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SPATIAL DISTRIBUTION OF BREEDING PASSERINE BIRD HABITATS IN A SHRUBSTEPPE REGION OF SOUTHWESTERN IDAHO

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Abstract. We mapped the spatial distribution of a habitat index for Sage Sparrows (*Amphispiza belli*), Brewer's Sparrows (*Spizella breweri*), Horned Larks (*Eremophila alpestris*), and Western Meadowlarks (*Sturnella neglecta*) in shrubsteppe habitats of southwestern Idaho. Landscape-level habitat associations of breeding passerine birds were determined from presence or absence at 119 randomly located points surveyed each year from 1992 through 1995. We developed a multivariate description of habitats used by each species from variables derived from coverages in a Geographical Information System. Habitat variables were number of shrub, agriculture, and hydrography cells, mean and standard deviation of shrub patch size, habitat richness, and a measure of spatial heterogeneity in a 1-kilometer radius around each survey point. We ranked each 50-meter cell in a Geographical Information System map by the generalized squared distance in multivariate space between values for habitat variables in the cell and the mean habitat vector for each species. We then generated a map of habitat probabilities of each species for a 200,000-hectare region in southwestern Idaho. In a verification survey at 39 sites, we correctly predicted presence or absence at approximately 80 percent of the sites for Sage and Brewer's sparrows and Western Meadowlarks but at only 36 percent of the sites for Horned Larks. Spatial distribution of habitats for breeding passerine birds was strongly related to distribution of large shrub patches. Because fire is rapidly converting shrublands to exotic annual grasslands in this region, we expect shrubland-obligate species to decline because of habitat loss and grassland species to become more predominant unless management practices change.

DISTRIBUCIÓN ESPACIAL DE HÁBITATS DE AVES PASERIFORMES EN REPRODUCCIÓN EN UNA REGIÓN DE ESTEPA ARBUSTIVA DEL SUROESTE DE IDAHO

Sinopsis. Delineamos mapas de distribución espacial de un índice de hábitat para el Gorrión de Artemisia (*Amphispiza belli*), el Gorrión de Brewer (*Spizella breweri*), la Alondra Cornuda (*Eremophila alpestris*) y el Pradero Occidental (*Sturnella neglecta*) en hábitats de estepa arbustiva en el suroeste de Idaho. Las relaciones de hábitat a escala de paisaje de los paseriformes reproductores se determinaron a partir de la presencia o ausencia observada en 119 puntos escogidos al azar, cada año entre 1992 y 1995. Desarrollamos una descripción multivariante de los hábitats utilizados por cada especie a partir de variables obtenidas de los datos de cobertura disponibles en un Sistema Geográfico de Información. Las variables de hábitat fueron: número de céldas arbustivas, agrícolas, e hidrográficas; media y desviación típica del tamaño de rodales con matorral; riqueza del hábitat; y una medición de la heterogeneidad espacial dentro de un radio de un kilómetro desde cada punto de censo. Ordenamos cada pixel de 50 metros de un mapa del Sistema Geográfico de Información de acuerdo con la distancia cuadrada generalizada entre el valor correspondiente a las variables de hábitat en el pixel y el valor medio correspondiente al vector hábitat de cada especie. Luego produjimos un mapa de probabilidades de hábitat para cada especie para una región de 200.000 hectáreas en el suroeste de Idaho. Censamos 39 sitios para verificar la presencia o ausencia de cada especie. Se predijeron correctamente en aproximadamente un 80 por ciento de los sitios para los Gorriones de Artemisia y de Brewer y para los Praderos Occidentales; sin embargo, sólo se predijo un 36 por ciento de los sitios para las Alondras Cornudas. La distribución espacial de hábitats para paseriformes reproductores se relacionó estrechamente con la distribución de rodales grandes de matorral. Como en esta región el fuego está convirtiendo rápidamente los matorrales a pastizales exóticos anuales, pensamos que, por la pérdida de hábitat, disminuirán las especies dependientes del matorral. Por otro lado, a menos que cambien las prácticas de manejo, esperamos que las especies dependientes de los pastizales se hagan más predominantes.

Key Words: *Amphispiza belli*; *Eremophila alpestris*; exotic annual grassland; Geographical Information System; habitat-selection model; shrubsteppe; *Spizella breweri*; *Sturnella neglecta*.

