A Landscape Analysis of Grassland Birds in a Valley Grassland-Oak Woodland Mosaic[1]

Devii Rao,[2] Sasha Gennet,[2] Michele Hammond,[3] Peter Hopkinson,[4] and James Bartolome[5]

Abstract

While little research has been done on California grassland birds, their populations are thought to be declining due to habitat loss, fragmentation, and degradation. We investigated the association between California grassland birds and their landscape-scale habitat matrix. The habitat is a mosaic of valley grassland with blue oak and coast live oak woodlands. In this study, we used logistic regression to analyze presence of grasshopper sparrows (*Ammodramus savannarum*), horned larks (*Eremophila alpestris*), western meadowlarks (*Sturnella neglecta*), savannah sparrows (*Passerculus sandwichensis*), and the guild as a whole in response to patch size, cover-type richness, and proportion of high-intensity development, low-intensity development, deciduous forest, and evergreen forest in the landscape. These landscape variables were analyzed for the 2004 and 2005 breeding seasons at three spatial scales: 500 m, 1 km, and 2 km buffer zones from the point count center. We found that the grassland bird guild as a whole was positively associated with patch size, proportion of low-intensity development, and proportion of evergreen forest and negatively associated with cover-type richness, proportion of high-intensity development, and proportion of deciduous forest. Patch size and cover-type richness were the most commonly significant variables across spatial scales and across years. Individual species showed similar trends to that of the guild.

Keywords: California, grassland birds, habitat fragmentation, landscape analysis, patch size.

Introduction

In California, the decline of grassland bird species is thought to be associated with major changes in the grassland ecosystem (California Partners in Flight 2000). Three of the foremost ecosystem alterations in recent California history are the near complete shift from native perennial grasses to European annual species, the large-scale conversion of grassland to farmland, and continued habitat fragmentation, primarily as a result of urbanization (California Partners in Flight 2000). Ecosystem changes have led to the decline of grassland bird species not only in California but throughout the United States. This nationwide decline has been faster and more steady than that of any other guild (Knopf 1994, Peterjohn and Sauer 1999). These large shifts in population dynamics suggest that to conserve grassland birds, land managers need more in-depth and current information on how these species are

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[2] Graduate Student, Department of Environmental Science, Policy, and Management, University of California, Berkeley, CA 94720. e-mail: devii@goldridgercd.org, asgennet@nature.berkeley.edu.
[3] Staff Research Associate, Department of Environmental Science, Policy, and Management, University of California, Berkeley, CA 94720. e-mail: mhammond@nature.berkeley.edu.
[4] Post-doctoral Researcher, Department of Environmental Science, Policy, and Management, University of California, Berkeley, CA 94720. e-mail: phopkin@nature.berkeley.edu.
[5] Professor, Department of Environmental Science, Policy, and Management, University of California, Berkeley, CA 94720. e-mail: jwbart@nature.berkeley.edu.

interacting with their environment at the landscape scale. In this paper, we focus on two species known to be decreasing nationwide: grasshopper sparrow (*Ammodramus savannarum*) and western meadowlark (*Sturnella neglecta*) (Herkert 1994).

Although there are no available data on grassland birds prior to the 1800s (California Partners in Flight 2000), a general portrait of the California grassland ecosystem has emerged. Upon arrival of Europeans in North America, the first major transformation in California grasslands was from native perennial plant species to European annuals. This transformation likely began prior to the 1769 establishment of the first Spanish mission in California (Heady and others 1991, Mensing and Byrne 1998). Heady and others (1991) suggest three factors led to the conversion of the grasslands: introduction of livestock, drought, and introduction of exotic annual plant species. It was the combination of these factors working together that allowed exotic annuals to replace the native grassland vegetation. Subsequently, 75 percent of the Central Valley, which originally contained the largest area of grassland in California (Huenneke 1989), was converted to farmland by 1880 (Hewes and Gannett 1883, cited in Huenneke 1989). Today, remaining grasslands are becoming fragmented as suburbs expand, and ranch lands and farm lands are divided into smaller parcels with larger homes (California Department of Forestry and Fire Protection 2003). We propose that these factors are leading to decreasing grassland patch size available for nesting grassland birds. Therefore, managing for fragmentation provides an important opportunity for conservation of grassland bird species.

