Abundance of Grassland Sparrows on Reclaimed Surface Mines in Western Pennsylvania[1]

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Abstract

Grassland songbird populations have experienced some of the most severe declines of any migratory songbird guild in North America and are continuing to disappear from portions of their historic ranges. Habitat loss and degradation have been implicated as primary causes of these declines. However, intensive surface coal mining and subsequent reclamation in western Pennsylvania have created large tracts of grassland habitat during the past 30 to 40 years. We estimated the area of habitat suitable for breeding grassland songbirds on reclaimed strip mines in nine western counties of Pennsylvania using a stratified random sample design. We used distance sampling methods to estimate abundance of Henslow's (*Ammodramus henslowii*), Savannah (*Passerculus sandwichensis*), and Grasshopper (*Ammodramus savannarum*) Sparrows. We estimated that 35,373 ha (95 percent CI = 26,758 - 46,870) of reclaimed-mine grassland suitable for breeding grassland songbirds were present in our 1.85 x 10^6 ha study area in 2001. Henslow's, Savannah, and Grasshopper Sparrow abundances were 4,884 (95 percent CI = 2,128 – 8,460), 1,921 (95 percent CI = 848 – 2,790), and 9,650 (95 percent CI = 4,390 – 13,614) singing males, respectively. Reclaimed-mine grasslands in western Pennsylvania supported substantial grassland songbird populations during the 2002 breeding season. Therefore, management of reclaimed surface mine areas as grassland reserves may help prevent populations of some species, notably Henslow's Sparrow, from becoming endangered.

Key words: *Ammodramus henslowii, Ammodramus savannarum,* Grasshopper Sparrow, grassland birds, grassland habitat, Henslow's Sparrow, *Passerculus sandwichensis,* Pennsylvania, reclaimed surface mine, Savannah Sparrow.

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Introduction

Many North American grassland bird species have experienced severe and consistent population declines during the past 30 years (Robbins et al. 1986, Herkert 1994, Sauer et al. 1996). In fact, since 1966 the guild of grassland bird species had the lowest percentage of increasing species in the U.S. Breeding Bird Survey (Pardieck and Sauer 2000). Population declines are rooted in the near collapse of the native tallgrass prairie ecosystem and severe losses in most other native prairie systems (Samson and Knopf 1994, Warner 1994). Most states have lost 99 percent of their native tallgrass prairie, and grasslands top the list of critically endangered native ecosystems (Noss et al. 1995).

Losses in native grassland ecosystems were largely the result of conversion to agriculture. Many grassland bird species, however, adapted to newly created agricultural habitats, and those that exploited these habitats expanded their ranges eastward with the felling of Eastern forests during the 19th Century (Askins 1999). However, changes in agricultural practices during the past 50 years, including conversion of pastures and hayfields to row crops, made much agricultural habitat unsuitable for native grassland species (Warner 1994). Population declines in grassland bird species observed today reflect those changing practices and the loss of agricultural areas to urban sprawl (Vickery et al. 1999).

Widespread habitat loss, fragmentation, and consequent population declines have drawn considerable conservation and research attention to grassland bird communities. Grassland symposia (Vickery and Herkert 1999) and special sessions on grassland birds during national meetings (this volume) have highlighted the plight of these species and the need to understand their population dynamics and habitat needs. This is especially apparent for the Henslow's Sparrow (*Ammodramus henslowii*), previously evaluated as a candidate for the U.S. Endangered Species List, which has a restricted geographic range and low relative abundance (Smith 1992, Pruitt 1996). Although not recommended for Federal listing (Federal Register 1998, 63(174) pp. 48162-64), it was identified as one of the highest priority bird species on the National Audubon Society's Watch List (Pashley 1996). Grasshopper Sparrows (*Ammodramus savannarum*) and Savannah Sparrows (*Passerculus sandwichensis*) currently have much wider geographic ranges but also have

experienced consistent population declines (Peterjohn and Sauer 1999).

