The Influence of Edge Effects on Habitat Suitability of Western Meadowlarks in East Bay Regional Park District Grasslands

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ABSTRACT

Even though Western Meadowlark is one of the most abundant and widely distributed grassland birds in central and western North America, its population has been steadily declining throughout the U.S. since the 1960s. Despite the increased loss of this grassland bird species, edge effects on the species distribution are poorly understood and acknowledged. Edge effects are the various ecological conditions and interactions that occur when two or more contrasting ecosystems converge. To better understand the influence of edge effects on the habitat suitability of Western Meadowlarks in East Bay Regional Park District (EBRPD), I created an empirical habitat suitability model of Western Meadowlarks using species presence data collected by the EBRPD Grassland Monitoring Project from 2004 to 2011 and landscape variables. Using ArcGIS, I mapped the presence of Western Meadowlarks in relation to distances from woody vegetation and roads. I found a significant correlation between increased Western Meadowlark presence and increased distance to woody vegetation, but no relationship with distance to roads. The loss of Western Meadowlarks with closer woody vegetation suggested that their habitat suitability was negatively affected by woody vegetation encroachment on grassland habitat. Thus, edge environments need to be taken into consideration in Western Meadowlark conservation and management plans to improve habitat suitability.

KEYWORDS

Edge environments, landscape variables, woody vegetation, road, grassland bird

INTRODUCTION

Human activities and the massive and rapid growth of cities result in landscape fragmentation and destruction of habitats. Human land use and development often introduce exotic species, decreasing the amount of native species and habitats in the process (Grant et al. 2004). In addition, urbanization strongly affects the available habitats due to the physical changes that occur in cities including increases in air and soil pollution, intensified soil compaction and alkalinity, and rising temperature (McKinney 2002). The amount of suitable habitat for organisms can also be affected by adjacent lands, as the edges experience biotic and abiotic changes (Murcia 2000). For instance, the development of roads often breaks up otherwise continuous habitat, creating patches of edge habitat along the sides of the road (Reed et al. 1996). The various ecological conditions and interactions that occur when two or more contrasting ecosystem converge are edge effects. Edge effects are changes in species diversity, abundance, spatial distribution, and productivity between two or more ecosystems (Ting and Shaolin 2008, Yahner 1998). Edge effects can influence species interactions and productivity through various processes such as predation, competition, parasitism, pollination and seed dispersal (Murcia 2000). Edge environments provide distinct habitats and easy access to food for certain species of plants and animals and help support adjoining communities (Zheng and Chen 2000). Some species depend on unique resources that are deficient in the interior environment or the bordering patches, thriving only in edges that possess these resources (Ries and Sisk 2004). Although high habitat and vegetation diversity in the edge environment tend to promote species richness, edge effects can have negative impacts as well (Yahner 1998).

Edge effects in fragmented landscapes trigger various biotic and abiotic responses that influence environmental conditions, species composition, and species interactions. Birds that are attracted to the vegetation on edges are often subjected to nest predation (Yahner 1998). Nest parasitism and predation, two primary issues associated with avian populations in edge habitats, tend to reduce host bird species' productivity and abundance (Chalfoun et al. 2002). Invasive plant and animal species along edges reduce native biodiversity (Ås 1999), and species that rely on relatively extensive and undisturbed interior habitat are less likely to survive in edge environments (Yahner 1998). Because of the positive and negative influences edge effects have on the environment and species distributions, edge environments present an interesting challenge to conservation.

Several grassland songbird species are facing population declines. My study subject is the Western Meadowlark (*Sturnella neglecta*), a songbird that is considered the focal species for grassland bird conservation due to its wide habitat requirements (Altman et al. 2011, Grant et al. 2004). Western Meadowlarks inhabit a wide variety of habitats such as natural and planted grasslands, some agricultural fields, tidal flats, prairies, and mountain meadows (McMaster and Davis 2001, Altman et al. 2011). Some theories of what has caused this species' decline include habitat fragmentation, encroaching woody vegetation, and native vegetation loss (Rao et al. 2008, Grant et al. 2004, Altman et al. 2011). Despite the increased loss of grassland bird species, edge effects on species distribution are poorly understood and acknowledged (Herkert 1994); it is unclear what is causing the decline of Western Meadowlark despite its wide habitat ranges.

