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ABSTRACT

*Adoption of ecological sites as monitoring and management units by a variety of land users has prompted discussion of their benefits for wildlife habitat management. Density and occurrence of shrub-steppe passerines are often related to key habitat characteristics such as plant species composition, cover, and structure. Until recently, ecological sites have not been tested as units for monitoring and management of passerines. We conducted a study implementing ecological sites as management units and used passerines as indicators of potential use of these sites. Ecological site characteristics and three sagebrush-obligate passerines were quantified on ecological sites at and near Browns Park National Wildlife Refuge in Colorado. In 2006 and 2007, we surveyed passerines and site characteristics using standard techniques within 101, 100-m radius plots. Density of Brewer's sparrow (*Spizella breweri*) and occurrence of Brewer's sparrow, sage sparrow (*Amphispiza belli*), and sage thrasher (*Oreoscoptes montanu*) were estimated for six ecological sites and then related to site characteristics. For example, Brewer's sparrow densities were greatest (3.0 birds/ha) on a Loamy Fine Sand Ecological Site containing taller vegetation than vegetation for other ecological sites. Scientific literature commonly associates Brewer's sparrows with sagebrush (*Artemisia tridentata*) presence, but on ecological sites at Browns Park Brewer's densities are related more to vegetative structure rather than species composition. Results show there are links between passerine populations and ecological sites; a relationship which provides a meaningful foundation in developing long-term monitoring protocols and enhancing management decisions to favor sagebrush-obligate passerines.*

INTRODUCTION

An ecological site is characterized by the ability to produce certain types and amounts of vegetation based on climate, topography and soil, and can be practical spatial units for monitoring and management (Pellant and others 2005; Herrick and others 2006a). Ecological site descriptions serve as repositories of geographic locations, climate, topography, soils, hydrology, vegetation communities, and state and transition models. State and transition models offer a tool for defining what is possible and realistic for management objectives, options and priorities (Bestelmeyer and others 2003; Herrick and others 2006a). Ecological sites are practical units because they are consistent with current monitoring, management and assessment frameworks used by land management agencies.

Adoption of ecological sites as basic management units by the U.S.D.A. Natural Resource Conservation Service (NRCS) and U.S. Bureau of Land Management (BLM) has prompted discussion in their application for wildlife habitat management and research. Units based on ecological site delineations enable land managers to evaluate not only potential and health of each site within a landscape, but also to examine management options and successes. Incorporation of qualitative and quantitative data for sites in a landscape will help determine where and how management will have the greatest impact on resources such as wildlife habitat. Recent suggestions are to expand ecological site descriptions to include vegetation and site characteristics that reflect wildlife habitat parameters such as plant distribution and structure. Ecological site descriptions by definition provide information on potential plant communities for a given soil in a particular climate; these soil and plant community characteristics dictate wildlife habitat.

Shrub-steppe passerine populations, particularly sagebrush-(*Artemisia tridentata*) obligate species, are an appropriate starting point for evaluating ecological sites as monitoring and management units for wildlife habitat because they are frequently monitored, often discussed within the context of other species of concern (for example, sage-grouse (*Centrocercus* spp.)), sensitive to anthropogenic and natural events, and have a tight association with shrublands. Sagebrush-obligate passerines, namely Brewer's sparrow (*Spizella breweri*), sage sparrow (*Amphispiza belli*), and sage thrasher (*Oreoscoptes montanus*) require sagebrush for some part of their lifecycle, mostly for nesting and shelter (McAdoo and others 2004). They have been studied extensively over the past 40 years. Despite the wealth of data, few studies have addressed sagebrush-obligate population parameters (abundance, density, occurrence, occupancy, etc.) in relation to ecological sites. This is partly due to challenges regarding scale and lack of information on linkages between ecological site characteristics and population parameters.

