, Baton Rouge, LA.

FULLER, G. T. 2004. Diet of Henslow's Sparrows *(Ammodramus henslowii)* wintering in pine savannas of coastal Mississippi. M.S. thesis, Georgia Southern University, Statesboro, GA.

GASTON, K. J., T. M. BLACKBURN, AND R. D. GREGORY. 1999. Does variation in census area confound density comparisons? Journal of Applied Ecology 36: 191–204.

HERKERT, J. R., P. D. VICKERY, AND D. E. KROODSMA. 2002. Henslow's Sparrow *(Ammodramus henslowii)*. In: The birds of North America, no. 672 (A. Poole, and F. Gill, eds). The Birds of North America, Philadelphia, PA.

HOLIMON, W. C., R. H. DOSTER, D. A. JAMES, M. L. MLODINOW, J. C. NEAL, AND W. M. SHEPHERD. 2004. First documentation that Henslow's Sparrow regularly occurs during the breeding and wintering seasons in Arkansas. Journal of the Arkansas Academy of Science 58:111–116.

HORN, M. E. 1962. Saline-alkali soils in Arkansas. Arkansas Farm Research volume XI, number 2: 10.

JAMES, D. A., AND J. C. NEAL. 1986. Arkansas birds, their distribution and abundance. University of Arkansas Press, Fayetteville, AR.

KIRKMAN, L. K., R. J. MITCHELL, R. C. HELTON, AND M. B. DREW. 2001. Productivity and species richness across an environmental gradient in a fire-dependent ecosystem. American Journal of Botany 88: 2119–2128.

PLENTOVICH, S., N. R. HOLLER, AND G. E. HILL. 1998. Site fidelity of wintering Henslow's Sparrows. Journal of Field Ornithology 69: 486–490.

PRUITT, L. 1996. Henslow's Sparrow status assessment. U.S. Fish and Wildlife Service, Bloomington, IN.

REINKING, D. L., D. A. WIEDENFELD, D. H. WOLFE, AND R. W. ROHRBAUGH, JR. 2000. Distribution, habitat use, and nesting success of Henslow's Sparrow in Oklahoma. Prairie Naturalist 32: 219–232.

SAS INSTITUTE. 2003. SAS software version 9.1. SAS Institute, Cary, NC.

THATCHER, B. S. 2003. Impacts of prescribed burns on Henslow's Sparrow winter home range and survival in coastal pine savanna habitats. M. S. thesis, University of Arkansas, Fayetteville, AR.

———, D. G. KREMENTZ, AND M. S. WOODREY. 2006. Henslow's Sparrow winter-survival estimates and response to prescribed burning. Journal of Wildlife Management 70: 198–206.

TUCKER, J. W., AND W. D. ROBINSON. 2003. Influence of season and frequency of fire on Henslow's Sparrows *(Ammodramus henslowii)* wintering on Gulf Coast pitcher plant bogs. Auk 120: 96–106.

U.S. FISH AND WILDLIFE SERVICE. 1993. Recovery plan for *Geocarpon minimum* (MacKenzie). U. S. Fish and Wildlife Service, Atlanta, GA.