My research examines the influence of edge effects on the habitat suitability of Western Meadowlarks in East Bay Regional Park District, California. I will map out the locations of species presence, encroaching woody vegetation, and roads in ArcGIS. Then I will create an empirical habitat suitability model of Western Meadowlarks using species occurrence and the environmental layers to determine whether encroaching woody vegetation and presence of roads affect the habitat suitability of Western Meadowlarks. The responses of Western Meadowlarks to the two edges – woody vegetation and roads – are essential in understanding the impact of landscape structure on habitat quality. I hypothesize that the variables of increased distance from woody vegetation and increased distance from roads will have strongly positive effects on the habitat suitability of Western Meadowlark.

METHODS

Study site

East Bay Regional Park District (EBRPD) is a park system with more than 113,000 acres of land in 65 parks operating in California’s Alameda and Contra Costa counties (37-52'06" N Longitude: 121-51'20" W). The study site is characterized by a Mediterranean climate, with cool, wet winters and hot, dry summers (Ornduff et al. 2003). The majority of annual precipitation occurs between October and April and ranges from 59.23 mm in the western region of the study area near Oakland to 37.41 mm in the eastern region of the study area near Livermore (WRCC

2008). The average minimum temperatures of inland regions of the study site reach between 2.8 to 12.7 degrees Celsius, and average maximum temperatures range from 14.0 degrees to 31.6 degrees Celsius (WRCC 2008). The vegetation in EBRPD parkland typically consists of grassland, coastal scrub, chaparral, oak woodland and forest, ornamental landscaping, and riparian habitats (Bartolome et al. 2007).

The investigators from the EBRPD Grassland Monitoring Project selected parks based on plant species composition, accessibility, and management practice (livestock grazing). They divided the parks into four vegetation subtypes to reduce variability among parks: riparian, valley grassland, coastal prairie, and harding grass-dominated (*Pharlaris aquatica*, PHAQ) plots. They randomly selected the sample plots by a stratified design. I only used plots of Valley grassland because the Western Meadowlark is a grassland-obligate species. In most Valley grassland plots, nearly all of the vegetation is exotic (Table 1) to the area and consists predominantly of Common Wild Oats (*Avena fatua*), Soft chess (*Bromus hordeaceus*), Ripgut brome (*Bromus diandrus*), Filaree species (*Erodium spp.*), and Italian Rye-grass (*Festuca perenne* synonym *Lolium multiflorum*). The area in valley grassland is typically used for recreation and livestock grazing management. All the selected parks have cattle grazing with different styles of management with the exception of Vasco Caves (sheep grazing). EBRPD manages the livestock grazing and leases the land to different livestock owners.

The investigators established permanent sampled plots in 2002, but only 27 plots were sampled. They designed a more concrete sampling system in 2004 and increased to 55 sampled plots. Therefore, I used the data starting from 2004. I chose six out of nine plots in Bushy Peak, ten out of ten plots in Morgan Territory, six out of nine plots in Pleasanton Ridge, six out of six plots in Sycamore Valley, and ten out of 11 plots in Vasco Caves, using a total of 38 out of 45 plots. I dropped the parks that were in different vegetation subtypes and the plots that had no bird sampling to minimize confounding factors in the analysis. See Table 2 in Appendix A for which plots were used in the selected EBRPD parks and species presence/absence data in those plots.

Table 1: Selected plots of EBRPD parks and their GPS coordinates, vegetation subtype (valley grassland, PHAQ plots), % vegetation cover, and management practice (Cattle-grazed, ungrazed, sheep-grazed, and no data) in my study, 2002-2004.