Although most grassland bird research has been done in the Midwest, researchers in California may gain insight from the results of such studies. For example, numerous publications from research in the Midwest have focused on area sensitivity: grassland birds showing preference for larger grassland patches (Herkert 1994, Vickery and others 1994, Helzer and Jelinski 1999, Winter and Faaborg 1999, Horn and others 2000, Johnson and Igl 2001, Renfrew and Ribic 2002, Bollinger and Gavin 2004, Davis 2004). Questions arising from the area sensitivity studies have led researchers to investigate the influence on grassland birds of other landscape-level factors, such as cover-type diversity, mean patch size of cover types, and amount of grassland edge (Ribic and Sample 2001, Bakker and others 2002, Fletcher and Koford 2002).

Very little research has been done on grassland birds in California. To date, studies have focused on the influence of local vegetation characteristics on grassland bird populations (Collier 1994, Goerrissen 2005, Gennet and others 2006). This paper is the first in a series of publications, in collaboration with the East Bay Regional Park District, that will take a holistic approach to grassland bird systems, looking at both landscape- and community-level factors. While there have been no studies in California to determine the influence of diminishing patch size on grassland birds, grassland fragmentation is probably exacerbating the decrease in California grassland birds (California Partners in Flight 2000). Due to this lack of information, basic data collection is needed before the proposal of any broad-scale conservation recommendations (California Partners in Flight 2000).

We aimed to quantify the effects of landscape variables on four grassland bird species: grasshopper sparrow, savannah sparrow (*Passerculus sanwichensis*), horned lark (*Eremophila alpestris*), and western meadowlark. We did this by investigating the following questions: 1. Is grassland bird presence positively associated with size of grassland patch? 2. Is grassland bird presence negatively associated with cover-type richness, in other words, number of land cover types within a specific buffer zone? 3. Is grassland bird presence negatively associated with proportion of urban development and oak woodland cover types in the landscape? The six landscape variables we analyzed were: patch size, cover-type richness, and proportion of high-intensity development, low-intensity development, deciduous forest, and evergreen forest.

Methods

Study Sites

Plots were located in seven East Bay Regional Park District properties in Alameda and Contra Costa counties (Brushy Peak, Lake Chabot, Morgan Territory, Pleasanton Ridge, Sycamore Valley, Vasco Caves, and Sunol) and in Camp Parks RFTA military installation in Dublin, California (*fig. 1*). Data were collected from 49 plots in 2004 and 62 plots in 2005. Shared characteristics of the majority of plots were large patches of valley grasslands (areas > 100 m radius) surrounded by oak woodlands and/or developed areas. The valley grassland type is primarily composed of European annual grasses, including annual ryegrass (*Lolium multiflorum*), rip-gut brome (*Bromus diandrus*), and soft chess (*Bromus hordeaceus*). The most common native species found on our plots is purple needle grass (*Nassella pulchra*, 2 percent cover), followed by: tomcat clover (*Trifolium willdenovii*), notchleaf clover (*Trifolium bifidum*), and Johnny jump-up (*Viola pedunculata*) all at 0.4 percent cover. The surrounding mosaic of oak woodland is largely made up of blue oak (*Quercus douglasii*) and coast live oak (*Quercus agrifolia*). In addition to oak woodlands, the study sites, especially Sycamore Valley and Lake Chabot, are surrounded by housing developments of differing intensity.

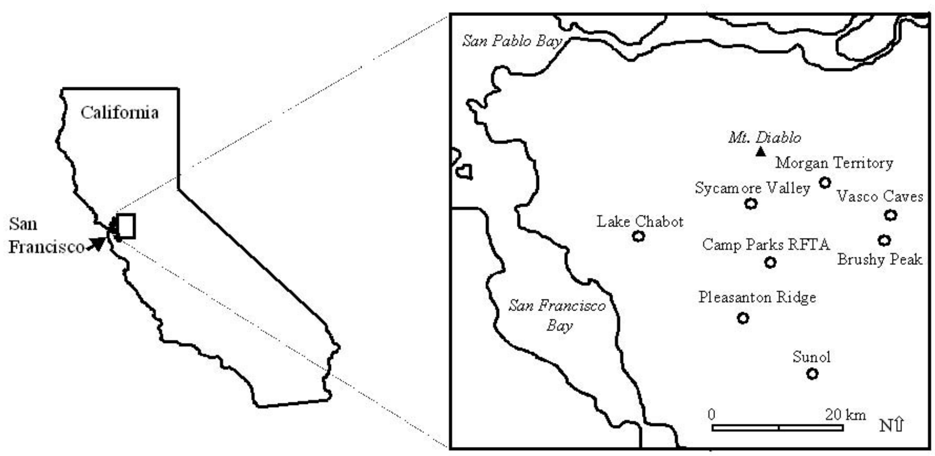

Figure 1—Study area showing East Bay Regional Park District properties and Camp Parks RFTA.