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Passerine populations fluctuate across time and space leading to mixed results in developing habitat association models (Rotenberry and Wiens 1980; Rotenberry and Knick 1999). Scales at which species parameters are defined have an effect on how habitat associations are interpreted (Wiens and Rotenberry 1981; Wiens and others 1987; Knick and Rotenberry 2000). Sage thrashers were positively associated with shrub and bare ground cover, vegetation height and habitat heterogeneity and negatively related to grass and low vegetation cover at broad spatial scales (tallgrass prairie to shrubsteppe regions of U.S.), but were inversely related to sagebrush and total shrub cover at regional scales (shrub-steppe of the Pacific Northwest) and positively related to standing dead vegetation and negatively related to shrub cover at the individual scale (territories within 9 ha plots) (Wiens and others 1987). Passerine parameters are often assessed in areas that are much larger than their breeding territories. Brewer's sparrow territories range from 0.1 to 2.4 ha (Paige and Ritter 1999; Rotenberry and others 1999; and Wiens and others 1985). Sage sparrow breeding territories range from 0.6 to 6.3 ha in shrub-steppe (Paige and Ritter 1999; Reynolds 1981; Rich 1980; Wiens and others 1985) and sage thrasher ranges from 1.1 to 1.9 ha (Reynolds 1981). Ecological sites are groupings of similar soils based on their potential to support certain types and amounts of vegetation and are mapped using second to third order soil surveys, which range between 1:12 000 to 1:63 000 in scale (for example, Soil Survey Geographic Database, SSURGO). Sites occur together in landscapes and generally repeat across landscapes. Therefore, an ecological site may include several potential passerine breeding territories and an individual territory may expand over more than one ecological site. Knowing the scales of both passerine breeding and habitat territories is essential for integration with ecological sites across a landscape.

The lack of information on linkages between site characteristics and passerine population parameters could be reflective of monitoring protocols and an insufficient number of studies conducted on ecological sites. Brewer's sparrow, sage sparrow and sage thrasher prefer similar breeding habitats – above average vegetation height, high shrub and bare ground cover, and low grass cover (Paige and Ritter 1999). Shrub species composition is also an important habitat characteristic for these species (Wiens and Rotenberry 1981). In addition, reductions in live shrub cover (Best 1972; Reynolds and Trost 1981; Wiens and Rotenberry 1985) and patch size (Knick and Rotenberry 1995; Vander Haegen and others 2000) have a negative effect on population size. Plant species composition, cover and structure measurements are common to passerine studies and are occasionally collected using standard monitoring methods which make it difficult for comparison and application across spatial scales. Some studies have shown that wildlife populations vary with soil types (Dobler and others 1996; Vander Haegen and others 2000). Vander Haegen and others (2000) found strong relationships between sagebrush-obligate passerine parameters and soil type; populations were associated with deep, loamy soil communities that supported greater cover of tall shrubs than shallow soils. Passerine association with soil type is a strong indicator that ecological sites (soil-vegetation associations) would be a valuable structure for assessing habitat characteristics and resource use for these populations.

Using an integrated framework we delineated and described upland ecological sites on a wildlife refuge in northwestern Colorado and linked site characteristics with sagebrush-obligate passerine density and occurrence. We used common, standard monitoring methods to measure passerines and site characteristics within the context of ecological sites. Our objectives were to 1) delineate and describe upland ecological sites, 2) survey passerines and intensively measure site characteristics within each site, 3) relate density and occurrence to site characteristics, and 4) determine how ecological site characteristics relate to observed density and occurrence of passerines. Studying habitat characteristics within an ecological site context can help identify site characteristics as potential habitat indicators for passerines. Illustrating that ecological sites are reflective of potential use by passerines provides the opportunity for researchers, land agencies and land owners to not only communicate in the same language, but also to determine management practices and provide a framework to evaluate management success.

MATERIALS AND METHODS

Study Area

The study was conducted on Browns Park National Wildlife Refuge (BPNWR) and on adjacent areas owned by BLM and State of Colorado in northwestern Colorado near Maybell. The area, approximately 5445 ha with an average elevation of 1,633 m, lies within the Upper Colorado River Ecosystem. Average annual temperature is 7.4 °C, with average annual winter, spring and summer temperatures of -3.7, 7.2 and 18.6 °C, respectively. Annual precipitation is 216 mm, half of which occurs in winter and spring as frontal storms. Soils are formed by alluvial and eolian processes from hard sandstone, limestone, and small amounts of quartzite. They range from loamy fine sands to sandy loams supporting a mosaic of upland shrub-steppe vegetation that covers more than 60 percent of the study area. Shrubs and perennial grasses common to both sagebrush-steppe and salt-desert plant communities are present and include Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*, hereafter referred as sagebrush), shadscale (*Atriplex confertifolia*), spiny hopsage (*Grayia spinosa*), black greasewood (*Sarcobatus vermiculatus*), Indian ricegrass (*Achnatherum hymenoides*) and needleandthread (*Hesperostipa comata*). Primary land uses are wildlife habitat, livestock grazing and recreation. The refuge was established in 1963 by U.S. Fish and Wildlife Service (FWS) to provide sanctuary for migratory birds, conserve threatened and endangered species, and enhance species' habitat. Winter livestock grazing ceased on the refuge in 1994 but continues on adjacent BLM and State lands.