Park (Plots)	GPS Coordinates	Vegetation Subtype	% Vegetation Cover	Management Practice
Brushy Peak (BP4-9)	N 37 44.485, W121 41 33	Valley Grassland	99% Exotic 1% Native	Cattle-grazed
Morgan Territory (MT1-3)	N37 50.167, W121 48.984	Valley Grassland	99% Exotic 1% Native	Ungrazed
(MT4-8)	"	"	98% Exotic 2% Native	Cattle-grazed
(MT9-10)	"	"	No Data	Ungrazed
Pleasanton Ridge (PR4-6)	N37 38.832, W121 55.644	Valley Grassland	91% Exotic 9% Native	Cattle-grazed
(PR7-9)	"	"	99% Exotic 1% Native	Sheep-grazed
Sycamore Valley (SV1-3)	N36 46.696, W119 25.076	Valley Grassland	99% Exotic 1% Native	Ungrazed
(SV4, 6)	"	"	99% Exotic 1% Native	Cattle-grazed
(SV5)	"	PHAQ plots	No Data	No Data
Vasco Caves	N36 46.696, W119	Valley Grassland	91% Exotic	
(VC1-3, 7-9)	25.076	"	9% Native	Sheep-grazed
(VC4-6, 10)	"	"	91% Exotic 9% Native	Ungrazed

Study Subject

My study subject was the Western Meadowlark (*Sturnella neglecta*) (WEME), one of the most abundant and widely distributed grassland birds in central and western North America (Rotenberry and Wiens 1980, Giovanni 2009). Although the Western Meadowlark is a prominent grassland generalist, its breeding populations have been declining by approximately 1% per year since at least 1966 throughout the U.S. and Canada (Erickson et al. 2008, Giovanni 2009, Altman et al. 2011). Western Meadowlarks inhabit a wide variety of habitats including natural and planted grasslands, some agricultural fields, tidal flats, prairies, and mountain meadows from sea level to 3700 meters (McMaster and Davis 2001, Giovanni 2009, Altman et al. 2011). Western Meadowlarks are ground foragers with distinct seasonal dietary patterns, probing the soil for insects such as ground beetles and grasshoppers in the late spring and summer, and foraging for grain during the winter and early spring and for weed seeds in the fall (Davis and Lanyon 2008). They nest on the ground in well-concealed pasture, prairie, or other grassland habitat between late March and late July (Davis and Lanyon 2008). But when they nest near wooded edges, nest predation and parasitism are the most common causes of nest failure (Johnson and Temple 1990). While Western Meadowlarks prefer habitats with grass and litter cover and avoid areas with tall and dense vegetation, wooded and urban edges (Wiens 1969, Wiens and Rotenberry 1981, Davis 2004, Grant et al. 2004), they also frequently perch on roadside fences to sing and attract mates (Rotenberry and Knick 1995).

Field Data Set

I used the bird survey data collected with the same central point as the vegetation sampling plots from 2004 to 2011 in the EBRPD Grassland Monitoring Project. Eight of the EBRPD's 55 parks were sampled in 2004. Each plot of vegetation sampling consisted of four, 17 meter vegetation transects that radiated in the four cardinal directions from a centroid (center of the plot). The investigators conducted 100 meter radius variable circular plot point count surveys during the spring breeding season, attempting three visits at least ten days apart at the same centroid of the plots used for vegetation sampling. They stood at the centroid of the plot during a ten minute time period to properly identify the birds, avoid over-counting of individuals, and maximize the number of birds detected within the plot. Birds were identified and counted by sight and sound. Point counts began within 15 minutes of sunrise and completed within four hours to avoid adverse wind conditions that might occur after 9:30 am for most parks, which could prohibit the counts. I converted the Western Meadowlark presence data into GIS layers in ArcGIS 10.1 (ESRI: Redlands, CA) using the GPS coordinates for each of the sites.