Bird Sampling

California Partners in Flight lists grasshopper sparrow, western meadowlark, and savannah sparrow as focal grassland species of conservation and management concern. We chose to study these three species in addition to the horned lark because they are dependent on grasslands for foraging and breeding.

We applied standard point count methodology for grassland bird surveys (Ralph and others 1995). Three, 10-minute point count surveys were done at each plot at least 10 days apart during the 2004 and 2005 breeding seasons. Surveys took place between March 15 and June 15. Barring high winds or inclement weather, point counts began within 15 minutes of sunrise, and the final point count of the day ended no later than four hours after sunrise. At our 100-m variable circular plots, we recorded each bird detected by sight or sound and its approximate distance to the plot center. To ensure independence among plots, point count stations were at least 200 m apart. Birds flying over the plot or detected > 100 m from the center were recorded but not used in this analysis.

Geographic Information Systems Analysis

We analyzed six landscape-level variables within three buffer zones around the plot center: 500 m, 1 km, and 2 km *(fig. 2)*. At each of these spatial scales we analyzed: 1) patch size, defined here as the total area of the grassland patch in which the point count was taken; 2) cover-type richness, defined as the total number of land cover types; 3) proportion of deciduous forest (deciduous forest is defined as areas dominated by deciduous trees); 4) proportion of evergreen forest (defined as areas with > 67 percent coniferous or broad-leaved evergreen trees); 5) proportion of low-intensity development (defined as having considerable amounts of constructed and vegetated surfaces); and 6) proportion of high-intensity development (defined as areas with high levels of constructed surfaces and little or no vegetation). To quantify these landscape variables, we used the California 2000 Land Cover Data (http://www.csc.noaa.gov/crs/lca/pacificcoast.html, last accessed August 14, 2006) created by National Oceanic and Atmospheric Administration’s Coastal Change Analysis Program. This land cover dataset was created in the year 2000, has 30 m resolution, and is projected in Albers Conical Equal Area, North American Datum 1983. We used FRAGSTATS (McGarigal and others 2002) to calculate all of the landscape variables.