Interpreting the environment from a species' perspective is an important focus in studies of animal-habitat associations. Descriptions of habitat associations are well known for many species, and numerous statistical techniques exist to develop models of resource selection (e.g., Johnson 1980; Alldredge and Ratti 1986, 1992; Manly et al. 1993). Recently, Geographical Information System (GIS) technology has advanced the capability to map the spatial distribution of single and multiple environmental variables. Just as realistic models have been developed to represent habitat use in a nonspatial context (Verner et al. 1986), it is now possible to describe the spatial distribution of elements in the landscape as perceived by an animal by mapping appropriate variables or indexes. It is then possible to manage landscapes for species based on concepts from theoretical biogeography, which have important implications for conservation biology (Urban and Shugart 1986, Temple and Cary 1988, Burkey 1989, Hansson and Angelstam 1991, Opdam 1991, Danielson 1992). For example, using maps of habitat distributions, managers can identify regions with high probability of use, maintain areas of sufficient size to contain viable populations, or identify habitat corridors for dispersal.

We studied four species of breeding passerines in a shrubsteppe region in southwestern Idaho. Two of the species, Sage Sparrow (*Amphispiza belli*) and Brewer's Sparrow (*Spizella breweri*), are shrubland obligates, and two, Horned Lark (*Eremophila alpestris*) and Western Meadowlark (*Sturnella neglecta*), are grassland species. Our first objective was to develop a resource-selection model for each species by combining field surveys for species presence with landscape variables derived from a classified GIS map. We then mapped the selection function for the entire study area to determine the spatial distribution of habitats potentially used by each species.

Our study involved several assumptions. We assumed that the scale and selection of environmental variables we measured were relevant to the species (Wiens 1989) and that our multivariate statistical model appropriately described the species-habitat associations (Rotenberry 1986, Rotenberry and Knick 1999). We also assumed that the relative probabilities of habitat configuration derived from the statistical model represented the probability that a species would fill available habitats (e.g., Fretwell 1972, Van Horne 1983, Hobbs and Hanley 1990, Vickery et al. 1992).

STUDY AREA

We conducted our study from 1992 through 1995 in a 200,000-ha region of shrubsteppe habitat in southwestern Idaho that included portions of the Snake River Birds of Prey National Conservation Area (116° W, 43° N). The primary management mandate of this area, which was designated as a national conservation area in 1994 (U.S. Public Law 103-64; 4 August 1994), is to maintain and conserve the high densities of nesting raptors and their prey (U.S. Department of the Interior 1979). Multiple uses, including livestock grazing and military training, are permitted if compatible with raptor-conservation management (Kochert and Pellant 1986, U.S. Department of the Interior 1995).

Wildfires are rapidly converting once-large expanses of big sagebrush (*Artemisia tridentata*), winterfat (*Kraschenninikovia lanata*), shadscale (*Atriplex confertifolia*), and other salt shrub (*Atriplex* spp.) communities in the Snake River plains into regions dominated by exotics such as cheatgrass (*Bromus tectorum*) or Russian thistle (*Salsola kali*; Whisenant 1990). As a result of numerous fires since 1980, the native shrub communities now are highly fragmented or have been converted to grassland (U.S. Department of the Interior 1996, Knick and Rotenberry 1997; Fig. 1). The highly flammable annual grasses increase fire frequency and reduce the potential for shrub reestablishment. More than 30% of the 76,910 ha that burned between 1980 and 1992 has reburned two to four times; human activities were responsible for 72% of the fire ignitions (U.S. Department of the Interior 1995).

METHODS

FIELD SURVEYS

We conducted unlimited-radius point-count surveys (Ralph et al. 1995) each year from 1992 through 1995 to determine habitat associations of breeding passerine birds. We established 119 sites by selecting random coordinates throughout the study area in an attempt to sample all habitats in proportion to their available distribution. Minimum distance between sites was more than 400 m, and we considered the sites spatially independent because 97% of all observations (N = 5,757) were estimated from a distance of less than 200 m. Final coordinates of each site were determined by Global Positioning System to an accuracy of less than 5 m (August et al. 1994). Order of sampling in each year was randomly determined.