Ecological Sites

Spatial data of the study area, which included Browns Park National Wildlife Refuge and surrounding areas, were integrated into a geographic information system (GIS) to identify upland ecological sites. Soil information was obtained from SSURGO for Moffat County, Colorado (Soil Survey Staff 2006). Supporting spatial data (vegetation, water features, roads, and elevation) were obtained from Browns Park National Wildlife Refuge. The area is within the 7 to 9 inch precipitation zone of NRCS Major Land Resource Area 34A-Central Desertic Basins, Mountains and Plateaus which extends into Wyoming and Utah. Because ecological sites had not been delineated or described we collected additional baseline information including onsite soil evaluations and data from similar ecological sites in 34A. We delineated six ecological sites based on soil profile and surface textures. Loamy Fine Sand sites occur in both upland and bottomland areas and have loamy fine sand surface and subsurface soil textures; the soils are slightly alkaline. The remaining five sites are upland sites. Upland Cobbly Sand sites have a loamy sand surface with cobble sand subsurface. A cobble layer exists approximately 4 cm deep in the profile. Upland Gravelly Sand site have a loamy fine sand surface with gravelly loamy fine sand subsurface textures. Upland Loamy Fine Sand sites have a loamy fine sand surface and subsurface textures with a possible calcium carbonate subsurface layer indicated by presence of winterfat (*Krascheninnikovia lanata*) (Blaisdell and Holmgren 1984). Upland Sands sites have a fine sand surface texture and loamy fine sand with occasional cobbles in subsurface layers. Site characteristics and passerines were measured in 101 plots randomly stratified within each ecological site at 250 m spacing (figure 1).

Site Characteristics

Standard monitoring methods adapted from Herrick and others (2005a, 2005b) were selected to measure site characteristics that would capture ecological site variability and indicate potential passerine density and occurrence. Site characteristics were measured in all plots along three 50 m line transects arranged in a spoke design between May and August 2006 and 2007.

Type and amount of cover (percent) and vegetation height (cm) were measured by line point intercept methods. Shrub density (shrubs/ha) was measured by means of a 2 by 50 m belt transect. Shrubs were grouped into four size categories (A < 10, B 10 to 50, C 50 to 100, and D > 100 cm in height). Amount and size of gaps (> 20 cm) between vegetation canopies and bases were measured by gap intercept methods. A qualifying canopy was defined as at least 50 percent of the plant canopy covering no less than 3 cm along the line. A qualifying base had to be large enough to interrupt a linear flow pattern. To further quantify shrub structure, the amount, size and area of intercanopy spaces between shrub bases and canopies, were also measured using gap intercept methods with height measurements. Canopy and basal gaps were calculated separately as the percentage of line covered in gaps 20 to 50, 51 to 100, 101 to 200 and > 200 cm in length. All measurements were averaged across the three transects for each plot. GPS locations and photographs were taken of each plot.

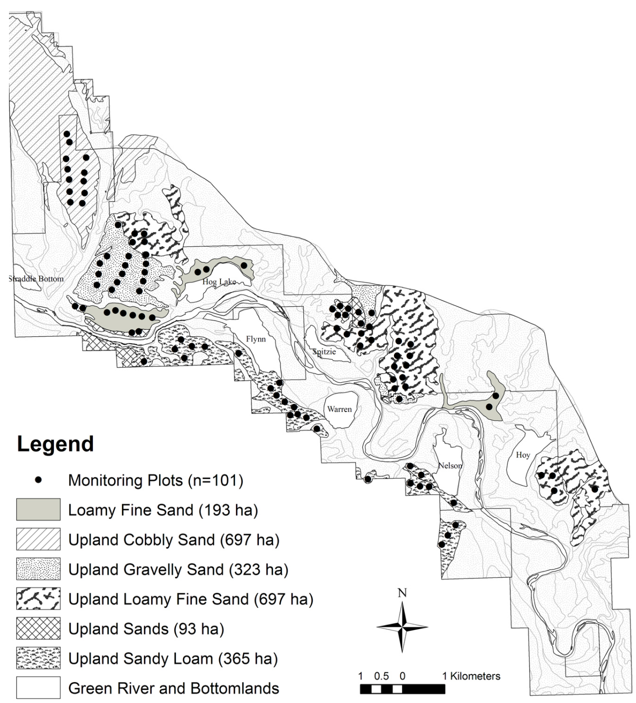

Figure 1—Upland ecological sites (number of ha) and monitoring plots at the Browns Park study area located 60 miles northwest of Maybell, Colorado. Sites were delineated by soil texture characteristics.

