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ABSTRACT.—Avian use of scoria outcrop habitats was compared to use of sagebrush (*Artemisia* spp.)/grassland habitats. Outcrop habitats exhibited higher species richness, total population density, density of lark sparrows (*Chondestres grammacus*), and density of rock wrens (*Salpinctes obsoletus*). Western meadowlarks (*Sturnella neglecta*) and vesper sparrows (*Pooecetes gramineus*) were more abundant in sagebrush/grassland habitats than in scoria outcrops. Habitat relationship models indicated that the unique plant community and structural diversity provided by the scoria outcrops were correlated with increased avian use.

Because of requirements that areas surface-mined for coal and other minerals be reclaimed to the original productivity found prior to mining (e.g., Surface Mining Control and Reclamation Act 1977, numerous state laws), regulatory agencies and mining companies have sought a variety of habitat improvement techniques for reclaiming surface-mined lands for wildlife. Recently, attention has focused on the use of rocks, rock piles, and rock outcrops to enhance wildlife habitats, but little is known about the effectiveness of these or many other mitigation practices on mined lands (Evans 1982).

Scoria (fused porcellanite) outcrops occur in native sagebrush/grassland habitats throughout the Powder River Basin in northeastern Wyoming and southeastern Montana. These outcrops resulted from erosion of soil that covered burned-out coal seams near the surface. Several relatively mesic tree and shrub species are associated with these outcrops. These include ponderosa pine (*Pinus ponderosa*), juniper (*Juniperus* spp.), skunkbush sumac (*Rhus trilobata*), currant (*Ribes* spp.), and chokecherry (*Prunus virginiana*).

Increased patchiness of vegetation in shrub communities has been shown to be associated with increased numbers of avian species (Roth 1976). Rotenberry and Wiens (1980a) reported that avian abundance and species diversity in shrubsteppe communities were associated with habitat heterogeneity. Maser, Geist et al. (1979) and Maser, Thomas et al. (1979) noted the importance of rocks, cliffs, talus, outcrop, and man-made rock piles as wildlife habitat. Wiens and Rotenberry (1981) also noted a unique avifauna associated with rocky outcrops. Otherwise, little information can be found to quantify the importance of outcrop habitats to avian species.

The objectives of this study were (1) to estimate the densities of avifauna associated with scoria outcrop habitats and compare them with densities in the sagebrush/grassland habitats, and (2) to evaluate the habitat associations of the avifauna that use these habitats.

STUDY AREA AND METHODS

This study was conducted approximately 10 km north of Decker, Montana, on land under lease by the Decker Coal Company. The vegetation of the area is classified as eastern Montana ponderosa pine–savannah, which consists of scattered stands of ponderosa pine with broad expanses of northern mixed prairie (Payne 1973). Scoria outcrops were locally abundant and supported a unique plant community of relatively more mesic shrub species (Biggins et al. 1985).

Thirty-eight study sites, 19 in scoria outcrop habitats and 19 in sagebrush/grassland habitats, were located and permanently marked. Outcrop study plots were selected to represent the full range of available outcrop habitats (few to many and small to large outcrops). Sagebrush/grassland habitats were selected for similarity of vegetation to the scoria outcrop plots, ignoring the direct influences of the outcrops on vegetation. Vegetation on the sagebrush/grassland plots generally

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TABLE 1. Average (± se) densities (birds per ha) and species richness of birds occupying scoria rock outcrop and sagebrush/grassland habitats.

Species	Scoria outcrop	Sagebrush/ grassland	Significance level[a]
Lark sparrow	3.8 ± 0.4	0.2 ± 0.1	**
Western meadowlark[b]	0.3 ± <0.1	0.4 ± 0.1	*
Brewer's sparrow[b]	0.1 ± <0.1	0.2 ± 0.1	NS
Vesper sparrow[b]	<0.1 ± <0.1	0.1 ± <0.1	**
Rock wren	0.2 ± <0.1	0.0	**
Total density	5.2 ± 0.4	1.4 ± 0.2	**
Species richness	4.5 ± 0.3	3.1 ± 0.3	**

[a]*P ≤ .10, ** P ≤ .05 based on two-tailed t-test, NS not significant.
[b]Density was calculated based on the number of individuals within 50 m of the census point.

consisted of scattered sagebrush (*Artemisia tridentata* and *A. cana*) with a grass understory consisting of bluebunch wheatgrass (*Agropyron spicatum*), needle and thread (*Stipa comata*), and threadleaf sedge (*Carex filifolia*).