Sites were sampled once each year between 0500 and 1000 on days with no precipitation and winds less than 12 km/hr. After waiting 2–5 min to reduce the disturbance from our arrival, we recorded all individuals we saw or heard at each site during a 5-min period. Sampling periods were 4 May–25 June 1992; 10 May–23 June 1993; 10 April–24 June 1994; and 3–29 May 1995. One observer participated in all 4 yr, one in 2 yr, and five in 1 yr. All observers participated in a 1- to 3-wk training before beginning surveys.

GIS COVERAGES

Our base coverage in the GIS was a vegetation map classified from Landsat thematic mapper satellite imagery (Knick et al. 1997). Resolution of the vegetation map was 50 m (resampled from 27-m cells in the original thematic mapper satellite image), and the study area contained 1,752,340 cells. After identifying water and agriculture areas, we classified each 50-m cell in the habitat map into one of five categories: sagebrush, winterfat, shadscale, disturbance (dominated by Russian thistle), or grasslands (including both cheatgrass and native grasses). Accuracy in separating shrub cells (>5% ground cover of shrub) from nonshrub cells was 80%; classification accuracy was 64% for classification of the five individual habitat classes (plus agriculture and water categories; Knick et al. 1997). Gross habitat characteristics such as percent shrub cover did not change during our study.

We derived variables that described both the composition and spatial heterogeneity of the landscape (Li

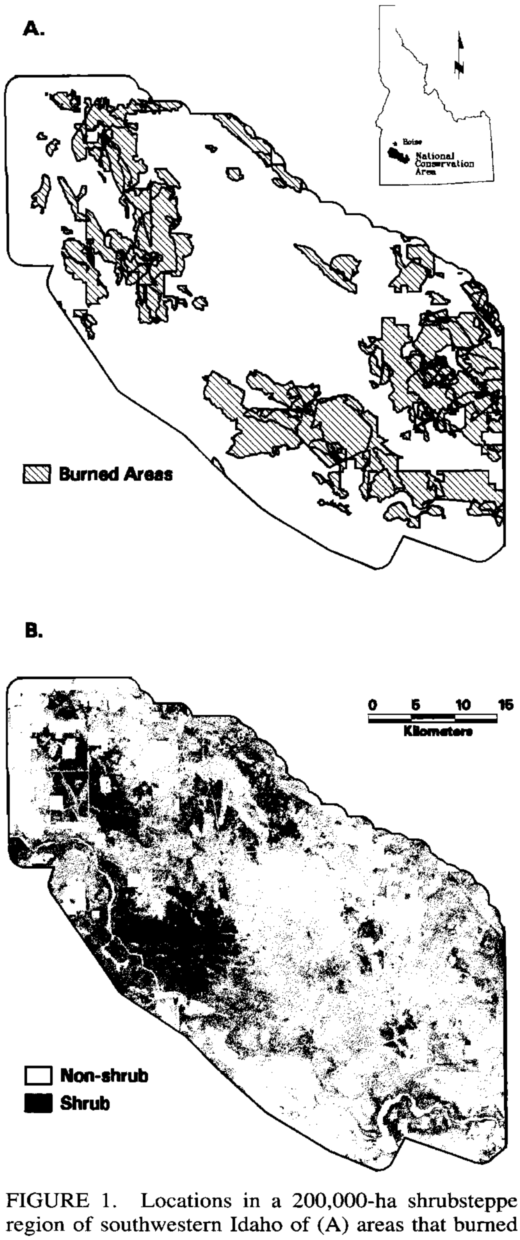

FIGURE 1. Locations in a 200,000-ha shrubsteppe region of southwestern Idaho of (A) areas that burned between 1980 and 1992 and (B) shrub patches and grassland in 1994. Burned areas were digitized from U.S. Bureau of Land Management fire boundaries on 1:24:000 quadrangle maps. Shrub and grasslands were classified from Landsat thematic mapper satellite imagery.

and Reynolds 1994; Table 1). We developed an index of habitat diversity from the number of habitats in a 1-km radius of each cell in the vegetation map. We also determined the number of shrub cells and the average size and standard deviation for shrub patches. We used the ratio of number of edges between shrub and grass cells to total the number of edges in the 1-km radius as an estimate of landscape heterogeneity. Habitat diversity was the only variable derived from the full habitat classification, which contained the lower classification accuracy. For the other landscape variables we used the binary shrub/nonshrub classification.