With loss and degradation of native grassland habitats and recognition that most agricultural habitat essentially serves as a population sink (Bollinger et al. 1990, Kershner and Bollinger 1996, Rohrbaugh et al. 1999), managed habitat areas have become vital for many grassland bird communities. Agricultural set-asides (e.g., CRP lands) and prairie reserves provide reservoirs of grassland habitat that may help support remaining populations of some grassland bird species (Delisle and Savidge 1997, Koford 1999, Coppedge et al. 2001, Johnson and Igl 2001). In addition, reclaimed surface mines have inadvertently become a source of grassland bird habitat. Whitmore and Hall (1978) documented the presence of grassland birds on reclaimed surface mines 25 years ago, although the contribution of those populations was not recognized for many years. Recent studies have confirmed the existence of substantial grassland bird populations on reclaimed mines throughout the Midwest and Northeast, which indicates these habitats may be important for conserving many grassland species (Yahner and Rohrbaugh 1996, Bajema et al. 2001).

In the eastern United States, and particularly in Pennsylvania, reclaimed bituminous coal fields are beneficial to grassland birds (Yahner and Rohrbaugh 1996). Widespread surface mining and subsequent reclamation in western Pennsylvania have resulted in an extensive patchwork of reclaimed sites among forests, woodlots, and agricultural fields. The acidic, nutrient-poor soils of reclaimed sites provide little potential for agricultural or timber production, and grasses and legumes tend to be the most successful and persistent vegetation types (Vogel 1981, J. Mattice pers. obs.). These often undisturbed fields have a slow rate of ecological plant succession, and they are ideal for Henslow's Sparrows and compatible for many other grassland-associated species (Bajema et al. 2001).

During a survey of the distribution of breeding birds in Pennsylvania (Brauning 1992) conducted in the 1980s, a large number of locations of grassland birds, including Henslow's, Grasshopper, and Savannah Sparrows, were on reclaimed surface mines. However, this survey did not provide abundance estimates, and population sizes could not be quantified. In an attempt to document population trends for the Henslow's Sparrow over its historic and current range, a federal status assessment was compiled in 1996 (Pruitt 1996). This assessment revealed that many states had inadequate data on population size because of a lack of consistent statewide monitoring efforts. Pruitt (1996) noted that "there is a need to coordinate and standardize monitoring" to improve the accuracy of global population estimates. We present large-scale, statistically defensible population estimates for several grassland bird species and an estimate of the area of suitable reclaimed surface mine habitat in western Pennsylvania. Specifically, we attempted to quantify the contribution of reclaimed surface mines in western Pennsylvania to populations of three obligate grassland bird species: Henslow's Sparrows, Grasshopper Sparrows, and Savannah Sparrows.

Study Area

We conducted our study in nine western Pennsylvania counties (Armstrong, Butler, Cambria, Clarion, Clearfield, Indiana, Jefferson, Somerset, and Venango), totaling 18,648 km^2, an area roughly equivalent to the state of New Jersey (*fig. 1*). These counties overlay the main bituminous coal field in Pennsylvania (Cuff et al. 1989), and coal is removed primarily by surface mining. Less than 30 percent of available coal has been mined in the majority of these counties. Post-mining reclamation, conducted primarily since the 1960s, has restored topographical contours and established vegetative cover on disturbed soils using a grass mixture dominated by fescue (*Fescue* spp.), clover (*Trifolium* spp.), and bird's-foot trefoil (*Lotus corniculatus*) (Buckwalter 1983, Piehler 1987, D. W. Brauning, pers. obs.). Trees and shrubs, primarily pine (*Pinus* spp.), locust (*Robinia* spp.), and autumn olive (*Elaeagnus umbellata*) were usually planted in reclaimed sites but often failed to become established.