Avian counts were made from a variable circular plot (Reynolds et al. 1980) located at the center of each site. Birds were counted for three consecutive mornings at three-week intervals from mid-May through June 1984–85 (nine counts each year). Upon arriving at a census point, observers waited for one minute and then conducted the census for the next six minutes. Distances to birds seen or heard were estimated to the nearest m out to 30 m and to the nearest 5 m beyond 30 m. Densities of lark sparrows, rock wrens, and total birds were estimated using the Fourier series procedures described for point transects of grouped data (Burnham et al. 1980). Variance estimates were obtained indirectly (Burnham et al. 1980:54). This method of estimating variances assumes that sample points are independent. Sample points were located between 200 m and several km apart and were usually located in habitats discontinuous with the next closest sample point. Because of limited data or sighting functions that did not conform to the assumptions of line transect theory (Burnham et al. 1980), western meadowlark, vesper sparrow, and Brewer's sparrow (*Spizella breweri*) densities were estimated from the average number of individuals within 50 m of the sampling point. Density estimates from fixed radius plots assume that the probability of detection in plots equals one. This assumption was probably violated for meadowlarks.

Several methods were used to estimate habitat characteristics. Herbaceous vegetative cover was estimated by species in thirty 20 × 50-cm quadrats spaced at 1-m intervals along each of three transects radiating from the plot center (Daubenmire 1959); the starting point on each transect was selected randomly. Density of shrub species was estimated by counting all shrubs in a 50 × 50-m subplot centered over the study plots. All rocks and outcrops within a 50-m radius of the plot center and taller than 0.5 m were counted; thereafter, height, width, and length were measured to the nearest dm.

Mean densities of bird species and total birds, and species richness (number of species) were compared between outcrop and sagebrush/grassland habitats using two-tailed t-tests (Steele and Torrie 1960). Species diversity was calculated using the Shannon-Wiener method for all observations within 50 m of the census point. Similarity in abundance of avian species between outcrop and sagebrush/grassland habitats was compared using Sorenson's index. Habitat relationships were tested using stepwise forward-backward multiple regression for all species except rock wrens. The dependent variable was the estimated density of each species for a plot. Stepwise forward-backward discriminant function analysis (Nie et al. 1975) was used to evaluate rock wren habitat relationships due to the presence-absence nature of their distribution on study plots. Classification functions from discriminant analysis were evaluated using the jackknife procedure in BMDP7M (Dixon et al. 1983). The following variables were used in the habitat analyses: percentages of total vegetative cover, grasses, forbs, bare ground, litter, threadleaf sedge, bluebunch wheatgrass, cheatgrass (*Bromus* spp.), needle and thread, and cactus (*Opuntia* spp.); densities of sagebrush and skunkbush sumac; densities and

TABLE 2. Habitat variables associated with avian use of rock outcrop and sagebrush/grassland habitats near Decker, Montana.[a]

Species	Independent variables	Standardized coefficient	Percent variation explained	Correlation coefficient
Rock wren	Density of rocks > 1.0 m in height	0.61	64.0	0.71
	Avg. height of rocks	0.59	71.9	0.58
Lark sparrow	Avg. height of rocks	0.78	67.2	0.82
	% cover of cactus	−0.16	69.8	−0.37
Brewer's sparrow	Density of sagebrush	0.41	17.2	0.41
Total density	Avg. height of rocks	0.56	58.2	0.76
	% herbaceous cover	−0.20	61.9	−0.40
	Vol. of rocks > 1.0 m in height	0.23	65.3	0.60
Species richness	Vol. of rocks > 1.0 m in height	0.45	31.7	0.56
	% cover of needle and thread	−0.38	44.6	−0.52

[a]Variables were selected using stepwise forward-backward multiple regression except rock wrens for which stepwise forward-backward discriminant analysis was used.

volumes of outcrops taller than 0.5 m; and densities and volumes of outcrops taller than 1.0 m. Regression equations were limited to those variables that reduced the sums of squares significantly at $P \leq .05$, and discriminant analysis was limited to those variables that contributed at least 5% to Wilk's lambda.

RESULTS

Avian Abundance

Higher total bird densities ($P \leq .05$) and higher average species richness were found on the scoria outcrop study plots compared with the sagebrush/grassland plots (Table 1). When summed over all plots, 23 species were counted within 50 m of the census points in the outcrop plots versus 10 on the sagebrush/grassland plots. Based on Sorenson's index, there was 19% similarity in the pooled species abundance between the outcrop and sagebrush/grassland habitats. Lark sparrows made up approximately 80% of the total observations in outcrop habitats, and their density on the outcrop plots was nearly 20 times greater than in the sagebrush/grassland plots. Rock wrens were found only in the outcrop habitats, although densities were relatively low. Densities of western meadowlark were greater on the sagebrush/grassland plots than on the outcrop plots ($P \leq .10$), as were vesper sparrow densities ($P \leq .05$). Brewer's sparrow densities were higher on the sagebrush/grassland plots, but the difference was not significant ($P = .38$). Species diversity in the scoria outcrop habitats (1.83) was less than in sagebrush/grassland habitats (2.70) because of lark sparrow dominance in the former. Species evenness (Pielou 1975:15) in the outcrop habitats was 0.40 versus 0.78 in the sagebrush/grassland habitats.