Data Analysis

Habitat Suitability Model: ArcGIS

To determine whether encroaching woody vegetation and roads affect the habitat suitability of Western Meadowlarks, I created an empirical statistical model relating species occurrence and landscape factors. Woody vegetation and roads are edges (landscape factors) that can cause changes in species interactions, physical conditions, and other ecological factors (edge effects) around the boundary of grasslands and other ecosystems in EBRPD parkland. I interpreted habitat suitability as the capacity of a habitat to support survival and reproduction of a selected species. Usually, a habitat suitability model examines multiple environmental layers and variables to select the most appropriate habitat, thereby predicting the species presence. My model, however, used species presence data and landscape variables to calculate whether or not these variables affect the presence of Western Meadowlark at the selected sites.

First, I mapped out the locations of WEME presence (1) and absence (0) with GPS coordinates starting from the centroid of the plots. I also identified the percentage of native vegetation in each of the plots to determine if Western Meadowlarks occurred in areas with both good nest habitat and edge effects. I used base maps from the program ArcGIS 10.1 (ESRI: Redlands, CA), satellite imagery from Google Maps, and the National Agricultural Imagery Program from The National Map Viewer (USGS, http://viewer.nationalmap.gov/viewer/) to digitalize the woody vegetation around the plots. Woody vegetation included single trees and multiple trees.