Methods

Quantification of Reclaimed Areas

We used a geographic information system (GIS) to overlay a square grid of 9-km^2 blocks over the entire 9-county study area. For the purpose of creating a stratified sampling scheme, we then used a GIS map of permitted and abandoned mine sites, combined with a vegetation cover classification map from the Pennsylvania Gap Analysis Project (PA GAP, Final Report, Pennsylvania State University and U.S. Geological Survey, June 2000), to estimate the percent area of reclaimed surface mine in each block. However, an informal evaluation of this GIS map found that although it provided an indication of the amount and location of mining activities, it did not include all reclaimed areas, and it included mining activities other than surface mining for coal (e.g., deep mining or other types of mineral extraction). Therefore, we calculated an index of the amount of reclaimed surface mine in each block in the entire study area by using a spatial smoothing function, calculating the average area permitted and abandoned for a 9-block "neighborhood" (a

given block and the 8 blocks immediately surrounding that block). This smoothing function allowed us to take into account the values of surrounding cells when assigning index values to each cell. These index values then were used to stratify the blocks into areas of high, medium, or low amounts of mined area (*fig. 1*). This stratification of our index to mining activity, as long as it was correlated with the actual amount of mined area, improved the precision of our estimates of reclaimed surface mine area and bird abundance (Cochran 1977:99-101).

We used a stratified random sampling design to select blocks from each of the high, medium, and low strata (Cochran 1977). There were 495 blocks (4,455 km^2) in the high stratum, 698 blocks (6,282 km^2) in the medium stratum, and 870 blocks (7,830 km^2) in the low stratum. Based on our estimates of the relative effort it would require to survey a block in each stratum type and estimates of the relative variability in amounts of habitat among blocks in each stratum, we used an optimal allocation equation (Cochran 1977:96-99) to calculate the number of blocks to sample in each stratum. We sampled 74 blocks: 18 high-density, 25 medium-density, and 31 low-density. For each sampled 9-km^2 block, we identified, on the ground, all reclaimed surface mine area in grasses and legumes, not actively managed (e.g., mowed), with <25 percent coverage (determined from visual estimation at the site) of shrubs or trees. We classified these patches as suitable grassland sparrow habitat and limited bird survey efforts to this subset of reclaimed surface mine conditions. These areas were mapped directly into a GIS database using methods and equipment described by Diefenbach et al. (2002).