Habitat Relationships

Discriminant analysis of plots with rock wrens present versus those without indicated that two variables were important in discriminating ($P \leq .01$) between the groups and accounted for 72% of the variation between groups (Table 2). Both of these variables characterized attributes of the scoria outcrops. The density of outcrops taller than 1.0 m accounted for 64% of the variation, while average height of outcrops taller than 0.5 m contributed an additional 8%. Both variables had high positive simple correlations with rock wren abundance. Classification functions correctly reclassified 92% of the study plots into the correct group; two study plots without wrens were classified as suitable habitat, and one with wrens was classified as unsuitable habitat.

Two variables, average height of rock outcrops taller than 0.5 m ($P \leq .05$) and percent cover of cactus ($P \leq .10$), explained 70% of the variation in the density of lark sparrows on study plots. Average height of rocks was positively associated with the density of lark sparrows; cactus was negatively associated with lark sparrow density. Only one variable, sagebrush density, contributed significantly ($P \leq$

.05) to the reduction in the sums of squares (17%) of Brewer's sparrow densities on the study plots.

Three variables, average height of outcrops, percent total herbaceous cover ($P \leq .05$), and volume of outcrops taller than 1.0 m ($P \leq .10$), were entered into the model for total avian density on study plots. Average height of the outcrops was positively associated with total avian density and was entered first in the model, accounting for 58% of the variation in bird abundance. Total herbaceous cover, which was negatively associated with total avian density, was entered next; volume of outcrops taller than 1.0 m, which was positively associated with total density, was entered last. Each of these latter two variables added an additional 3% to the total variation accounted for by the model.

Volume of outcrops taller than 1.0 m and percent cover of needle and thread explained 45% of the variation ($P \leq .05$) in species richness. Volume of the outcrops taller than 1.0 m was positively associated with species richness, while percent cover of needle-and-thread grass was negatively associated with species richness. No significant habitat relationships were found for western meadowlarks or vesper sparrows.

Discussion

Scoria rock outcrops provide a unique habitat in this shrubsteppe region. Shrub species such as skunkbush sumac, chokecherry, currant, and juniper are not found except in association with the scoria outcrops in this ecosystem. The occurrence of these shrub species was probably related to shading, protection from wind, snow drift accumulation, and mulch effects of the rocks (Biggins et al. 1985).

Rock wrens, as expected, were confined to some of the scoria outcrop habitats. Some outcrop study plots did not support rock wrens, presumably because of limited foraging areas or lack of crevices for nesting. Rock wrens selected the habitats with larger outcrops. Study plots with rock wrens had an average of 9.3 outcrops per ha that were taller than 1.0 m and an average height of 0.8 m. These averages can be somewhat misleading in that plots with rock wrens generally had several outcrops 2.0 m or greater in height with numerous smaller, sometimes single, rocks. Classification of rock wren habitats, based on these criteria, suggests that all suitable habitats for rock wrens were not filled. Wiens and Rotenberry (1981) reported high variation in local avian population densities which may have indicated "unfilled" habitats. Both of the "unfilled" habitats in the present study were relatively smaller and isolated from contiguous outcrop areas and thus may not have been large enough to meet the habitat requirements of wrens. Alternatively, other parameters not measured in this study may have limited rock wren distributions (i.e., the remaining 28% of variance not accounted for by the discriminant analysis). Renaud (1979) reported rock wrens in most eroded bedrock outcrops in Saskatchewan.

Average height of outcrops and percent cover of cactus were probably not the habitat features to which lark sparrows were responding. Skunkbush sumac was closely associated with average height of outcrops ($r = .75$). In general, larger outcrops had larger sumac and other shrubs associated with them, and lark sparrows used these shrubs for perching, singing, and nesting. Skunkbush sumac was the most common shrub in the outcrop habitats, and lark sparrows showed a high positive association with sumac density ($r = .70$). Lark sparrows also used areas occupied by tall, dense sagebrush within the study area, probably because of the increased structural habitat diversity. Wiens and Rotenberry (1981) reported that lark sparrows were correlated with shrub cover, horizontal heterogeneity, and sagebrush coverage. Percent cover of cactus was greater on grassland plots and was closely associated with several variables indicative of homogeneous single-layered stands. It is doubtful that lark sparrows avoided cactus, but rather they avoided habitats of which it was indicative. Lark sparrows occurred on 29 of the 38 study plots, and regression analysis of only these plots resulted in the same variables, order of entry, and nearly the same standardized coefficients. This would suggest that although the interpretation of the regression model may be somewhat confounded, the same two variables were describing the observed use of habitats by lark sparrows.

