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RECLAIMED COAL MINE GRASSLANDS AND THEIR SIGNIFICANCE FOR HENSLOW'S SPARROWS IN THE AMERICAN MIDWEST

ROBB A. BAJEMA,[1] TRAVIS L. DEVAULT,[2] PETER E. SCOTT, AND STEVEN L. LIMA[3]

Department of Life Sciences, Indiana State University, Terre Haute, Indiana 47809, USA

ABSTRACT.—Present methods of surface coal-mine reclamation in the Midwest produce large grasslands, some of which exceed 2,000 ha in extent. Total "mine grassland" production in southwestern Indiana alone is well in excess of 70 square miles (180 km^2). Our work in 19 reclaimed coal mines in southwestern Indiana indicates that mine grasslands harbor many Henslow's Sparrows (*Ammodramus henslowii*). We base that conclusion on point-count and line-transect surveys that yielded between 200–300 singing male Henslow's Sparrows during the 1997 and 1998 breeding seasons. Those survey results imply an uncorrected population density of ~0.10 males per hectare, and a corrected density of ~0.16 males per hectare (correcting for undetected males). Extrapolating this corrected density to total habitat coverage suggests an overall population of a few thousand Henslow's Sparrows in the mine grasslands of southwestern Indiana. Small-scale vegetational surveys suggest that much of the within-mine variation in Henslow's Sparrow abundance reflects local vegetative structure, with males preferring sites typically associated with that species of bird: tall, dense grass-dominated vegetation with a substantial litter layer. Management for this kind of vegetative structure could greatly increase the number of Henslow's Sparrows inhabiting reclaimed mines. Midwestern mine grasslands could play a significant role in stabilizing the populations of Henslow's Sparrows and other grassland birds. *Received 23 August 1999, accepted 5 February 2001.*

FEW LARGE POPULATIONS of Henslow's Sparrows (*Ammodramus henslowii*) are known to exist, especially east of the Mississippi River (Pruitt 1996). Our study, however, indicates that reclaimed surface coal-mine grasslands in southwestern Indiana harbor such populations of Henslow's Sparrows. Grassland birds have been recorded in the reclaimed surface mines of Appalachia (Whitmore and Hall 1978, Whitmore 1980, Allaire 1981, Wray et al. 1982), including Henslow's Sparrows (Peterjohn and Rice 1991; see also Koford 1999), but the conservation potential of mine grasslands in general is far from being completely evaluated. In fact, it appears that large mine grasslands of the Midwest have gone virtually unnoticed by avian biologists. Hence, our overall goal was to evaluate those midwestern mines as potential habitat for Henslow's Sparrows, and in doing so, derive basic estimates of population density and size.

The potential importance of mine grasslands for Henslow's Sparrows reflects the fact that midwestern grasslands (native or otherwise) have declined precipitously in the last 150 years (Samson and Knopf 1994, Warner 1994, Noss et al. 1995). Against that backdrop of grassland destruction, the Henslow's Sparrow has declined perhaps most significantly of any grassland bird (Herkert 1995), and more than most forest-dwelling Neotropical migrants (Knopf 1994, Peterjohn et al. 1994, Herkert 1995). Although several factors may contribute to that overall population decline, such as state of wintering habitat (Plentovich et al. 1999), disappearance of suitable breeding habitat has probably been the most critical determinant of the decline of this species (Askins 1993). That decline can readily be understood in terms of the nature of suitable breeding habitat for this species: large, undisturbed grasslands (Herkert 1994b, Walk and Warner 1999) with relatively little woody vegetation and a significant litter layer (Zimmerman 1988; see Herkert 1998). Such habitat is scarce in the Midwest, where the Henslow's Sparrow's breeding range is concentrated (Pruitt 1996, Herkert 1998).

[1] Present address: Department of Biology, Aquinas College, Grand Rapids, Michigan 49506, USA.

[2] Present address: Department of Forestry and Natural Resources, Purdue University, West Lafayette, Indiana 47907, USA.