We created a coverage of all agriculture fields from a composite of a 1979 vegetation map of the Snake River Birds of Prey National Conservation Area (U.S. Department of the Interior 1979), 1993 U.S. Bureau of Reclamation agriculture maps, and our classified satellite imagery. The composite agriculture map included areas of both actively growing and fallow vegetation. We also created a coverage of hydrography, to include wetlands, lakes, and ephemeral or permanent streams and rivers, from U.S. Geological Survey 1: 100,000 digital line graphs. We used the number of agriculture and hydrography cells in the 1-km radius of each cell in our analyses.

Habitat Associations

We determined habitat associations for each species based on the mean values for the habitat variables at all sites where a species was detected. This multivariate habitat mean and the associated covariance matrix were then used to develop habitat maps for each species. We used a site in the analysis if a species was detected in any of the 4 yr of sampling. By including sites where a species was present in only 1 yr, we determined the optimistic range of habitat associations in our analysis because yearly variation in temporal persistence was related to habitat characteristics (Knick and Rotenberry 1995, Rotenberry and Knick 1999). Because of the relative ubiquity of Horned Larks, we defined presence of this species as more than four birds at a site.

Six of the seven variables were transformed to best approximate a normal distribution as determined by Kolmogorov-Smirnov tests. Distributions of all variables remained significantly different from normal ($P < 0.05$), but statistical power remained high because of large sample sizes in the GIS map. Although normality tests failed, we proceeded without meeting this assumption using the best approximations to a normal distribution to minimize the potential bias. We transformed average patch size and standard deviation by $\log_{10}(x + 1)$, number of shrub cells by $x^{0.4}$, landscape heterogeneity by $x^{0.8}$, habitat diversity by x^2, and hydrography by $x^{0.9}$. The distribution of the agriculture variable could not be improved and was not transformed.

Habitat Maps

We created maps of habitat distributions for each species by first determining the generalized squared distance (or Mahalanobis distance) between the landscape variables in each cell of the GIS map and the multivariate mean of those variables associated with a species (Clark et al. 1993, Knick and Dyer 1997). The generalized squared distance was then converted to a Chi-squared probability distribution with P (number of variables) − 1 = 6 degrees of freedom. Therefore, we simply rescaled the generalized squared distance, a dimensionless statistic, to a probability distribution be-

TABLE 1. LANDSCAPE-LEVEL VARIABLES USED IN AN ANALYSIS OF HABITAT SELECTION BY SAGE AND BREWER'S SPARROWS, HORNED LARKS, AND WESTERN MEADOWLARKS IN A SHRUBSTEPPE REGION IN SOUTHWESTERN IDAHO

Variable	Description
Agriculture	Number of 50-m agriculture cells
Habitat richness	Number of different habitats
Hydrography	Number of cells containing wetlands, lakes, or permanent or ephemeral streams and rivers
Shrubs	Number of 50-m cells classified in shrubland category
Mean shrub patch	Mean patch size of all shrubland patches in the 1-km radius
Shrub patch variance	Standard deviation of all shrubland patches in the 1-km radius
Habitat patchiness	Number of edges between shrubland and grassland cells

Note: All variables were determined for a 1-km radius around each 50-m cell in a GIS map of the study area.

tween 0 and 1. As such, we determined the probability that the variables at a cell were similar to the multivariate mean that described habitats associated with sites where a species was detected.

VERIFICATION SURVEYS

We conducted verification surveys in 1995 at an additional 39 sites located at random coordinates throughout the study area. Sites were classified into predicted absence or presence for each species based on a χ^2 probability of 0.5 for the cutpoint.

RESULTS

At 119 points surveyed annually from 1992 through 1995, we observed Sage Sparrows at 36 points, Brewer's Sparrows at 83, Horned Larks at 102, and Western Meadowlarks at 96. Habitats associated with Sage and Brewer's sparrows included large shrub patches and relatively lower amounts of edge between shrubland and grasslands than at habitats associated with Horned Larks and Western Meadowlarks (Table 2).