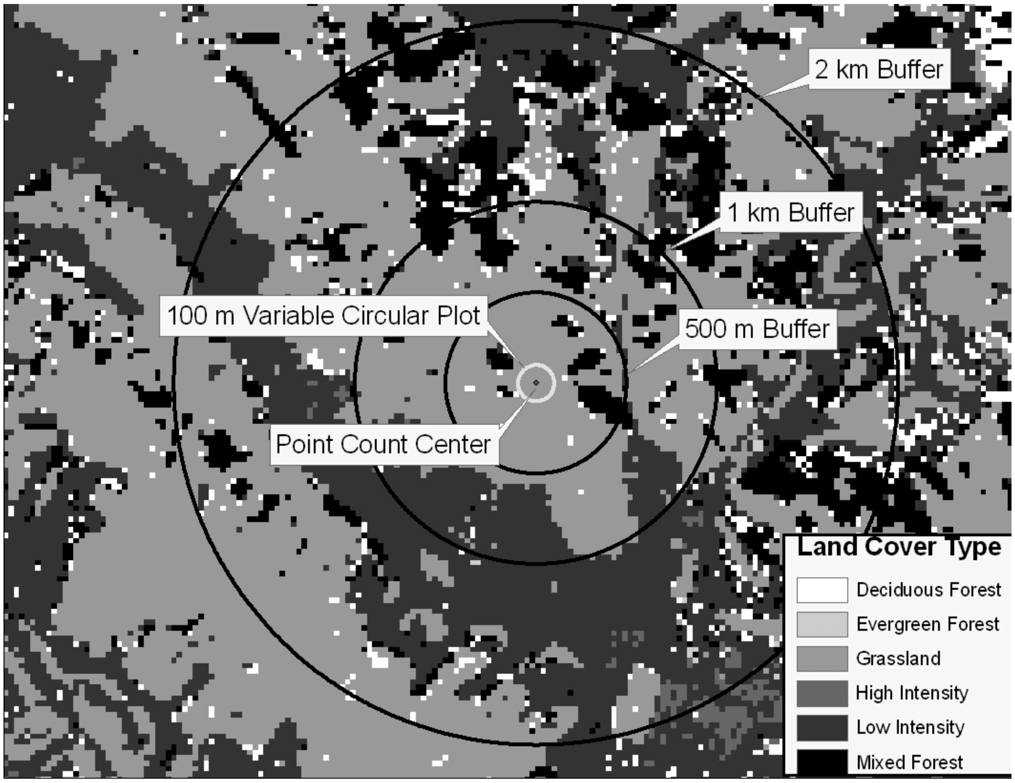

Figure 2—Land cover layer and plot layout: four concentric rings indicating extent of the plot and three buffer zones around the point count center.

Statistical Analysis

Due to the limited number of grassland bird detections, we built logistic regression models (Hosmer and Lemeshow 2000), appropriate for presence/absence data. Separate models were built for each species and for the grassland bird guild as a whole at three spatial scales and for each year. We performed backward stepwise logistic regression to generate models describing the influence of landscape scale variables on the presence of grassland birds, hand-selecting variables at each step. In each plot, a species was counted as present if it was seen at least once over the three visits per year; the guild was counted as present if any one of the four grassland bird species was detected on a plot. All six predictor variables were entered into the full model. At each step, the variable with the highest p-value was removed until only variables with a $p\text{-value} < 0.10$ remained in the model. We used $p < 0.10$ instead of the more standard $p < 0.05$ because this is a preliminary study and we did not want to exclude any important variables. The unweighted sum of squares test was used to determine the overall model fit. Final models were those with variable $p\text{-values} < 0.10$ and model fit $p\text{-values} > 0.10$. All logistic regression analyses were performed using S-PLUS 6.1. The two years of data (2004 and 2005) were analyzed separately because 13 new plots were added during the second field season.

Results

Grassland Bird Guild

The final model for the grassland bird guild, using all four species, included two variables that were consistently significant ($p < 0.10$) across both years: patch size *(fig. 3)* and cover-type richness *(fig. 4)*. In 2004, patch size was significant at 500 m and 2 km, while cover-type richness was significant at the 1 km and 2 km scales (*table 1*). In 2005, patch size entered the final model at 1 km and 2 km, while cover-type richness was significant across all three scales. The guild was also significantly associated with proportion of high-intensity development, proportion of low-intensity development, proportion of deciduous forest, and proportion of evergreen forest.

Individual Species

In both 2004 and 2005, western meadowlarks were detected on a greater number of plots than any other grassland bird species. This probably drives the similarities between results from the guild model and the individual western meadowlark species model. Like the guild as a whole, presence of western meadowlarks was associated with all six landscape variables (*table 1*). In 2004, cover-type richness was significant across all three scales. In 2005, patch size and proportion of low-intensity development were in the model at 1 km and 2 km. The only variable that was consistently significant across years for western meadowlarks was cover-type richness.

Savannah sparrows were associated with patch size, cover-type richness and proportion of evergreen forest (*table 1*). In 2004, presence of savannah sparrows was consistently associated with patch size at all three spatial scales. In 2005, cover-type richness was significant at 500 m and 1 km, and proportion of evergreen forest was significant at 500 m and 2 km. Patch size was the only variable that remained in the models for both 2004 and 2005.

Over the two years of the study, only the 2 km spatial scale in 2005 produced significant results for the horned lark (*table 1*). These significant variables were patch size, cover-type richness, proportion of deciduous forest, and proportion of evergreen forest.