[3] Address correspondence to this author. E-mail: lslima@scifac.indstate.edu

Ironically, surface coal mining in the Midwest is a form of environmental disturbance that produces large blocks of grassland habitat. Those mine grasslands are found mainly in the Illinois coal basin (portions of Indiana, Illinois, and Kentucky) and portions of Ohio, and represent the main result of mine reclamation (Brothers 1990). Newly reclaimed mines are typically stocked with quick growing, cool-season grasses such as tall fescue (*Festuca arundinacea*), orchard grass (*Dactylis glomerata*), and smooth brome (*Bromus inermis*), as well as various legumes such as clovers (*Melilotus* spp.) and alfalfa (*Medicago sativa*), to establish a vegetative structure and minimize soil erosion (Brothers 1990). Tree planting and crop production may then follow, but often in only a relatively small portion of the reclaimed area; the bulk of a reclaimed mine usually remains as grassland (Brothers 1990). Furthermore, soil conditions and isolation from forested habitat (Hardt and Forman 1989) often inhibit woody plant invasion, allowing those grasslands to persist for many years with no management.

Several aspects of midwestern mine grasslands make them particularly attractive for the conservation of grassland birds in general. First, most midwestern mine grasslands exceed the apparent size thresholds for even the most area-sensitive grassland species (Samson 1980, Herkert 1994a, Vickery et al. 1994, Bollinger 1995, Walk and Warner 1999, Winter and Faaborg 1999; see also Horn et al. 2000). Second, although reclaimed mines are not always managed as grasslands, soil conditions may leave them largely unsuitable for other purposes. Finally, entire reclaimed mines are often owned by a single entity, which makes long-term conservation of those large grasslands more feasible. In short, midwestern mine grasslands provide a unique opportunity for the large-scale, diverse grassland management approach to conservation of grassland birds (Herkert et al. 1996, Sample and Mossman 1997).

Methods

Establishing study sites.—Mine grasslands were located using satellite imagery and a Geographic Information System (GIS) (ArcInfo) as described in Bajema and Lima (2001). After locating a given mine grassland, we made contact with the owners, and then inspected the mine to determine whether it contained suitable Henslow's Sparrow habitat. Such habitat consists of relatively dense, undisturbed grass-dominated vegetation with a significant litter layer (reviewed by Herkert 1998). If a mine had a significant extent of such vegetation, we established fixed survey routes. Only very recently reclaimed mines, or a few small mine grasslands converted to cattle grazing operations, lacked such habitat (Bajema and Lima 2001). We note that our working definition of "suitable habitat" was meant to be broadly inclusive so as to not exclude any potential Henslow's Sparrow habitat. We present a more refined perspective on habitat suitability below.

Survey methods.—We used two survey methods: 5 min, unlimited distance point counts, and unlimited distance line transects (see Bibby et al. 1992, Ralph et al. 1993). Point counts were performed in a fashion similar to the Breeding Bird Survey (Price et al. 1995) and took advantage of the gravel-road network within most reclaimed mines. A survey route was established by stopping every 0.5 km along mine roads in suitable Henslow's Sparrow habitat. That distance between point counts eliminated the risk of censusing the same sparrows twice although still allowed adequate coverage of an area. During a point count, all Henslow's Sparrows detected by song were recorded, as was the time of day. Location of the point count itself was recorded with the use of Garmin® Global Positioning System units (10–30 m accuracy). A total of 249 points counts were established in 1997, with 248 points established in 1998; most points (>98%) were in the same locations both years.

Line transects were conducted in the larger "roadless" units of Henslow's Sparrow habitat. Transects began at least 200 m from the nearest point-count location, and were walked slowly at ~2 km per hour. Exact shape and length of a given transect were dictated by terrain and extent of suitable habitat, but most traversed a rectangular pattern in a large field. GPS units were used to map the location of each transect and Henslow's Sparrow detections. Overall, a total of 36 transects (average length = 1,220 m, range 300–4,200 m) covering 44.0 km were established in 1997, with 39 transects covering 45.5 km in 1998 (average length = 1,170 m, range 300–4,200 m); enhanced access to some mines allowed us to establish a few new transects in 1998, otherwise all transects were in the same locations across years.

We conducted our surveys from mid-May through mid-July during both 1997 and 1998 breeding seasons, which largely ensured that all detected Henslow's Sparrows were on established breeding territories (Herkert 1998). During 1998, we performed three complete rounds of surveys (Round 1, 12 May–6 June; Round 2, 28 May–23 June; Round 3, 23 June–10 July). A single survey round, spread over the entire breeding season, was performed during 1997 (mid-May to mid-July). We confined our daily surveys to a 5 h period beginning 0.5 h before sunrise, the period during which Henslow's Sparrows sing most actively (Heller and Hughes 1997, Koford 1999). Survey work was postponed during inclement weather (high wind and rain). Surveys were conducted by a crew of five experienced observers during each breeding season.