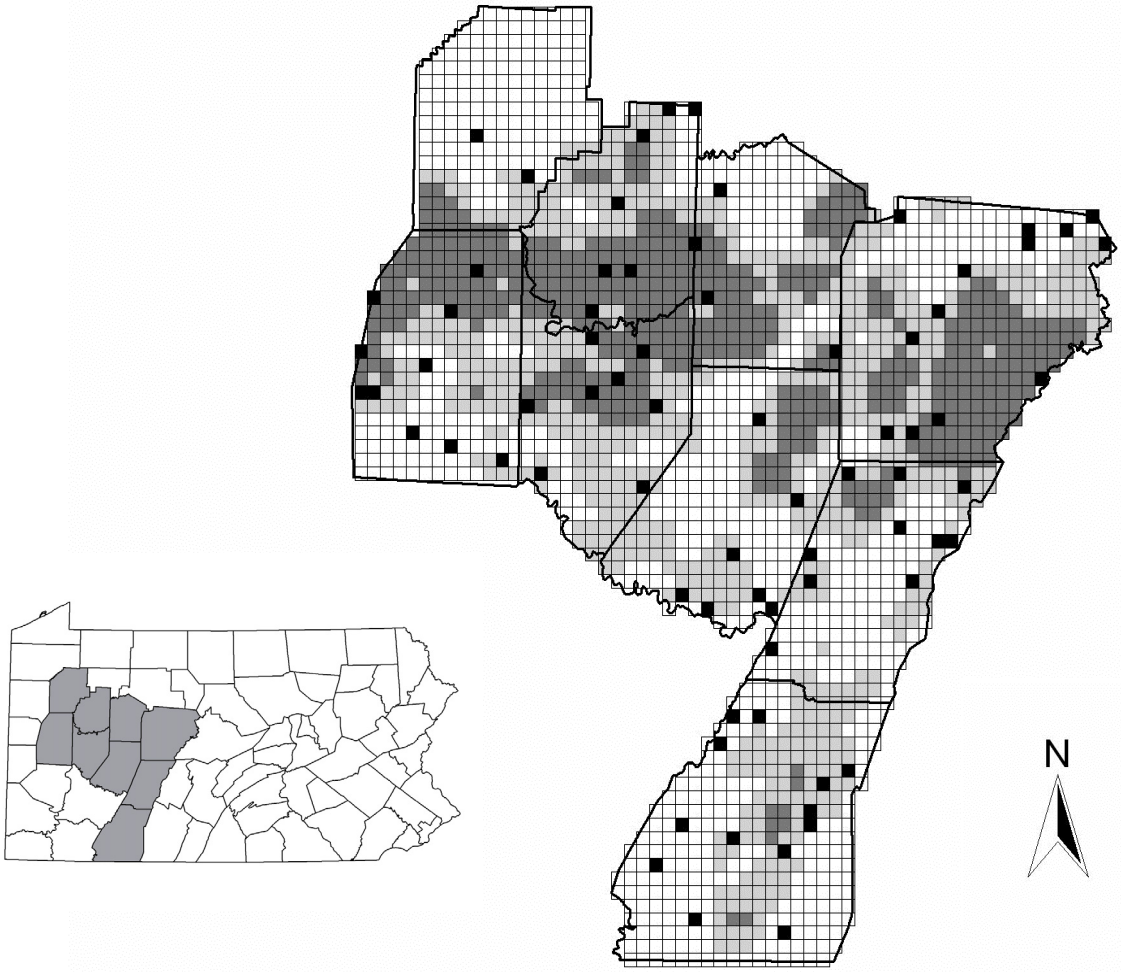

Figure 1— Map of the state of Pennsylvania with the study area shaded, and a larger diagram of the nine-county study area detailing the stratification and sampling scheme. White, light gray, and dark gray blocks represent low, medium, and high amounts of mining activity, respectively. Black indicates the locations of the 74 randomly selected blocks in our sample.

Bird Surveys

Two field technicians surveyed birds by walking parallel line transects within grassland patches on reclaimed mine areas. Each patch was surveyed once during the summer. Technicians surveyed each individual reclaimed habitat patch independently but often surveyed patches in the same block. Transects were separated by 250 m and located perpendicular to the long axis of a grassland patch. We placed the first transect 100 m from the grassland edge and walked parallel transects in the habitat patch until the entire patch was surveyed.

Observers walked at a slow pace (approximately 1 km/hr with occasional pauses) along transects across the extent of contiguous habitat and measured transect length with a handheld Global Positioning System (GPS). Surveys were conducted from 0530 to approximately 0930 EST, between 15 May and 1 July 2001. We did not conduct surveys during heavy rain, intense heat, or excessive wind. After mid-June, fieldwork often ended by 0900 because hot and humid conditions caused grassland birds to cease singing.

Observers recorded only visually detected, singing male Henslow's, Grasshopper, and Savannah Sparrows. Observers measured line-of-sight distance (m) to birds from line transects with Yardage Pro 500 laser binoculars (Bushnell Corporation, Overland, Kansas, U.S.A.), as recommended by Buckland et al. (2001). We measured the horizontal angle from the transect using a compass equipped with a sighting mirror (Silva Ranger CL515, Johnson Outdoors, Binghamton, NY, U.S.A.).

Data Analysis

We estimated the hectares of suitable reclaimed surface mine area in the 9-county area using estimators for a stratified random sampling design (Cochran 1977). We estimated log-normal 95 percent confidence intervals for the area estimate (Chao 1989).