Passerine Density and Occurrence

Upland passerines were surveyed in each plot during the breeding season using fixed-radius point transect sampling methods (Bibby and others 2000 and Buckland and others 2001). Survey dates were May 6 to 11 and May 26 to 31, 2006 and May 6 to 11 and 23 to 27, 2007. One observer (same individual) surveyed passerines on mornings between 0600 and 1000 hours with no precipitation and wind less than 20 km/h. Male passerines were identified by sight or sound within 100 m of each plot for 5 minutes following a 1 to 2 minute settling period. For each detected male passerine, species was recorded and distance estimates were made with a laser range finder. Although all passerine species were recorded, we are limiting analyses to Brewer's sparrow, sage sparrow and sage thrasher.

Densities were estimated with program DISTANCE, version 5.0, release 2 (Thomas and others 2005). DISTANCE uses perpendicular distances of each observation to create a histogram of the number of detections by distance. A series of key functions (half-normal, hazard and uniform) with possible hermite and simple polynomial and cosine adjustments were used to model detection functions for each species. Prior to modeling, data were pooled across survey dates and at least 10 percent of the largest distances were truncated as recommended by Buckland and others (2001). Model fit was evaluated with a chi-square goodness-of-fit (GOF) test and Akaike's Information Criterion with a second order correction for small sample size (AICc) was used to select the most robust model (Buckland and others 2001). Through modeling a detection function, an estimate of the proportion of individuals detected in the survey area was derived using standard distance estimation methods for point transects (Buckland and others 2001; Buckland and others 2010).

Occurrence (percent) by ecological site was estimated for each species and defined as the number of plots where the species was present divided by the number of plots on each site. A species was considered present in a plot if it occurred in at least one survey in any year.

Table 1—Site characteristic means (standard error) for six upland ecological sites at the Browns Park study area. Within each site characteristic, ecological site means with followed by the same letter are not statistically different (Fisher's protected least significant difference, $p \geq 0.05$).

Site Characteristic	Loamy Fine Sand (11)[y]	Upland Cobbly Sand (12)	Upland Gravelly Sand (19)	Upland Loamy Fine Sand (24)	Upland Sands (10)	Upland Sandy Loam (25)
Cover (%)						
Sandberg bluegrass	0.1 (0.1)b	1.1 (0.5)a	0 (0)b	0.1 (0.1)b	0 (0)b	0.1 (0.03)b
Greasewood	23.9 (3.8)a	12.1 (1.9)b	0.2 (0.1)d	3.9 (0.7)cd	1.1 (0.5)d	7.9 (2.3)bc
Rabbitbrush	0.5 (0.4)b	0.2 (0.2)b	1.3 (0.5)b	0.3 (0.2)b	3.4 (2.1)a	0.1 (0.1)b
Shadscale	1.9 (0.8)c	2.7 (0.5)c	9.7 (1.0)a	5.5 (0.7)b	2.3 (0.6)c	1.1 (0.3)c
Spiny hopsage	2.4 (1.2)bc	0.1 (0.1)c	0.3 (0.3)c	2.7 (0.9)b	7.3 (1.9)a	3.6 (0.6)b
Winterfat	0 (0)b	0 (0)b	0 (0)b	2.3 (1.0)a	0.1 (0.1)b	0 (0)b
WY big sagebrush	1.8 (1.4)bc	8.8 (2.1)a	8.5 (2.2)a	0.9 (0.7)c	5.7 (1.2)ab	4.1 (0.9)bc
Total shrub	30.9 (3.1)a	23.9 (1.7)ab	20.1 (2.3)bc	15.7 (1.1)c	20.4 (2.0)bc	17.2 (2.0)c
Interspace litter	17.8 (1.1)b	16.8 (1.5)b	20.6 (0.9)ab	20.7 (1.3)ab	18.6 (1.8)b	23.6 (1.5)a
Height (cm)[z]						
Vegetation	26.3 (1.9)a	21.7 (1.1)b	15.2 (0.9)c	15.2 (0.9)c	18.7 (1.2)bc	20.9 (1.5)b
Shrub	30.5 (2.1)a	24.0 (1.0)bc	20.2 (1.4)c	20.8 (0.9)c	25.4 (2.8)ab	28.3 (1.4)a
Shrub Gap	45.6 (2.5)a	32.0 (1.0)cd	26.2 (0.9)d	26.8 (1.3)d	36.0 (2.2)bc	39.2 (2.5)b
Canopy Gaps (%)						
All 20-50 cm	4.4 (0.6)c	6.0 (0.4)abc	7.8 (0.6)a	7.3 (0.8)ab	7.8 (0.8)a	5.8 (0.8)bc
All 51-100 cm	9.6 (1.0)c	12.4 (0.6)bc	14.6 (0.9)ab	15.2 (1.1)ab	16.5 (1.2)a	11.8 (1.2)c
Shrub 20-50 cm	3.7 (0.5)bc	5.0 (0.4)ab	5.7 (0.7)a	4.3 (0.7)ab	3.4 (0.6)bc	2.5 (0.3)c
Shrub 51-100 cm	8.3 (0.8)bc	10.7 (0.6)ab	12.2 (1.4)a	11.3 (1.2)ab	8.7 (0.9)bc	7.0 (0.8)c
Shrub 101-200 cm	16.9 (1.6)ab	21.4 (1.4)a	19.4 (1.7)a	19.2 (1.1)a	16.7 (1.3)ab	14.6 (1.1)bc
Shrub > 200 cm	28.4 (4.7)bc	26.0 (2.7)bc	24.8 (3.6)c	35.6 (2.9)b	37.4 (3.6)ab	45.0 (2.8)a
Shrub Density (no/ha)						
A (< 10 cm)	851.6 (320.0)b	3255.5 (635.7)a	3420.6 (568.0)a	2866.4 (598.4)a	1250.0 (289.8)b	1268.0 (369.1)b
B (10-50 cm)	5966.6 (1535.7)c	15394.4 (1430.7)ab	18629.1 (2011.4)a	17333.3 (2666.6)a	9880.0 (1620.4)bc	8019.9 (1574.4)c
C (50-100 cm)	4724.3 (398.7)a	2983.3 (316.3)b	1022.1 (176.0)c	1456.9 (234.3)c	2700.0 (357.0)b	3345.3 (398.6)b
D (> 100 cm)	327.2 (109.1)a	16.6 (8.7)bc	7.0 (4.1)c	9.7 (5.1)c	80.0 (35.2)bc	131.9 (54.2)b