We also surveyed pasture and hay-field habitats. These areas constitute under 15% of most reclaimed mines, but as much as 45% in two mines (Bajema and Lima 2001). We confined these surveys to fields that were intensively managed for hay but uncut at the time of censusing, and areas that were actively grazed by cattle. We used roadside (5 min) point counts only, with 50 and 54 points established in 1997 and 1998, respectively. As before, three survey rounds were completed in 1998, with a single survey round in 1997.

Singing behavior, correction factors, and detection distances.—Observations made during extended visits to specific point-count locations (in 1997) strongly suggested that our surveys were missing many nonsinging male Henslow's Sparrows. At one time, there may be three or four males singing at a site, whereas several minutes later only one or two may be singing. Point counts significantly longer than 5 min could have detected many of those missed males (see also Gutzwiller 1991, McShea and Rappole 1997), but longer counts were not feasible given logistical constraints imposed by remoteness of many mines and amount of territory that we surveyed. Instead we devised a correction factor for missed males.

Correction factors are implied in the basic theory of point counts (e.g. Barker et al. 1993), although examples of their use in estimating avian abundance are few. Our particular correction factor involved determining the proportion of time (s) that the typical male will sing at least once during a 5 min interval (the duration of an individual point count). With s determined, the true number of males (M) at the typical point-count location is related to the number of males detected at that location (m) by $m = sM$, which rearranged to $M = m/s$. In other words, the factor correcting for missed males is $1/s$. Robb et al. (1998) describe an analogous correction factor applicable to spot-mapping surveys for Henslow's Sparrows.

To estimate the value of s, we chose 25 count locations that were known to harbor Henslow's Sparrows and recorded whether or not a given male sang at least once during each of 12 consecutive 5 min periods (1 h). The proportion of these 12 periods during which a male sang is an estimate of s. We first estimated s on a per-site basis by combining data from all males detected at a given site. Because the number of males detected during a given 1 h observation period was not correlated significantly with the site-specific estimate of s (Spearman rank correlations ranging between -0.04 and 0.10, $P > 0.6$), we averaged site-specific s values to determine our overall estimate of s. During 1998, we visited "singing sites" at the end of each survey round. We thus determined s values for each round of censusing. During 1997, we quantified singing behavior mainly in the middle of the breeding season, corresponding to the midpoint of our single round of censusing. During both years, hour-long observation periods were evenly distributed throughout the 5 h morning surveying period.

We were able to make visual contact with almost all singing males, hence monitoring multiple individuals was feasible. We nevertheless excluded data from a given male if there was any confusion about its identity during the 1 h observation period. We also excluded data taken from males so distant that we could not reliably detect each (brief) act of singing. Following the 1 h observation period, we measured distances to singing perches of all detected males. We did this at about 50% of observation sites.

Vegetational mapping and surveys.—Large-scale patterns in vegetative cover within each mine were mapped with the aid of recent, large-format aerial photographs obtained from the controlling mining companies. On-the-ground observers used those aerial photographs to record the following habitat types: suitable Henslow's Sparrow habitat (as defined earlier), grazed grassland, intensively hayed grassland, forest, shrubland (presence of several young trees <10 cm diameter at breast height [DBH]), open water, and barren ground (usually actively mined areas). The resulting maps were then scanned into the GIS, which was then used to determine the coverage of general grassland habitat and suitable Henslow's Sparrow habitat (see Bajema and Lima 2001 for details). That GIS also contained the locations of all transects and point counts.

During the 1998 field season, we characterized vegetative patterns on a finer scale within apparently suitable Henslow's Sparrow habitat. Our goal was to determine which vegetative components of that habitat (if any) were most closely associated with site occupation by Henslow's Sparrows (see also DeVault 1999, T. DeVault et al. unpubl. data). To accomplish that goal we chose, at a given mine, the 5–10 most populated point-count locations and an equal number of locations at which Henslow's Sparrows were apparently absent. We did that within mines large enough to provide an adequate sample of such points. Overall, we sampled vegetation at 104 point-count locations.