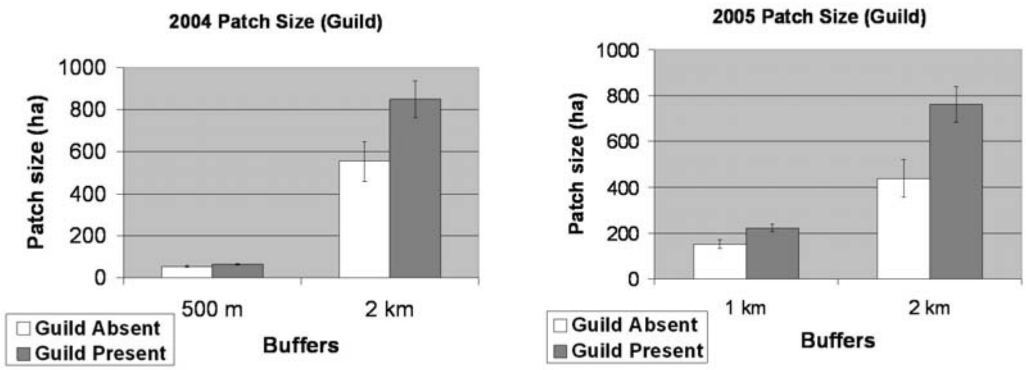

Figure 3—Mean and standard error for patch size (ha) at multiple spatial scales in plots with (shaded) and without (white) the grassland bird guild for 2004 and 2005.

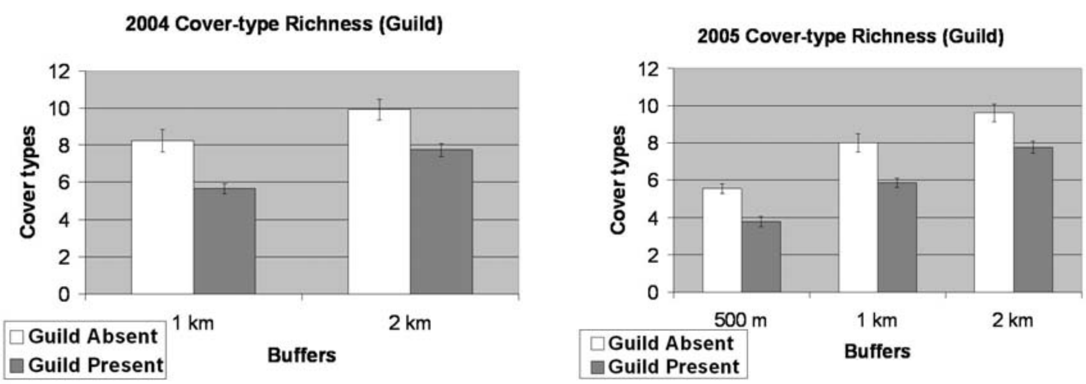

Figure 4—Mean and standard error for cover-type richness (number of cover types) at multiple spatial scales in plots with (shaded) and without (white) the grassland bird guild for 2004 and 2005.

Grasshopper sparrows were detected less frequently than the other three grassland bird species in both years. Despite their rarity in our study area, grasshopper sparrow presence was significantly associated with several variables, including: cover-type richness, proportion of low-intensity development, proportion of deciduous forest, and proportion of evergreen forest (*table 1*). Proportion of deciduous forest in 2005 was the only variable that was consistently significant across spatial scales. No variables were significant in both years for grasshopper sparrows.

At the 500-m spatial scale in both years, grassland birds tended to be absent in patches that contained development. For example, grasshopper sparrows and savannah sparrows were found only in habitat matrices that did not include high-intensity development. Similarly, horned larks were found in areas with no high- or low-intensity development. Conversely, western meadowlarks were not restricted to patches without development at this scale.

Table 1—*Significant variables for the grassland bird guild and for each species individually at 500 m, 1 km and 2 km for 2004 and 2005. P-V is the p-value for the variable and P-M is the p-value for the model fit. A plus sign indicates a positive association and a minus sign indicates a negative association.*