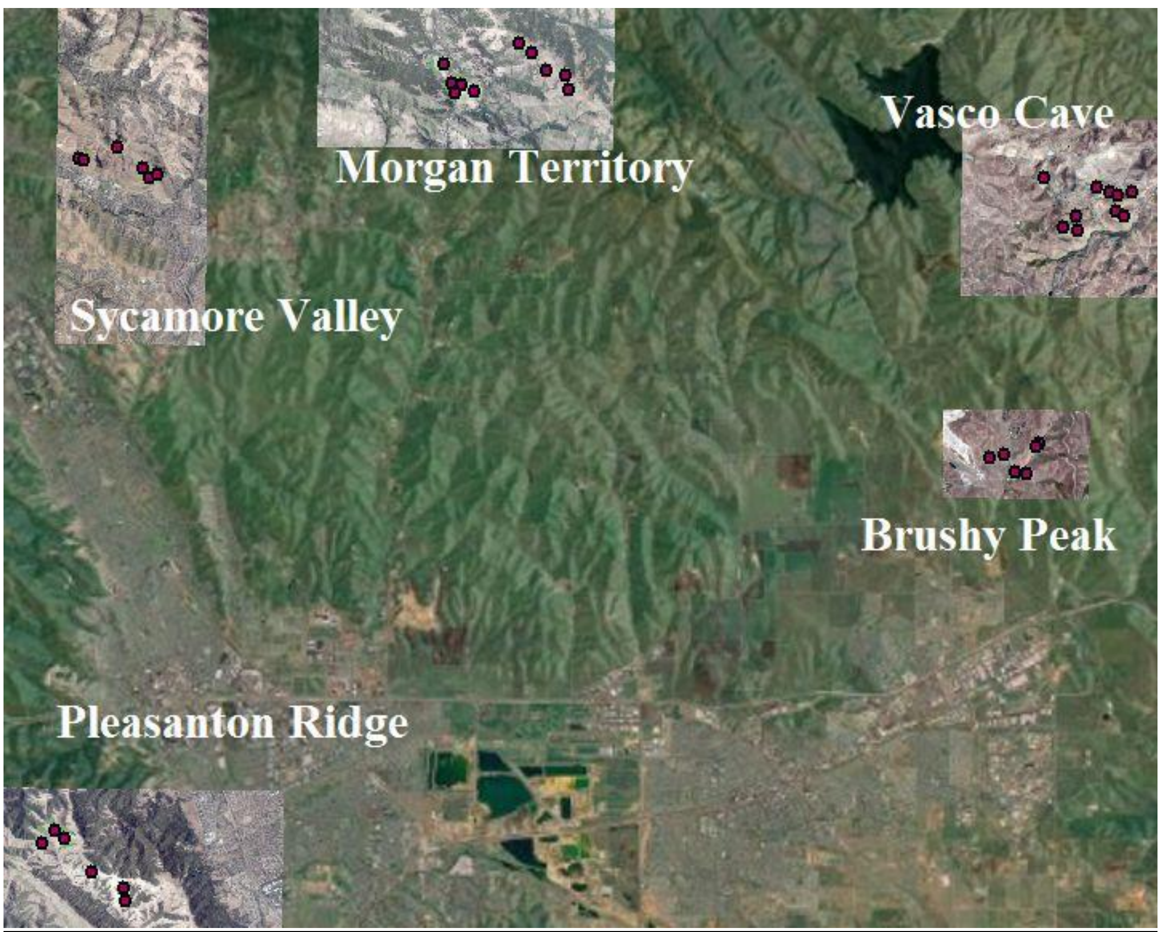

Fig. 1: Map of study sites with WEME presence. Each red dot is a study site with three WEME sightings conducted annually from 2004-2011.

I then built a habitat suitability model for Western Meadowlarks. To determine the distance from species presence to the model inputs, I used the “Near” function in Proximity

Analysis in ArcGIS. Model inputs included distance to woody vegetation and distance to roads. After I mapped and geoprocessed all the variables using the "Near" function, I exported my database to Excel (Microsoft, 2010) for statistical modeling.

Logistic Regression: R

To calculate whether the probability of Western Meadowlark presence (dependent variable) was associated with the distance to woody vegetation and distance to roads (independent variables), I used logistic regression in R v2.15.1 (R Core Development team, 2009) and package R Commander (Rcdmr). I then used a generalized linear model to determine whether or not Western Meadowlark presence was associated with distances to woody vegetation and distances to roads. The scatterplots of WEME presence and absence in relation to distance to woody vegetation and roads and predicted probabilities of WEME presence in relation to distance to woody vegetation were created by Excel (Microsoft, 2010).

RESULTS

Presence of Western Meadowlarks (WEME)

There were more Western Meadowlarks detected in Vasco Cave, Brushy Peak, and Sycamore Valley than in Pleasanton Ridge and Morgan Territory. WEME presence was 81% in VC and 64% in BP, which was a high percentage of WEME presence compared to 29% in PR and 11% in MT (Table 3).

Table 3: Percentage of Western Meadowlark presence found in plots of selected parks from 2004 – 2011. There was a high percentage of WEME presence in BP and VC, but low percentage of WEME presence in MT and PR.

Park	% WEME presence found	Plots with WEME/Total Plots
Vasco Caves (VC)	81%	65/80
Brushy Peak (BP)	64%	27/42
Sycamore Valley (SV)	46%	22/48
Pleasanton Ridge (PR)	29%	14/48
Morgan Territory (MT)	11%	9/80

GIS analysis of landscape variables

Distance to woody vegetation

I found a trend of increased presence of WEME in plots that were greater distance away from woody vegetation (Bushy Peak and Vasco Caves). Looking at the mean values for distances to woody vegetation (Table 4), they were greatest in VC (300 m) and BP (238 m) where the plots also had the highest percentage of WEME presence (Table 1).

Table 4: Range, Mean, and Median of distance to woody vegetation for plots of selected parks from 2004 – 2011. VC and BP have the greatest distance from woody vegetation. PR and MT have the lowest distance from woody vegetation.

Plots	Range of distance to woody vegetation (meters)	Mean of distance to woody vegetation (meters)	Median of distance to woody vegetation (meters)
VC 1-10	135-498	300	287
BP 4-9	40-509	238	143
SV 1-6	67-224	117	98
PR 4-9	43-134	79	74
MT 1-10	37-151	69	61

Distance to roads

I did not find a noticeable relationship between presence of Western Meadowlarks and distance to roads (Table 5).

Table 5: Range, Mean, and Median of distance to woody vegetation for plots of selected parks from 2004 – 2011. VC and BP have the greatest distance from woody vegetation. PR and MT have the lowest distance from woody vegetation.