Maps of habitat probabilities for each cell reflected the strong association of Sage and Brewer's sparrows (Fig. 2) with existing shrublands (Fig. 1). At the landscape scale, burned areas were associated with low similarities to the mean habitat vectors at sites where we observed Sage and Brewer's sparrows (Fig. 1).

Maps generated from the χ^2 probability distribution of the generalized squared distances for Horned Larks and Western Meadowlarks were more conservative in predicting the spatial extent of habitats than we expected because of these species' ubiquity in the samples (Fig. 3). However, areas of predicted habitats for Horned Larks and Western Meadowlarks included both greater spatial extent and more grassland regions than maps generated for Sage and Brewer's sparrows.

Cumulative frequency distributions represented the proportion of the study area relative to the mean habitat vector for each species (Fig. 4). As expected, a smaller proportion of the habitat in the study area was similar to the mean habitat vector associated with Sage Sparrow, the least-observed and most habitat-specific species, when compared to Brewer's Sparrow, Horned Lark, or Western Meadowlark.

We correctly predicted presence or absence at 79% of the verification sites for Sage Sparrows and Western Meadowlarks, at 82% of the sites for Brewer's Sparrows, but at only 36% of the sites for Horned Larks (Table 3). In most classification errors, a species was present at a site where the selection model predicted absence. Horned Larks, present at 22 of 39 sites where

TABLE 2. SUMMARY STATISTICS FOR HABITAT VARIABLES AT SURVEY SITES IN SOUTHWESTERN IDAHO FOR SAGE AND BREWER'S SPARROWS, HORNED LARKS, AND WESTERN MEADOWLARKS

Habitat variable	Sage Sparrow (N = 36)		Brewer's Sparrow (N = 83)		Horned Lark (N = 102)		Western Meadowlark (N = 96)	
	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
Agriculture (no. cells)	21.3	13.0	34.0	11.8	28.2	9.6	36.6	11.0
Habitat richness	6.1	0.1	6.1	0.1	6.1	0.1	6.0	0.1
Hydrography (no. cells)	37.4	4.8	45.4	3.7	48.1	3.7	51.1	3.6
Shrubs (no. cells)	854.0	46.5	647.6	38.2	466.2	34.7	502.5	33.4
Mean shrub patch (km^2)	47.0	9.1	30.2	5.2	22.6	4.6	14.5	2.5
Shrub patch variance	19.1	2.9	14.5	1.7	11.8	1.8	11.6	1.6
Habitat patchiness	405.6	33.2	439.6	22.4	462.5	22.6	471.3	21.2

Note: Sample sizes (N) are the number of sites where presence was recorded at 119 sites surveyed annually from 1992 through 1995.