Brewer's sparrows were associated with dense areas of sagebrush within the study area and are considered sagebrush obligates

(Braun et al. 1976, Castrale 1982). Brewer's sparrows nest off the ground under the dense canopy of sagebrush (Best 1972), and in this study dense stands of sagebrush larger than 0.5 ha usually contained at least one singing male. Other shrub species such as *Crateagus* spp., *Prunus* spp., *Amelanchier* spp., *Ceanothus velutinus*, and *Arctostophylos patula* (Johnsguard and Rickard 1957, Beaver 1976) can provide the necessary habitat requirements for Brewer's sparrows, thus demonstrating the importance of plant physiognomy rather than plant species to birds when compared across regions or habitat types. Best (1972) reported Brewer's sparrows nesting in dead sagebrush, substituting densely branched plants for the cover normally provided by live foliage. Skunkbush sumac could presumably provide nesting cover at least comparable to sagebrush killed with herbicide. However, Brewer's sparrows were rare in the outcrop habitats, possibly because spacing between sumac plants was too great. A similar segregation of habitat selection was noted by Wiens and Rotenberry (1981) for Brewer's sparrows.

Total avian density and species richness on study plots were both best modeled by positive associations with attributes of the outcrops and negative associations with habitat features characteristic of the sagebrush/grassland habitats on the study area. It was not possible to separate the effects of the shrubs and rocks in this study since the former were dependent, at least for establishment, on the latter (Biggins et al. 1985). Average height of the outcrops and volume of outcrops taller than 1.0 m were both positively correlated with abundance of sumac and currant ($r \geq .70$) on study plots. Taller and larger outcrops provide more protection from wind, greater snow accumulation on the lee side, greater surface area for runoff of rain, and a large mass to ameliorate the fluctuations in soil temperature. Total herbaceous cover and percent cover of needle-and-thread grass were higher on the sagebrush/grassland study plots and were indicative of the homogeneous, single-layered stands. Thus, the negative correlation of these variables with total avian density and species richness was probably indicative of negative relationships between lack of structural diversity and use of habitats by these bird species.

Most small birds apparently distinguish habitats on the basis of structural characteristics (Cody 1985:7). Abundance of avian species in shrubsteppe habitats has been shown to be associated with increased vertical and horizontal diversity of the habitat (Rotenberry and Wiens 1980a). Even though the species diversity in sagebrush/grassland habitats was higher because of a more even distribution of individuals, species richness was higher and positively associated with the habitat provided by the scoria outcrops and the immediate plant community. Large differences in habitat structure result in unequal species abundance and possibly a decline in species diversity (Rotenberry 1978). Rice et al. (1980), Rotenberry and Wiens (1980b), and Wiens and Rotenberry (1981) suggested that species of vegetation were more important in determining use of areas by avian species within habitat types. Within a habitat type, vegetative structural characteristics are usually provided by particular species. It was not possible to separate the effects of individual shrub species from the added structural diversity in this study. Shrub species associated with the outcrop habitats are not typical shrubsteppe species, and the surrounding sagebrush/grassland study plots did not provide similar structural diversity from which comparisons could be made between structural diversity and plant species. The results of this study indicate that at least to some extent the unique habitat provided by the scoria outcrops and the associated plant species resulted in increased species richness and total avian densities, and a different avian community during the breeding season compared with adjacent habitats.

Management Recommendations

Reclamation specialists may enhance wildlife habitats by placing suitable rocks on reclaimed mined land. While these habitats will be different from those originally on the site, it does not seem unreasonable to take advantage of opportunities to improve wildlife habitats in view of historic losses in many areas. Based on the results of this study, I recommend the following where rock piles are selected as a reclamation goal: (1) rock should be placed in piles of varying sizes up to 2 m in height; (2) rocks and rock piles should be grouped, as opposed to evenly scattered, over large areas with approximately 9.0 rock piles per ha taller than 1.0 m; (3) the minimum area to include outcrop habitats should be about 1 ha; and (4) shrub species should be planted in and around piles to encourage establishment of unique plant communities (Biggins et al. 1985).

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