	2004						2005					
	500 m		1 km		2 km		500 m		1 km		2 km	
Species and Variables	P-V	P-M	P-V	P-M	P-V	P-M	P-V	P-M	P-V	P-M	P-V	P-M
Guild		0.8		0.3		0.8		0.4		0.2		0.8
Patch size	+ 0.008				+ 0.04				+ 0.03		+ 0.01	
Cover-type richness			- 0.004		- 0.008		- 0.001		- 0.02		- 0.006	
% High intensity dev.	- 0.07								- 0.05			
% Low intensity dev.									+ 0.04			
% Deciduous	- 0.05											
% Evergreen forest	+ 0.04											
Western Meadowlark		0.4		0.3		0.3				0.2		0.8
Patch size									+ 0.01		+ 0.006	
Cover-type richness	- 0.003		- 0.007		- 0.01						- 0.01	
% High intensity dev.									- 0.07			
% Low intensity dev.									+ 0.05		+ 0.03	
% Deciduous forest											+ 0.098	
% Evergreen forest					- 0.06							
Savannah Sparrow		0.8		0.7		0.5		0.3		0.2		0.9
Patch size	+ 0.01		+ 0.008		+ 0.004						+ 0.01	
Cover-type richness							- 0.001		- 0.003			
% Evergreen forest							+ 0.04				+ 0.03	
Grasshopper Sparrow				0.6						0.98		0.2
Cover-type richness											- 0.098	
% Low intensity dev.											+ 0.06	
% Deciduous forest									+ 0.04		+ 0.02	
% Evergreen forest			+ 0.09									
Horned Lark												0.4
Patch size											+ 0.01	
Cover-type richness											- 0.04	
% Deciduous forest											+ 0.03	
% Evergreen forest											+ 0.06	

Discussion

Patch Size

Our results show a significant relationship between patch size and western meadowlarks, horned larks, and savannah sparrows. Western meadowlarks were found in patches ≥ 55 ha in 2004 and ≥160 ha in 2005. Savannah sparrows were found in patches ≥ 376 ha in 2004 and ≥ 124 ha in 2005. Horned larks were found in patches ≥ 124 ha in both years. Our model for grasshopper sparrows does not include patch size as a significant variable; however, they were found only in patches that were ≥ 139 ha during both study years. For both years, grassland patches in our study areas ranged from 55 to 1234 ha. Research in forest ecosystems suggests that smaller patches may cause higher rates of nest predation (Gates and Gysel 1978) and parasitism (Brittingham and Temple 1983), more interspecific competition (Ambuel and Temple 1983), and fewer appropriate breeding sites (Wilcove and others 1986).

Perhaps similar processes are occurring in grasslands. Our results agree with several studies showing that grassland birds are sensitive to patch size. For example, in Illinois, Herkert (1994) found that grasshopper sparrows only occurred in patches > 30 ha, and savannah sparrows occurred in patches > 40 ha. Grassland patch size in Herkert's study varied from 0.5 to 650 ha. In Maine, Vickery and others (1994) found that grasshopper sparrows required grassland patches of about 100 ha, whereas savannah sparrows required patches of about 10 ha. Grasslands in Vickery's study ranged from 0.3 to 404 ha. Collier (1994) found that in Southern California, grasshopper sparrow subspecies *A. s. perpallidus* had a territory size of 0.37 ± 0.16 [SD] ha. In the Midwest, grasshopper sparrows only chose breeding patches that were approximately 100 times the size of their territory (California Partners in Flight 2000). Further research may show a similar trend for California populations as well.

Cover-type Richness

At the 2 km scale, there were 14 possible cover types. Cover types fell into the following categories: grassland, forest, cultivated, developed, scrub, wetland, bare land, and water. In our study, savannah sparrows were significantly negatively associated with cover-type richness at 500 m and 1 km in 2005. Grasshopper sparrows were negatively associated with cover-type richness at the 2 km scale in 2005. Additionally, cover-type richness was in our models for the guild, western meadowlarks, and horned larks. This negative relationship between grassland bird presence and cover-type richness was expected because the more cover types in an area, the less likely grassland habitat will be available for grassland bird species. Similarly, in Wisconsin, Ribic and Sample (2001) showed that cover-type diversity, measured by the Shannon diversity index, was a key predictor of grassland bird density. They found that transects with less cover-type diversity had higher densities of grassland birds. These less diverse landscapes consisted mainly of grasslands. Savannah sparrow (at 800 m) and grasshopper sparrow (at 200 and 400 m) densities were higher in landscapes with lower cover-type diversity. Our study evaluated a similar variable using cover-type richness instead of the Shannon diversity index. We used cover-type richness because we found a multicollinear relationship between Shannon diversity index and patch size: as Shannon diversity index increased, patch size decreased. There was no multicollinear relationship between cover-type richness and patch size.