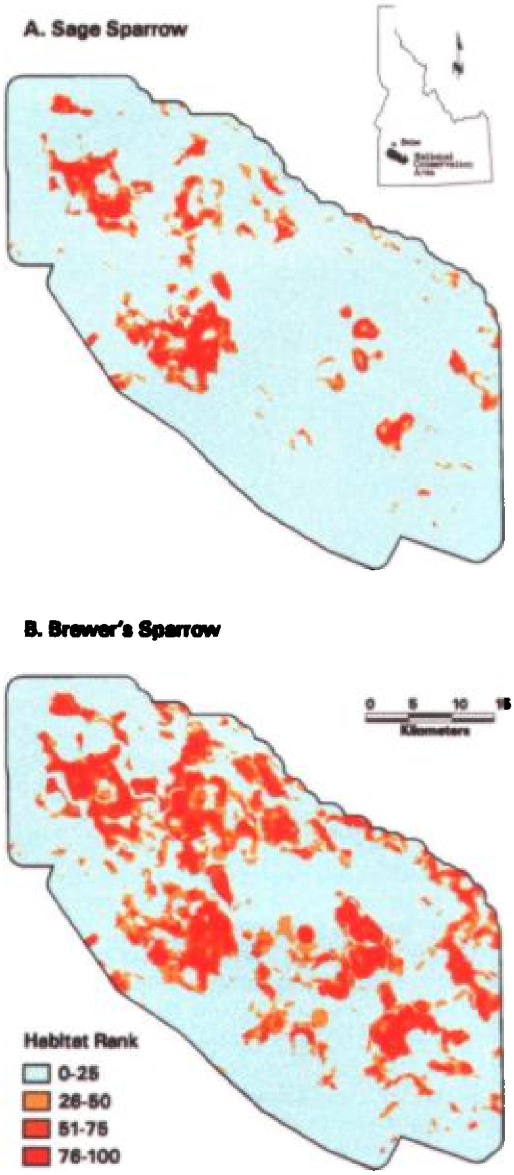

FIGURE 2. Spatial distribution of habitats for (A) Sage Sparrow and (B) Brewer's Sparrow in a 200,000-ha shrubsteppe region of southwestern Idaho. Habitat rank is the χ^2 probability that habitats in individual map cells were similar to the multivariate mean habitat vector associated with the species presence at survey sites (ranks closest to 100 have the highest probability of similarity).

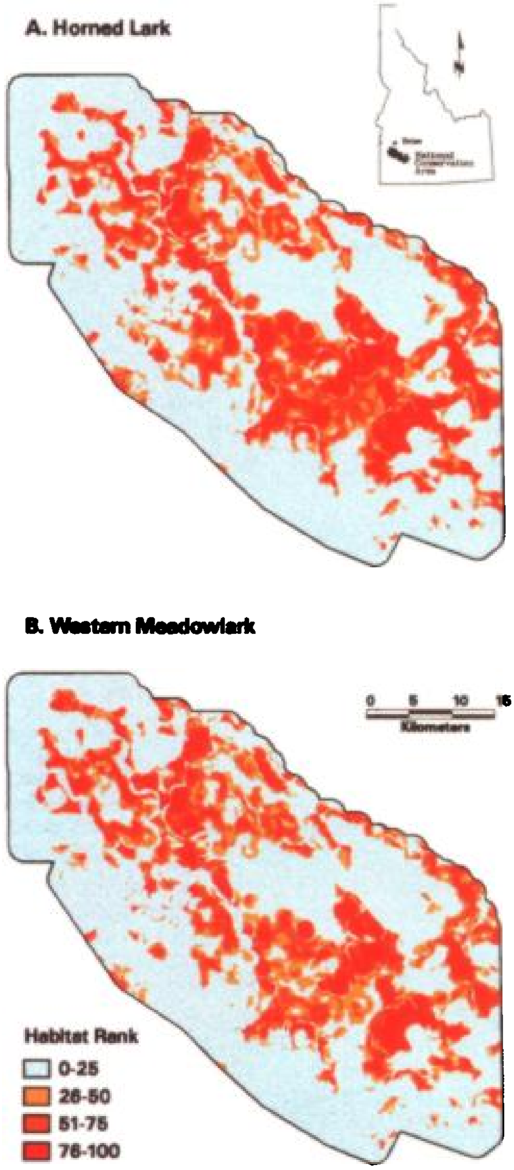

FIGURE 3. Spatial distribution of habitats for (A) Horned Lark and (B) Western Meadowlark in a 200,000-ha shrubsteppe region of southwestern Idaho. Habitat rank is the χ^2 probability that habitats in individual map cells were similar to the multivariate mean habitat vector associated with the species presence at survey sites (ranks closest to 100 have the highest probability of similarity).

absence was predicted, represented the extreme in these errors (Table 3).

DISCUSSION

Spatial distribution of habitats for the two shrubland-obligate species, Sage and Brewer's sparrows, was clearly related to existing shrublands. Because large-scale fires have converted shrublands to exotic annual grasslands with increased fire frequency, we expect that habitats for shrubland-obligate species will continue to

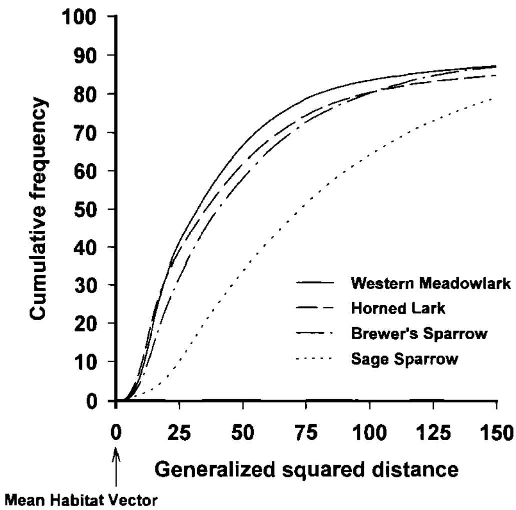

FIGURE 4. Cumulative frequency distribution of generalized squared distances for Sage and Brewer's sparrows, Horned Larks, and Western Meadowlarks in a 200,000-ha shrubsteppe region of southwestern Idaho. Relative shift in distribution toward the right indicates greater proportions of areas that are less similar to habitats (mean habitat vector) where the species was observed.