Plots	Range of distance to woody vegetation (meters)	Mean of distance to woody vegetation (meters)	Median of distance to woody vegetation (meters)
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Statistical Analysis: Impact of landscape variables

Distance to woody vegetation was significantly, positively correlated with the presence of Western Meadowlarks in EBRPD grasslands in my logistical regression model (P = 8.32e-12), corroborating the patterns seen in my GIS data above. The estimate of distance to woody vegetation when a WEME was present was 0.0083 (Table 6). Many WEME were absent from the plots that were approximately 120 m away from woody vegetation (Fig. 2). The midpoint of the logistic curve indicated a distance threshold of woody vegetation at approximately 210 m (Fig. 3). The logistic curve showed there was a 80% and higher chance of finding a Western Meadowlark at sites that were approximately 360 m or farther away from woody vegetation.

Distance to roads did not significantly affect the presence of Western Meadowlarks (*P* = 0.7), similar to what I found with my GIS analysis (Table 6). There were similar counts of WEME presence and absence up to 150 m away from the road (Fig. 2).

Table 6: Logistic regression analysis of Western Meadowlark presence/absence in relation to edge effects. The dependent variable is the presence of Western Meadowlark at the selected plots (presence = 1), using 38 plots. This is a simple logistic regression analysis in relation to distance to woody vegetation and distance to roads.

	Estimate	**Standard Error**	**Z value**	**P (>|z|)**
Distance to woody vegetation	0.0083	0.0012	6.833	8.32e-12***
Distance to Roads	0.0009	0.0016	0.554	0.580

***P-value is greater than 0.05.

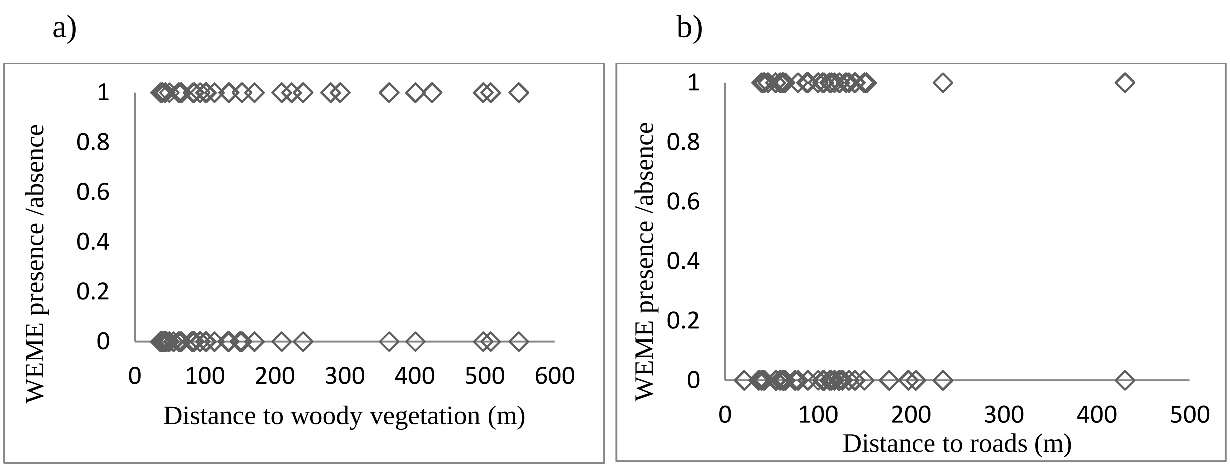

Fig. 2: Scatterplots of the presence and absence of WEME in relation to (a) distance to the nearest woody vegetation, (b) distance to the nearest roads. WEME presence = 1, WEME absence = 0.