[y]Ecological site (number of plots).
[z]Vegetation and shrub height measured with line point intercept methods. Shrub gap height measured with gap intercept methods.

Data Analysis

Site characteristics were assessed for differences among ecological sites using univariate analysis of variance (ANOVA). Residuals were assessed for meeting the assumptions of ANOVA. As a result of heteroscedasticity, sagebrush, greasewood, rabbitbrush (*Chrysothamnus viscidiflorus*), shadscale, spiny hopsage, and winterfat cover and density of small (A and B) and large (D) shrubs were natural log transformed. Results from analyses of original data did not change with transformation. Where significant differences occurred among sites (alpha = 0.05), mean separations were conducted using Fisher's protected least significant difference (FLSD).

Differences in ecological site passerine density were assessed using ANOVA. Multiple linear regression was used to examine relationships between density and site characteristics and differences in density among ecological sites. Prior to performing regressions, Pearson correlation coefficients were generated to select site characteristics that were significantly related to species density because the original data set included over 60 site characteristics. Best subsets regressions were conducted using sagebrush and total shrub cover, vegetation height, shrub density, and species-specific site characteristics to select the best one, two and three predictor models for density. Adjusted R^2, Mallows Cp, and parameter standard errors were evaluated to select the best set of models with up to three site characteristics. Models were further evaluated with respect to multicollinearity and sampling logistics. Comparisons of occurrence across ecological site were made for each species, as well as evaluation of occurrence for species on each ecological site.

RESULTS

Ecological Site Characteristics

As expected, ecological sites differed in several site characteristics (table 1). Major differences were found in shrub cover and density among sites, while there were also some significant differences in height and canopy gaps. Loamy Fine Sand had greater density and cover of large shrubs, especially greasewood, whereas Upland Gravelly Sand was characterized by greater cover of low shrubs such as shadscale and shorter overall vegetation. Upland Cobbly Sand was distinguished by having several intermediate shrub canopy gaps (101 to 200 cm) and greater sandberg bluegrass (*Poa secunda*) and sagebrush cover. Upland Loamy Fine Sand had the greatest cover of winterfat relative to all other ecological sites. Upland Sands had greater spiny hopsage and rabbitbrush cover and Upland Sandy Loam had greater interspace litter and several, large shrub canopy gaps (> 200 cm).

Passerine Density and Occurrence

Including three sagebrush-obligates (Brewer's sparrow, sage sparrow and sage thrasher), 25 species and 989 male passerines were observed over the two years. The most common species observed was Brewer's sparrow (30 percent of all observations and 2.02 birds/ha over the entire study area). Sage sparrows and sage thrashers were detected in 9 and 4 percent of all observations (0.19 and 0.09 birds/ha over the entire study area, respectively). We recorded densities of Brewer's sparrow, sage sparrow and sage thrasher similar to other shrub-steppe communities (Boyle and Reeder 2005; Rotenberry and others 1999). Greater density of Brewer's sparrow than sage sparrow and sage thrasher is consistently seen in the shrub-steppe (Paige and Ritter 1999). Of the sagebrush-obligates, only Brewer's sparrow observations were sufficient to estimate plot density.