We characterized each of those 104 locations by measuring vegetation at 6 positions along a transect perpendicular to the road, starting 20 m off the road, with 20 m spacing between positions (see Millenbah et al. 1996). At each sampling position, we measured visual obstruction (a measurement of horizontal cover, in decimeters; Robel et al. 1970) and the maximum height of vegetation using a Robel pole. We then estimated overall percentage cover of grasses and forbs by species, as well as the percentage cover of dead litter and bare soil as per Daubenmire (1959)

TABLE 1. Locations, ownership, and characteristics of the 19 reclaimed surface-mine study sites in southwestern Indiana.

			Grassland (ha)[a]	
Mine	Ownership[b]	County[c]	Overall	Suitable
Universal	Peabody, private	Vermillion	2,630	1,140
Snow Hill	Peabody	Vigo	270	270
Centerpoint	Private, County	Clay	150	110
Saline City	Private	Clay	220	190
Chinook	Midwest, IDNR	Clay	1,580	1,220
Cass	Kindill	Sullivan	350	310
Dugger	IDNR	Sullivan	550	440
Hymera	Private	Sullivan	180	170
Minnehaha	Kindill, IDNR	Sullivan	1,040	890
Hillenbrand 1[d]	IDNR	Greene	440	400
Hillenbrand 2[d]	IDNR	Greene	200	200
Phoenix	Black Beauty	Daviess	670	550
Alford	Kindill	Pike	590	560
Cup Creek	Private	Pike	110	100
Petersburg	Kindill	Pike	730	680
Westfield	Kindill	Pike	1,040	810
Ayrshire	Amax, IDNR, priv.	Warrick	3,180	1,060
Lynnville	Peabody	Warrick	1,830	1,500
Squaw Creek	Peabody	Warrick	1,000	900
		Totals	16,760	11,500

[a] "Overall" grassland habitat covers all grassland types; "suitable" habitat refers specifically to Henslow's Sparrow habitat.
[b] Amax = Amax Coal Company; Black Beauty = Black Beauty Coal Company; Kindill = Kindill Mining, Inc.; IDNR = controlled or managed by the Indiana Department of Natural Resources; Midwest = Midwest Coal Company; Peabody = Peabody Coal Company; Private = held in private ownership.
[c] Counties (and mines) listed from north to south.
[d] The Hillenbrand Fish and Wildlife Area occurs as two geographically separate reclamation units.

and Patterson and Best (1996). All six subsamples were averaged, for each vegetational measure, to characterize the vegetation at a given point count. Those average measures were compared between occupied and unoccupied points using simple pairwise comparisons. Individual plant species were included in our analysis only if their canopy cover exceeded 1%.

Statistical considerations.—Parametric statistics were used whenever appropriate, but nonparametric statistical procedures were necessary in many instances. Observations from individual point counts and transects were treated as independent estimates of Henslow's Sparrow abundance, with observations across rounds (1998 surveys) treated as repeated measures for a given location. Singing data from individual observation points (averaged across all males at a given location) were similarly treated as independent estimates of singing propensity. We illustrate temporal effects in Henslow's Sparrow detections using point-count data only; identical temporal trends were also seen in transect data in all cases. Means are given ±SE. All statistical analyses were performed using the SPSS statistical package (Norušis 1993).

RESULTS

Mine grassland characteristics.—We located 19 reclaimed mine grasslands in southwestern Indiana (Table 1) in which the apparent extent of suitable Henslow's Sparrow habitat warranted establishment of survey routes. Extent of general grassland habitat within those mines varied from 110 to 3,180 ha (Table 1). On average, 68% of grassland habitat was suitable for Henslow's Sparrows at a coarse scale of analysis. However, relative coverage of suitable habitat varied among mines (Table 1), largely reflecting the extent of hayed or grazed grassland. There was very little change between years in configuration and amount of suitable Henslow's Sparrow habitat, which summed to 11,500 ha during the 1997 and 1998 breeding seasons. Other grassland types such as pasture and hayfield were similarly stable over the two-year period.

Basic survey results.—Our survey work in suitable habitat detected a total of 252 male Henslow's Sparrows during the 1997 breeding

TABLE 2. Basic (uncorrected) survey results by round for the 1998 breeding season. Totals indicate number of males detected using a given survey technique for a given round. The dates of the survey rounds are: Round 1, May 12–June 6, Round 2, May 28–June 23, Round 3, June 23–July 10.