We estimated parameters of the detection function for each observer and species using program DISTANCE, version 3.5, release 5 (Thomas et al. 1998). DISTANCE uses the perpendicular distance of observed objects from the transect line to estimate a model of the probability of detection by distance. The monotonic, decreasing key function (half-normal, hazard, or uniform), with possible cosine adjustment terms, that best fit the data was selected using Akaike's Information Criterion (AIC, Burnham and Anderson 1998). We used this key function to estimate $f(0)$, which then was used in the abundance estimator described below (Buckland et al. 2001). Methods for fitting detection functions, truncating observations at extreme distances, and other particulars of distance sampling are described in detail in Buckland et al. (2001).

Two observers conducted independent surveys and, therefore, we stratified data by observer. We used exact distances in the analysis but inspected the histogram of observations, binned by distance, to decide whether truncating observations at the farthest distances (<5 percent of observations) was warranted (Buckland et al. 2001).

The sampling unit in our study was a 9-km^2 block, which complicated the procedure for estimating abundance and precluded our use of program DISTANCE to estimate abundance. Therefore, we estimated abundance as:

$$\hat{N} = \sum_{s=1}^{3}\left[\sum_{b=1}^{hs}\left(\sum_{obs=1}^{2}\left[\frac{n_b \hat{f}(0)_{obs}}{2}\times 10{,}000\right]\right)\times\frac{A_s}{h_s}\times B_s \Big/ \left[L_{s1}+L_{s2}\right]\right]$$

where $\hat{N}$ is the estimated number of birds for a given species, s is the number of strata, h_s is the number of blocks in stratum s, obs references the observer, n_b is the number of birds observed in block b, $\hat{f}(0)_{obs}$ is the estimated probability density function of detected distances from the line evaluated at zero distance for observer obs, $L_{s,obs}$ is the total transect length (m) for observer obs in stratum s, A_s is the m^2 of habitat found in stratum s, and B_s is the total number of blocks in stratum s. This estimate of abundance was the density estimator described by Buckland et al. (2001), weighted by transect length for each observer and multiplied by the estimated area of habitat in the study area.

We estimated 95 percent confidence intervals (CI) with Monte Carlo simulation using a FORTRAN program written by D. R. Diefenbach. First, we generated random-normal variates for the estimated parameters of each observer's detection function (using the point estimate and estimated standard error for each parameter). For each stratum, we then randomly selected, with replacement, an equivalent sample size of blocks from our dataset and used the corresponding amount of habitat and number of singing males observed. This bootstrap resampling allowed us to incorporate sources of sampling variability due to estimating the amount of habitat as well as the number of birds among transects. We repeated this bootstrap procedure 1,000 times to obtain estimates of N as described above. We ordered these estimates of N and selected the 2.5 and 97.5 percentiles as the limits for 95 percent CI.

Results

Within the 74 surveyed blocks, we mapped 108 reclaimed areas totaling 1,634 ha of suitable grassland

songbird habitat. These patches of habitat ranged in size from 1 to 120 ha and averaged 15 ha. We estimated a total of 35,373 ha (95 percent CI = 26,758 – 46,870) of suitable reclaimed surface mine grassland habitat in the 9-county study area.

Observers walked a total of 70.45 km of transects and recorded 325 Grasshopper Sparrow, 144 Henslow's Sparrow, and 83 Savannah Sparrow singing males within the 108 surveyed areas. We estimated the total population of singing males occupying the estimated 35,000 ha of suitable reclaimed surface mine habitat to be 1,921 Savannah Sparrows (95 percent CI = 848 – 2,790), 9,650 Grasshopper Sparrows (95 percent CI = 4,390 – 13,614), and 4,884 Henslow's Sparrows (95 percent CI = 2,128 – 8,460). From the estimates of total suitable reclaimed-mine grassland area and total populations, we calculated an average density of singing males of each species on suitable reclaimed surface mine habitat over the entire study area: 7 Savannah Sparrow, 28 Grasshopper Sparrow, and 14 Henslow's Sparrow singing males per 100 ha.