Brewer's sparrow densities differed among ecological sites and ranged from 1.2 to 3.0 birds/ha. Brewer's sparrows were denser and greater in Loamy Fine Sand than in Upland Sands, Upland Loamy Fine Sand and Upland Gravelly Sand sites. Brewer's sparrow densities were regressed against the following site characteristics: sagebrush and total shrub cover, vegetation height, shrub density, and vegetation and shrub canopy and basal gaps. Three regression models generated from best subsets were selected (table 2). In the first model, Brewer's sparrow density increased with increasing vegetation height and reduced presence of small gaps between plant bases and density of small shrubs (accounting for 53 percent of variation in density). For the second model, density increased with increasing vegetation height and reduced presence of small gaps between plant canopies, explaining 50.8 percent of the variance in density. Using a single site characteristic model, vegetation height, explained 48.5 percent of the variation in density. Of all site characteristics, vegetation height had the strongest independent correlation to density ($r = 0.70$). Vegetation height was negatively correlated to small canopy and basal gaps and density of small shrubs ($r > -0.40$). Densities were strongly related to vegetation height on ecological site (figure 2). Overall, Brewer's sparrows were denser in ecological sites dominated by taller vegetation. The relationship between density and vegetation height was not as strong in the Upland Gravelly Sand and Upland Sands sites.

Brewer's sparrow was present more than 70 percent of the plots across all ecological sites, but least in Upland Loamy Fine Sand (figure 3). Both sage sparrows and sage thrashers were less common overall, but their occurrences were greatest in Upland Cobbly Sand and Upland Sands sites. Sage thrashers were not recorded in Upland Gravelly Sand.

Table 2—Best subset regression models for Brewer's sparrow density (birds/ha).

Model	Coefficient	Standard Error	P	Adj R^2
Vegetation Height (cm)[a]	0.12	0.02	0.000	53.0
All Basal Gaps 51-100 cm (%)	-0.06	0.03	0.024	
B (10-50 cm)[b]	-3.61×10^{-5}	1.16×10^{-5}	0.002	
Constant	0.54	0.56	0.335	
Vegetation Height (cm)	0.14	0.02	0.000	50.8
All Canopy Gaps 51-100 cm (%)	-0.05	0.02	0.021	
Constant	0.18	0.59	0.766	
Vegetation Height (cm)	0.16	0.02	0.000	48.5
Constant	-0.99	0.33	0.003	

[a]Vegetation height measured by line point intercept methods.
[b]Density of shrubs between 10 and 50 cm in height.