Survey round	Point counts		Line transects	
	Total	Males/point	Total	Males/km
Round 1	137	0.557 ± 0.057	150	4.42 ± 0.714
Round 2	99	0.400 ± 0.051	104	2.73 ± 0.534
Round 3	109	0.436 ± 0.058	102	2.54 ± 0.543

season (131 from point counts, 121 from transects; those numbers exclude the many additional males detected during our study of singing behavior, see below). Point counts detected an uncorrected average of 0.478 ± 0.052 males per point. One or more males were detected during 31.3% of point counts. An (uncorrected) average of 3.04 ± 0.780 males per kilometer were detected during line-transect surveys. The 1998 surveys yielded similar overall results, which are presented by census round in Table 2 (recall that only one round was conducted during 1997). There were significant differences across survey rounds in number of males detected per point count (Friedman repeated measures ANOVA on ranks, $\chi^2 = 12.6$, df = 2, $P = 0.0018$), owing entirely to higher number of detections in Round 1 (pairwise comparisons, Student-Newman-Keuls method, $P < 0.05$). A similar survey round effect is also evident in the transect data (Table 2).

Number of male Henslow's Sparrows detected tended to decline with time of day. However, there was no significant time-of-day effect in 1997 (Spearman rank correlation, $r_s = 0.010$, $n = 249$, $P = 0.877$) or in any survey round during 1998 ($-0.046 \leq r_s \leq -0.020$, $P > 0.45$).

We did not detect any male Henslow's Sparrows in grazed and hayed grasslands. Our survey effort in those habitats involved a cumulative total of 212 point counts over the two breeding seasons. We have nevertheless made casual observations of a few male Henslow's Sparrows in hayed areas. However, we virtually never detected that species in areas with recent or active cattle grazing.

Singing behavior, correction factors, and detection distance.—Our study of singing behavior showed that male Henslow's Sparrows sing intermittently. When observed for 12 consecutive 5 min intervals, the proportion of intervals during which the typical male sang (the value s) was 0.595 ± 0.039 (1997 breeding season; 70 males observed over 25 observation periods). There was no correlation between that measure of singing tendency and time of day (Pearson's $r = 0.279$, $n = 25$, $P = 0.177$). The inverse of that average proportion (or $1/s$) yields the correction factor of 1.68, implying that the true number of males at a site with Henslow's Sparrows was on average 68% greater than suggested by the actual number of males detected during 1997 surveys. Very similar results were obtained in 1998 with an overall estimate of s at 0.610 (188 males observed during 73 observation periods over 3 rounds), implying a correction factor of 1.64. Male Henslow's Sparrows tended to sing somewhat less as the (1998) breeding season progressed, with average estimates of s at 0.632 ± 0.039, 0.608 ± 0.034, and 0.586 ± 0.032 for Rounds 1–3, respectively. However, a one-way ANCOVA, with time-of-day as the covariate, indicated no significant effect of survey round ($F = 0.566$, df = 2 and 69, $P = 0.570$) or time of day ($F = 2.214$, df = 1 and 69, $P = 0.141$) on the singing tendencies of males.

The validity of our correction factor can be assessed by determining the ratio of males detected after 1 h of observation to the number of males detected during the most recent (preceding) "official" 5 min point count for that location. With s estimates in excess of 0.5, the expectation of $1/s$ males at a given site should be realized by the twelfth observation interval (i.e. every male should have sung within the hour). During 1997, the number of males detected at a given location was on average 1.63 ± 0.126 times that detected during the preceding official point count; that value is not significantly different from the expected value of 1.68 (t-test, $t = -0.29$, df = 24, $P = 0.779$). Similarly, during 1998, number of males detected increased by a factor of 1.59 ± 0.133, which was also not significantly different from the expected value of 1.64 (t-test, combining data from all three segments of the breeding season; $t = -0.30$, df = 53, $P = 0.766$).