Proportion of Different Habitat Types

We analyzed proportion of deciduous forest and evergreen forest separately and found that grassland birds were most often positively associated with these variables. However, in 2004, the guild was negatively associated with deciduous forest, and western meadowlarks were negatively associated with evergreen forest. This inconsistent result is currently not understood. A negative relationship was expected between grassland birds and forested areas (oak woodlands) because the study species are dependent on grasslands for foraging and breeding, and more oak woodland in an area likely means less grassland. The generally positive association indicates, perhaps, that grassland birds require some amount of heterogeneity in their habitat at a landscape scale. Alternatively, grasslands surrounded by oak woodlands may be larger and more intact or have greater connectivity to other grassland patches than those surrounded by high-intensity development.

Studies in the Midwest have also examined proportion of different land cover types. Bakker and others (2002) analyzed proportion of woodland area at 400 m, 800 m, and 1,600 m buffers in a landscape analysis of grassland birds in South Dakota. While this variable did not enter any of their final models, they found that as the percent of woody vegetation at the grassland patch edge increased, occurrence of savannah sparrows, grasshopper sparrows, and western meadowlarks decreased. Additionally, Fletcher and Koford (2002) included proportion of woodland in the landscape in their analysis in Iowa. While their analysis included grasshopper sparrows and savannah sparrows, amount of woodland was only retained in the best model for red-winged blackbirds (*Agelaius phoeniceus*) indicating a negative relationship.

Mixed forest was another land cover type classified in our dataset that occurred in large proportions. However, there was a multicollinear relationship between mixed forest and patch size; therefore it was not used in this analysis. In the future, consideration of the proportion of mixed forest in a landscape analysis for California grassland birds may offer additional insight.

Proportion of high-intensity development was significant for the grassland guild as a whole and for western meadowlarks. The negative association with high-intensity development was expected because highly developed areas lack large grassland patches and other habitat requirements. Similarly, Bock and others (1999) evaluated edge effects at the grassland suburban interface in Colorado. Their plots were either at the suburban edge or at least 200 m from the edge. Their research showed a significant decrease in abundance of savannah sparrows and grasshopper sparrows from interior plots to the suburban edge plots. While this relationship with horned larks was not significant due to high interplot variances, they were also more often observed on interior plots. While our data cannot be directly compared to the Colorado study due to different parameters, both studies show a significant negative relationship between grassland bird populations and increased human development.

Surprisingly, the guild as a whole, western meadowlarks, and grasshopper sparrows were positively associated with proportion of low-intensity development. Low-intensity development was defined as having considerable amounts of constructed surfaces and considerable amounts of vegetated surfaces. Perhaps these species were utilizing the vegetated surfaces within the low-intensity development cover type.

Variation

Variation between buffer zones and between years is not yet clearly understood. The scope of this study was limited to landscape-scale variables which may not be adequate to explain interannual variation in species responses to their habitat. Thus, additional analysis including landscape-scale, local-scale, and environmental variables may provide a better understanding of the system. For example, grassland birds may require smaller grassland patches in heavy rainfall years, if such years produce a higher density of seeds or invertebrate prey species.

Conclusion

On our plots, California grassland birds were consistently more likely to be found in large grassland patches within a habitat matrix of few land cover types and limited development. We sampled a relatively small proportion of California grasslands, and additional research throughout the state's grasslands is needed to make broad-scale generalizations and recommendations. However, our results are consistent with research in the Midwest. Ribic and Sample (2001) noted that grassland birds respond to their landscape out to at least 800 m, Fletcher and Koford (2002) up to 1 km, and Bakker and others (2002) up to 1,600 m. Our research shows that grassland birds are responding to their habitat matrix out to at least 2 km. As urbanization continues to expand into formerly undeveloped regions, large grassland patches will shrink. We expect further research will support our assertion that in order to support California grassland bird species, land management agencies should consider purchasing unprotected lands adjacent to existing parks and other protected open space. Additionally, land trusts should build relationships with private land owners to educate and promote conservation easements. Such easements provide a flexible approach to land conservation and open space retention, allowing private land owners to continue living and working on their land. California Partners in Flight (2000) advocate protecting high-quality grassland habitat and areas that support high-grassland bird abundance. To do so, we need to define these areas by studying a broad cross-section of California's grasslands. Protection of grasslands is the first step toward conservation of grassland birds. Maintaining each grassland area will likely require site-specific management plans detailing appropriate methods for habitat enhancement.

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