TABLE 3. ERROR MATRICES FOR PRESENCE OR ABSENCE PREDICTED BY RESOURCE-SELECTION MODELS DEVELOPED FOR SAGE AND BREWER'S SPARROWS, HORNED LARKS, AND WESTERN MEADOWLARKS AT 39 SITES IN A SHRUBSTEPPE REGION OF SOUTHWESTERN IDAHO

		Known		
Species	Predicted	Absent	Present	Total
Sage Sparrow	Absent	27	5	32
	Present	3	4	7
	Total	30	9	39
Brewer's Sparrow	Absent	24	6	30
	Present	1	8	9
	Total	25	14	39
Horned Lark	Absent	12	22	34
	Present	3	2	5
	Total	15	24	39
Western Meadowlark	Absent	28	7	35
	Present	1	3	4
	Total	29	10	39

decline. We expect the current trajectory of habitat changes to have a particularly adverse effect on Sage Sparrow habitats.

Since 1979 fires have destroyed more than 30% of the existing shrublands in our study area (U.S. Department of the Interior 1996). We do not know the fire regime of presettlement periods, but large-scale fires, although present, likely were much less frequent than they now are because of the difference in grassland understory (Whisenant 1990). Because of cheatgrass invasion into this system in the late 1800s and early 1900s, continuous fuels are now omnipresent in the understory and facilitate firespread. In addition, cheatgrass cures earlier than native grasses, thus increasing the length of the fire season (Klemmedson and Smith 1964). The larger and more frequent fires in the present disturbance regime have either eliminated or widely dispersed the existing seed sources of shrub species (Knick and Rotenberry 1997). The potential for recovery of shrubs, such as sagebrush, is far outpaced by the rate of loss. Thus, the system has lost much of the once-dominant shrubland and now exists in a new grassland state that potentially represents a habitat sink from which shrub recovery by natural means of gradual recolonization by seedling establishment is unlikely or extremely long-term.

Our study demonstrated the potential of landscape-scale attributes to determine habitats for shrubland-obligate species; we correctly predicted presence/absence at approximately 80% of the verification points. Both species persisted in burned areas when measured at a local scale (< 10 ha; Petersen and Best 1987, 1999), but local plots still were embedded in larger-scale landscapes of shrubland. Loss of shrublands at our larger scale of investigation (1-km radius around each point) was reflected in complete absence of habitat for shrubland-obligate species, and those species were not present.

Our technique clearly represented the spatial distribution of habitat for shrubland-obligate specialists, such as Sage and Brewer's sparrows, and for Western Meadowlark, a grassland species. For these specialists, the mean and covariance matrix represented the distribution of the habitats used by the species. For more generalist species, however, such as Horned Lark, the mean and covariance matrix more likely represented the distribution of habitats in the study area rather than a species-habitat association. Thus, the generalized distance from the mean habitat vector may not represent the wide range (or variance) of habitats used by generalist species. As the species-habitat association becomes more general, the mapped distribution changes from the mean habitat vector of the species to represent the mean configuration of habitats in the study area.

Based on verification surveys, our habitat maps were consistently conservative in predicting species presence, despite using a relatively liberal definition of habitats used (species presence at a site in any of 4 yr) to define the multivariate mean habitat. By using a narrower definition, such as species presence at a site in all years, map predictions likely would underestimate further the actual distribution of habitats. Alternatively, we could change the χ^2 probability that defines presence or absence, or simply rescale the generalized squared distance into user-defined quantiles (e.g., Knick and Dyer 1997). When rescaled into quantiles, the categories then represent a percent of the study area in each class (e.g., the top 10% of the study area) rather than a probability of similarity to the multivariate habitat mean.

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