Discussion

Concern about declines of grassland bird species continues to grow, but our knowledge of even basic population ecology remains incomplete. Research attention needs to be focused on better understanding population dynamics of these birds. To date, few researchers have attempted to document the size of the populations of grassland birds at regional scales, and published estimates have been based on diverse methods. We used a statistical sampling design and distance sampling to obtain the first regional estimates for Henslow's, Grasshopper, and Savannah Sparrow populations on reclaimed surface mines in Pennsylvania. Obtaining regional population estimates will allow us to track temporal population trends of these grassland bird species.

We have not quantified reproductive success on these reclaimed sites in western Pennsylvania. However, we have anecdotal evidence of successful reproduction, including observations of active nests and feeding behavior of adults of all three species on our study sites (J. Mattice, pers. obs.). We realize the importance of estimating productivity on these sites because these reclaimed areas could potentially function as population sinks, as has been seen in other fragmented habitats (Winter and Faaborg 1999).

Our estimates of bird abundance incorporated the sampling variance associated with the sampling design to estimate the amount of habitat within the study area as well as the sampling variance associated with the estimates of abundance of birds among blocks. However, the accuracy of our estimates depends on how well we met the three assumptions of distance sampling techniques. One assumption is that measurements of distance and angle of birds from the transect line are accurate. We attempted to meet this assumption by using laser rangefinders to measure distance and compasses with sighting mirrors to measure angles. Our evaluation of these methods indicated they provided precise measurements with no systematic bias.

Another assumption is that birds did not move in response to the observer prior to being detected, and we attempted to meet this assumption by searching for birds on or near the transect line well ahead of the observer. Our detection functions exhibited no evidence of birds moving away from the transect line prior to being detected (Buckland et al. 2001:33), but if it did occur our estimates are negatively biased ($\hat{N} < N$; Buckland et al. 2001:32).

The last assumption is that all birds on or near the transect line were detected with certainty. We know this assumption was violated because of the behavior of these species of grassland songbirds and our criteria for recording an observation. These birds often spend a substantial portion of time on the ground where they cannot be seen, and we recorded only visually detected singing males because that was the only way to identify birds to species and to measure distances. Consequently, we likely underestimated abundance, and preliminary research on the proportion of birds that are detectable suggest that our underestimates may be as great as 50 percent (M. R. Marshall, pers. comm.). We are conducting research to estimate the proportion of time singing males are detectable, and we plan to use this information to reduce the underestimation of abundance estimates (Buckland et al. 2001:57-58). Although we believe our estimates represent a minimum number of birds on the study area, we have adjusted for detectability differences related to observer skill, and we provide an associated measure of precision that can be used to test for statistically significant differences in abundance over time or space.

Pennsylvania's contribution to the global population of Henslow's Sparrows is substantial, with approximately 5,000 singing males on reclaimed sites in our 9-county study area. Moreover, we believe we have underestimated their abundance. To place our estimate in context for conservation and management planning, we chose to compare it to estimates for states reported in the 1996 Henslow's Sparrow Federal status assessment (Pruitt 1996). Although these estimates were based on different methods, we found comparisons informative. Few states estimated populations in excess of several hundred birds, and only Oklahoma, Missouri, and Kansas reported populations in excess of 1,000 birds in known colonies or projected to occur in the matrix of

natural and agricultural grasslands. In comparison to our estimates for Pennsylvania, Missouri is the only state with a larger population of Henslow's Sparrows (Pruitt 1996).

Since publication of the Henslow's Sparrow status assessment (Pruitt 1996), many studies, including this one, have been initiated to evaluate the status of Henslow's Sparrow populations. In some instances, significant new populations were identified. Notably, many of these have been on reclaimed surface mines, including locations in Indiana (Bajema et al. 2001), Illinois, and Ohio (Ingold 2002). These surveys indicate larger populations than expected from the 1996 assessment, suggesting that much of the extant population occurs on reclaimed surface mines. Therefore, management of reclaimed strip mine areas as grasslands may help mitigate overall declines in global grassland songbird populations due to habitat loss and degradation.

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