A plot of distances to detected males (Fig. 1) suggested that detections faded appreciably by 125 m from the observer, with only one male detected beyond 160 m. The detection of birds beyond 125 m required unusually good listening conditions. We thus take 125 m as our working estimate of detection radius. Note also that

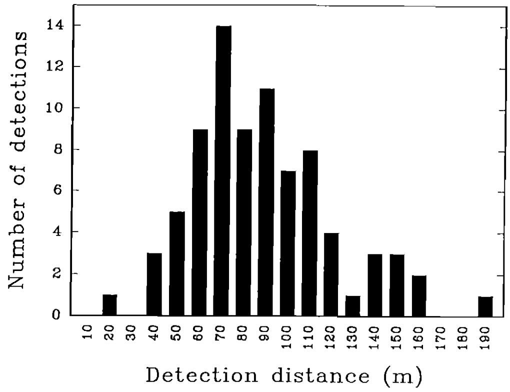

FIG. 1. Frequency histogram of detection distances for male Henslow's Sparrows. Data were obtained during a study of singing behavior in which visual contact was made with most males (1998 breeding season only).

few Henslow's Sparrows were detected at distances <50 m from the observer, suggesting that males close to observers were silent or moved away to sing at greater distances. If close-by males did remain silent, then one could easily devise a correction factor to account for absence of detections around an observer. Because we could not distinguish between these two possible hypotheses for the lack of nearby detections, we conservatively assumed that all males within 125 m were equally likely to be detected.

Density estimates.—We derived estimates of Henslow's Sparrow density by year and by survey round (1998). For 1997, our point counts yielded 0.478 ± 0.052 males per count. Assuming a detection radius of 125 m, we arrive at a point-count estimate of 0.097 ± 0.014 males per hectare. With a correction factor of 1.68, our corrected point count density is 0.164 ± 0.023 males per hectare. Our line transects yielded 3.04 ± 0.779 males per kilometer. With a transect width of 250 m, those estimates translate into a density of 0.122 ± 0.031 males per hectare. Our correction factor applies specifically to point counts, hence we leave transect estimates uncorrected. Density estimates for 1998 were determined in the same manner for each survey round (Table 3). The 1998 point count estimates (using round-specific correction factors) ranged from about 0.14 to 0.18 males per hectare, with an overall breeding season average of 0.159 males per hectare. The 1998 line-transect estimates (uncorrected) ranged from 0.10 to 0.18 males per hectare, with an overall average of 0.129 males per hectare. Note further that the 1998 average point-count density compares closely to the 1997 value of 0.164 males per hectare (which also covered the entire breeding season), suggesting a stable population over the two-year period; the corresponding values of 0.129 and 0.122 males per hectare for the 1998 and 1997 transect data support the same conclusion.

We used corrected point-count density estimates to derive a rough estimate of number of Henslow's Sparrows actually inhabiting those mines. Assuming a density of ~0.16 males per hectare and 11,500 ha of suitable habitat (Table 1), there are about 1,800–1,900 males in the overall population. If densities away from the road network are greater than those at (roadside) point counts, as suggested by generally higher (uncorrected) density estimates from transects (see above and Table 3), then overall population size might be about 10–20% larger than the above estimate.

Fine-scale vegetation analyses.—So far, we have defined suitable Henslow's Sparrow habitat solely in terms of gross vegetative structure. Within that basic habitat type, however, Henslow's Sparrows were relatively dense in some areas and largely absent in others. For instance, pooling the results of three survey rounds during 1998, only 47% of our point counts pro-

TABLE 3. Density estimates for male Henslow's Sparrows during the 1998 breeding season, determined according to survey round. Uncorrected and corrected densities are given as the mean ± SE males per ha, and are based on a detection radius of 125 m. The correction factor given applies only to point counts.

	Point counts			Line transects
Survey round	Uncorrected males per ha	Correction factor	Corrected males per ha	(Uncorrected) males per ha
Round 1	0.116 ± 0.012	1.58	0.184 ± 0.019	0.177 ± 0.029
Round 2	0.083 ± 0.010	1.64	0.137 ± 0.017	0.109 ± 0.021
Round 3	0.091 ± 0.012	1.71	0.156 ± 0.020	0.102 ± 0.022

TABLE 4. Vegetation structure and composition at point-count locations occupied or unoccupied by male Henslow's Sparrows (1998 breeding season). All values are means ± SE. Significant associations ($P < 0.05$) with Henslow's Sparrow occupation are highlighted.