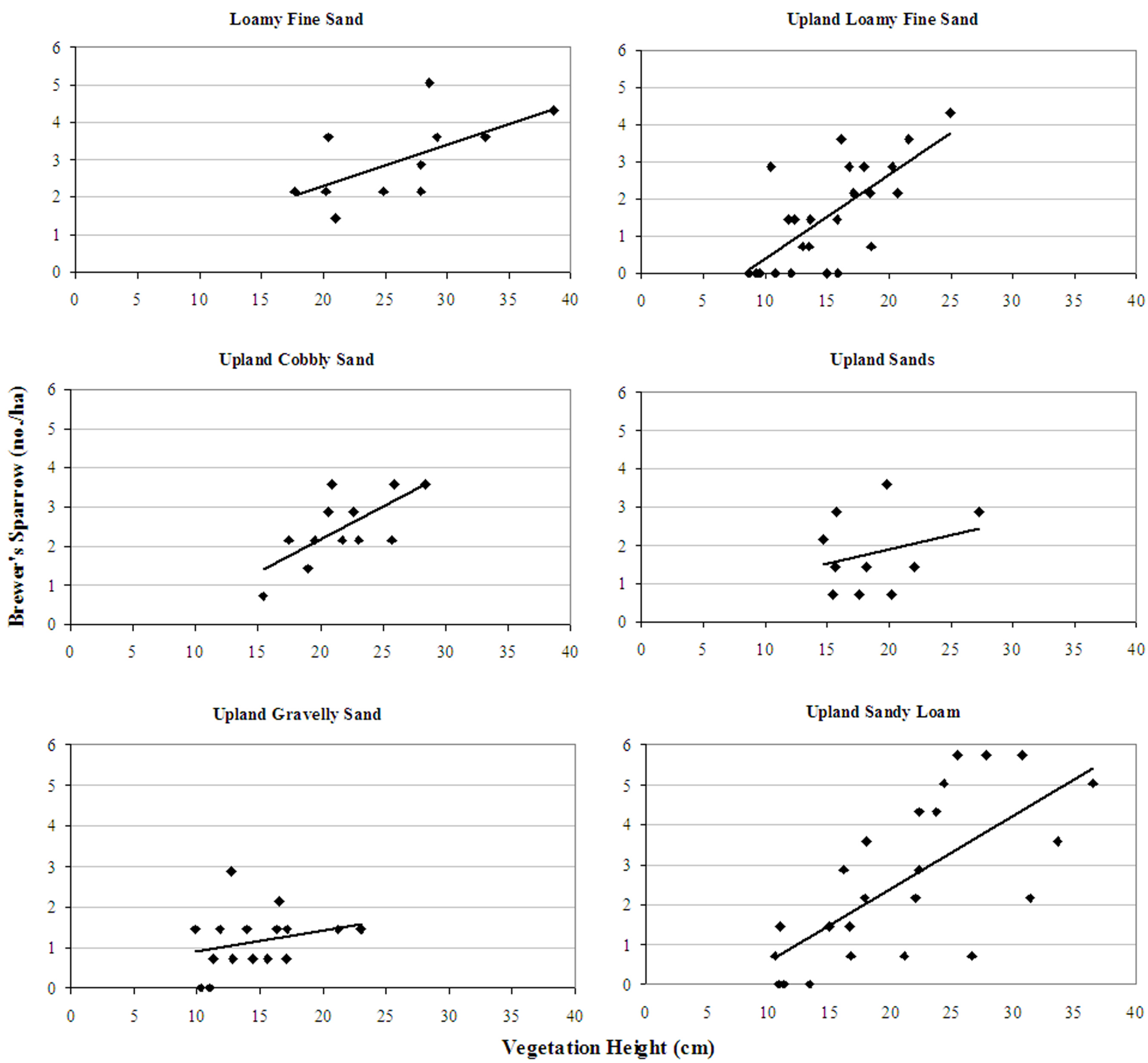

Figure 2—Brewer's sparrow density and vegetation height for Loamy Fine Sand (n =11), Upland Cobbly Sand (n =12), Upland Gravelly Sand (n =19), Upland Loamy Fine Sand (n =24), Upland Sands (n =10), and Upland Sandy Loam (n =25) ecological sites. Lines are fitted regression line of density and height on each site.

DISCUSSION

Variation and similarities among and on sites at Browns Park coupled with results from passerine observations point toward the importance of ecological site proximity and size in developing long-term monitoring and management protocol for a landscape. Sites existing in small proportions or in small patches within the entire landscape may not be given high monitoring or management priority because of operation constraints. Whereas, management options may be evaluated for large, adjacent ecological sites with similar soils such as Upland Loamy Fine Sand and Upland Gravelly Sand, to improve sagebrush-obligate passerine habitat, which could potentially benefit other sagebrush-obligate species.

Differences in Brewer’s sparrow densities among ecological sites showed a strong response to plant community structure rather than plant species composition. Brewer’s sparrow is commonly and consistently associated with shrublands dominated by sagebrush (Paige and Ritter 1999), but in this study, greater densities were associated with sites with tall, widely spaced vegetation. The negative influence of small plant canopy and basal gaps on species density is notable as gap size is a common indicator measured on ecological sites. Gaps between plant canopies and bases are important indicators of resistance to runoff, water and wind erosion, and invasive species establishment (Pellant and others 2005). However, because of multicollinearity between vegetation height, gaps and shrub density it is difficult to interpret their individual effects on observed densities for each site. Brewer’s densities were influenced strongly by vegetation height, especially in sites with mean heights greater than 20 cm. Relationships between density and height were inconsistent in sites where densities were low. Mean density and vegetation height did not differ among Upland Gravelly Sand, Upland Loamy Fine Sand and Upland Sands, but there was a stronger linear relationship between density and height on Upland Loamy Fine Sand than the two other sites. For Upland Sands, this was attributed to a smaller mapped area and number of plots relative to other sites at Browns Park. In both sites, however, Brewer’s sparrow may be responding to site characteristics other than vegetation height such as small canopy and basal gaps and density of small shrubs. Monitoring of additional Upland Sands and Upland Gravelly Sand sites within MLRA 34A will help to distinguish sample size from site characteristic effects on Brewer’s sparrow density. Measuring vegetation height using line point intercept methods was easier and faster than measuring gaps and shrub density. As revealed by the coefficient of determination, vegetation height could provide as much information as gap size and shrub density in understanding densities found on sites.