Variable	Unoccupied sites $N = 43$	Occupied Sites $N = 61$	t	P
Male Henslow's Sparrows[a]	—	3.51 ± 0.30	—	—
Visual obstruction (dm)	3.39 ± 0.20	3.23 ± 0.18	0.61	0.540
Max. vegetation height (dm)	8.60 ± 0.28	9.32 ± 0.25	1.85	0.066
Litter depth (cm)	**3.80 ± 0.31**	**5.38 ± 0.36**	**3.13**	**0.002**
% ground cover by litter	**70.9 ± 3.49**	**79.1 ± 2.06**	**2.16**	**0.033**
% Canopy cover by:				
Grass (all species)	**57.5 ± 4.14**	**68.1 ± 3.12**	**2.08**	**0.040**
Tall fescue	30.8 ± 6.64	33.2 ± 3.55	0.41	0.684
Smooth brome	**7.47 ± 2.16**	**15.8 ± 2.66**	**2.29**	**0.024**
Orchard grass	7.63 ± 2.5	7.59 ± 1.99	0.01	0.99
Japanese brome[b]	5.93 ± 1.62	4.32 ± 1.17	0.83	0.411
Kentucky blue grass[c]	1.49 ± 0.78	3.13 ± 0.75	1.48	0.141
Broomsedge	**0.63 ± 0.39**	**4.11 ± 1.14**	**2.50**	**0.014**
Grass species diversity	**1.70 ± 0.10**	**2.01 ± 0.08**	**2.37**	**0.020**
% Canopy cover by forbs	31.0 ± 3.70	24.0 ± 2.93	1.50	0.138
Forb species diversity[d]	2.55 ± 0.18	2.29 ± 0.12	1.68	0.096

[a] Sum of males detected over three survey rounds.
[b] *Bromus japonicus.*
[c] *Poa pratensis.*
[d] No individual forb species were associated with Henslow's Sparrow occupation (all $P > 0.10$).

duced one or more (up to 11) singing males. Those results suggest that some sites were less suitable for Henslow's Sparrows than others.

To determine which aspects of mine grassland vegetation (if any) were associated with presence of Henslow's Sparrows, we compared sites occupied by Henslow's Sparrows to those at which they were apparently absent (Table 4). Simple pairwise comparisons of vegetation structure and composition indicate that litter depth and cover were significantly (positively) associated with Henslow's Sparrow presence. Both the percentage of canopy cover by grass and grass species diversity were also positively associated with Henslow's Sparrow presence. Regarding individual grass species, only canopy cover of smooth brome and broomsedge (*Andropogon viginicus*) showed a significant association with presence of those sparrows. Finally, Henslow's Sparrow presence was marginally associated with both taller vegetation (positively) and forb species diversity (negatively).

DISCUSSION

Reclaimed coal mine grasslands of southwestern Indiana provide habitat for a substantial number of Henslow's Sparrows. Corrected density estimates averaged about 0.16 males per hectare, which implies a population of male Henslow's Sparrows approaching 2,000. Such an estimate is probably conservative. One might argue that density estimates from the earlier survey round (0.184 males per hectare, Table 3) provide the best estimate of male density, in which case the overall population might exceed 2,000 males. This estimate would rise still further if roadless areas harbor greater densities of males than point-count locations by roads. Finally, if one assumes a roughly equal sex ratio, the overall population of Henslow's Sparrows was probably approaching 4,000 adults. Whichever is the best density estimate, those mine grasslands clearly contain a large number of Henslow' Sparrows, and possibly a significant proportion of the global population of this species (Pruitt 1996).

Our estimates of male density are sensitive to the detection radius used to determine survey coverage. We assumed a detection radius of 125 m, on the basis of actual detection distances. A detection radius of 150 m has been suggested for Henslow's Sparrow (e.g. Robb et al. 1998), but our detections of singing males were well in decline at that distance (Fig. 1). If one feels that a detection radius of 150 m is nevertheless warranted, then our density estimates would drop by ~30%. Our density estimates also include relatively large correction factors (1.58–1.71) for nonsinging males likely to have been missed by our censuses. Our data show clearly that standard point counts missed several males. A similar realization led Robb et al. (1998) to develop a correction factor applicable to spot-mapping surveys for that species.