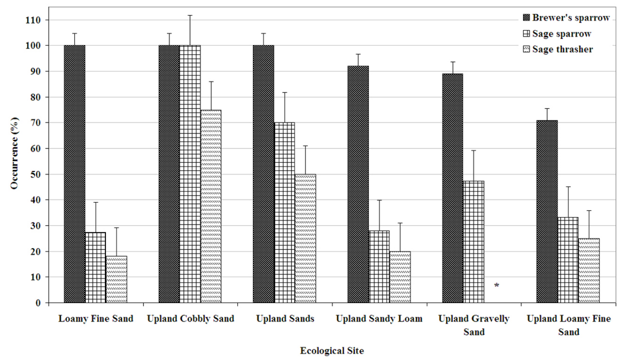

Figure 3—Occurrence (± 1 standard error) of Brewer’s sparrow, sage sparrow and sage thrasher for Loamy Fine Sand (n=11), Upland Cobbly Sand (n=12), Upland Gravelly Sand (n=19), Upland Loamy Fine Sand (n=24), Upland Sands (n=10), and Upland Sandy Loam (n=25) ecological sites.

Vegetation height reflects soil characteristics and past management efforts. Recognizing that height is a meaningful indicator of potential use by Brewer’s sparrow encourages inclusion of height measurements in ecological site descriptions, monitoring protocols and evaluation of sites and management options that favor this species. For instance, Upland Loamy Fine Sand includes two soil types, one having a minor component with elevated amounts of calcium carbonate in surface and subsurface layers. Three monitoring plots in this site are dominated by winterfat (9-20 percent), a low growing shrub rarely exceeding 10 cm in height at this site. The dominance of winterfat certainly contributes to structural characteristics of the vegetation – low vegetation height, high density of small shrubs and several small plant gaps – characteristics not favored by Brewer’s sparrow as there were no detections for these plots. Long-term monitoring will help detect any changes to vegetation height, but will also help determine if these winterfat-dominated areas on the site are exhibiting a plant community state or a transition to another, separate ecological site.

Brewer’s sparrows occurred in all sites, indicating a ubiquitous pattern across the study area. However, observed densities varied among ecological sites indicating and point toward existence of primary and secondary habitats on sites. All three sagebrush-obligate species frequented sites with high cover of tall shrubs (Upland Cobbly Sand and Upland Sands), in contrast, sage sparrow and sage thrasher had low occurrence in sites with greater cover of greasewood and spiny hopsage and lower cover of sagebrush. This pattern implies that sage sparrow and sage thrasher prefer sites dominated or co-dominated by sagebrush, which is consistent with literature. Sage sparrows have similar breeding habitat preferences as Brewer’s sparrow, but are perhaps more obligate to sagebrush, preferring large, continuous stands of sagebrush (Rich 1978). Affinity for sagebrush is less straightforward for the sage thrasher, especially on Upland Gravelly Sand where sagebrush cover is higher than other sites but sage thrashers were never observed. Presence of sagebrush cover alone therefore does not indicate potential use by sage thrasher. Sage thrashers are almost always associated with shrublands dominated by sagebrush and prefer areas with more shrub and bare ground cover and less grass and spiny hopsage cover (Rotenberry and Wiens 1980; Wiens and Rotenberry 1981). In this study, occurrence of sage thrasher in Upland Cobbly Sand and Upland Sands indicates a preference for sagebrush height rather than its presence. Occurrence patterns indicate a difference among the three sagebrush-obligates in response to ecological site characteristics and illustrate that it is important to not only measure plant composition but also community structure. Upland Gravelly Sand may never provide suitable habitat for sage thrashers even with management activities, whereas Upland Sandy Loam has potential for improving the existing plant community to favor sage sparrow and sage thrasher.

Using sagebrush-obligate passerines as indicators of potential use of ecological sites present in northwestern Colorado provided an opportunity to study these populations in a diverse shrub community where sagebrush is not the dominant shrub species. The patterns of sagebrush-obligate density and occurrence indicate that shrub community composition is driving their distribution more than presence of a shrub species. Baseline data coupled with continued monitoring and state and transition models for each site will aid determining management options.

CONCLUSIONS

Response from sagebrush-obligate passerines to ecological sites and site characteristics at Browns Park suggests that ecological sites are a practical framework as wildlife management units. For the refuge, having these ecological sites mapped and described within a spatial context will be useful for making landscape scale management decisions that favor sagebrush-obligate passerines. Monitoring and management should be prioritized according to ecological site potential, representative size and proximity to ecological sites favored by sagebrush-obligate passerines. Some sites have a wide range of variability in site characteristics that are potentially attractive to sagebrush-obligates, whereas other sites have a narrow range of variability and thus less attractive. Long-term monitoring of site characteristics using appropriate methods will aid in determining site range of variability, assessing plant community states, and evaluating management success. Further, monitoring other wildlife species on ecological sites and incorporation of sites within a landscape will significantly improve functionality of this framework.

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