How do Henslow's Sparrow densities on reclaimed coal mines compare to those observed in non-mine grassland habitats? A few published estimates of Henslow's Sparrow density make some comparisons possible. Herkert (1994b) reported densities of about 0.22–0.28 males per hectare in large prairie fragments in Illinois near their peak suitability for this species. Robb et al. (1998) reported an uncorrected density of 0.55 male Henslow's Sparrows per hectare at Jefferson Proving Ground in southeastern Indiana; that grassland habitat is uniquely suited to Henslow's Sparrows and harbors relatively few grassland species overall. In the prairie fragments of southwestern Missouri, Swengel (1996) reported a density of ~7 males per kilometer of transect. Our comparable uncorrected mine-grassland estimates of ~0.10 males per hectare and 3.1 males per kilometer of transect suggest that mine grasslands support a lower density of Henslow's Sparrows than those other habitats. However, some of our "suitable" mine grassland habitat (very broadly defined) may have been only marginally suitable for Henslow's Sparrows. If we focus only on suitable habitat as defined by Henslow's Sparrow occupation (47.5% of point counts in 1998), then our overall estimate of Henslow's Sparrow density increases to ~0.20 males per hectare. That density is more comparable to that in Herkert's large, high-quality grassland fragments (0.22–0.28 males per hectare), but still considerably lower than Robb et al.'s estimate of 0.55 males per hectare at Jefferson Proving Ground; only 5% of our occupied point counts, and 3.1% of our total transect length produced densities above 0.55/ha. Similarly, only 9% of our total transect length produced the 7 (or more) males per kilometer observed by Swengel (1996). Overall, a substantial portion of undisturbed mine grassland habitat is probably more suitable for grassland birds other than Henslow's Sparrows, such as Grasshopper Sparrows (*Ammodramus savannarum*), Eastern Meadowlarks (*Sturnella magna*), Dickcissels (*Spiza americana*), and Field Sparrows (*Spizella pusilla*) (T. DeVault 1999; DeVault et al. unpubl. data).

What constitutes high- or low-quality habitat in these mine grasslands? At a coarse level of analysis, Henslow's Sparrows clearly avoided grazed and intensively hayed areas. The avoidance of sparse vegetation typical of grazed areas is well established for Henslow's Sparrows (Herkert 1998). We suspect that intensively hayed areas are unattractive to Henslow's Sparrows because of the relative lack of a significant litter layer (R. A. Bajema pers. obs.). At a finer scale of analysis, Henslow's Sparrows were associated with vegetational features often associated with that species: tall, dense grass with relatively few forbs and a substantial litter layer (Herkert 1998). Few individual plant species were associated with Henslow's Sparrow occupation, with the exception of smooth brome and broom sedge (see also Robb et al. 1998). Notable for its lack of a statistical effect on Henslow's Sparrow abundance was tall fescue, a grass often avoided by wildlife in general (e.g. Barnes et al. 1995). However, tall fescue is the most common plant in reclaimed mines (Brothers 1990; see also Table 4), and its ubiquity may have made its effects difficult to detect. We suspect that the positive association between Henslow's Sparrows and grass-species diversity reflects the positive effect of grasses that are not fescue. We should note, however, that smooth brome (one of the "positive" non-fescue grasses) has been associated with negative effects on other wildlife species (Wilson and Belcher 1989).

An important unanswered question is whether these mine grasslands represent source or sink habitat (as per Donovan et al. 1995; Trine 1998) for Henslow's Sparrows. We suspect that mine grasslands are reasonably productive places for that species. An ongoing study of nesting success of grassland birds in reclaimed mines indicates relatively high daily nest-survival values for ground-nesting grassland birds in general, due in part to extremely low rates of brood parasitism (<1% of nests, S. L. Lima unpub. data). That lack of brood parasitism probably reflects the large size of mine grasslands and their relative isolation from forested areas (Johnson and Temple 1986, 1990; Burger et al. 1994; see also Hahn and Hatfield 1995).

It is indeed ironic that Henslow's Sparrows should find a refuge in a habitat produced as a result of profound environmental disturbance of surface mining. It is perhaps that incongruity that has diverted biologists' attention away from investigating reclaimed coal mines as habitat for grassland birds. Reclaimed coal-mine grasslands nevertheless have many features that lend themselves well to conservation of grassland birds, not least of which is their sheer size. With management explicitly focussed on those areas as important grassland habitats, reclaimed surface mines of the Midwest may be a major factor in conservation of Henslow's Sparrows and other species of grassland birds.

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