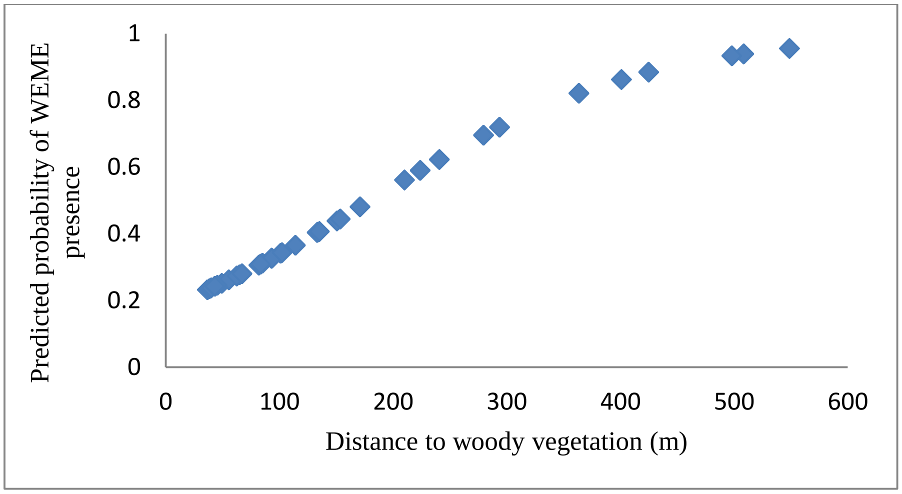

Fig. 3: Scatterplot of the predicted probabilities from logistic regression model of the WEME presence in relation to distance to woody vegetation.

DISCUSSION

My research examined the influence of edge effects on the habitat suitability of Western Meadowlarks (WEME) in East Bay Regional Park District, California. The purpose of this study was to assess the effect of landscape variables on the habitat suitability of WEME as possible causes for their continuous population decline. I created an empirical habitat suitability model of WEME in ArcGIS to investigate the relationship between WEME presence, distance to woody vegetation and distance to roads. I found that WEME were more present in plots farther away from woody vegetation. Distance to roads, on the other hand, had no significant effect on the presence of WEME. The continuous presence of WEME over time in Brushy Peak and Vasco Caves suggested that the sites that are furthest from woody vegetation are the most suitable habitats in EBRPD grassland for WEME. Examining edge responses such as these two landscape variables can help identify and address the critical effects of edge environments and landscape structure on habitat suitability, subsequently providing more comprehensive management plans for threatened species.

Distance to woody vegetation

My results showed that woody vegetation strongly influenced the presence of Western Meadowlarks in EBRPD grasslands. There were more WEME detected in plots with greater distances from woody vegetation (Bushy Peak and Vasco Cave). The loss of WEME due to encroaching woody vegetation suggested that the habitat suitability of WEME was negatively affected by distance to woody vegetation. Previous studies have also shown that populations of

WEME decreased with increasing woody cover (Coppedge et al 2001; Bakker et al 2002; Grant et al 2004). Woody vegetation potentially attracts exotic bird species, consequently decreasing the habitat suitability of native and endemic grassland bird species and increasing competition for resources (Coppedge et al. 2001). Also, WEME are subjected to nest predation and parasitism near wooded edges (Johnson and Temple 1990). The logistic curve indicated that a distance of 250 m away from woody vegetation would give a 50% chance of finding a Western Meadowlark in the plot, and a distance of 360 m would give a 80% chance. One quality of a suitable habitat for WEME would be a grassland area that is at least 360 m away from woody vegetation.

Distance to roads

Although roads conventionally create edge environments (Reed et al. 1996), my results indicated no relationship between distance to roads and presence of WEME. Habitat loss, degradation, and fragmentation are often associated with the spatial arrangement of roads (the distance between the road and habitat), road size (traffic volume), and size and shape of natural habitat (Forman 2006). I expected that WEME presence would decrease in plots with shorter distances to roads because roads would transform interior habitat into edge habitats. In addition, roads in my study sites did not have any fences. Fences could be a potential confounding factor because WEME use fences near the roads as elevated song perches (Rotenberry and Knick 1995). There are several possibilities why the roads seemed to have no effect on WEME presence. Most of the roads were restricted from public use, and were narrow dirt trails or fire roads instead of wide asphalt roads, which indicated infrequent traffic volume and low traffic noise. Subsequently, these "roads" have less adverse effects on WEME habitat. Lastly, it was difficult to distinguish previously-made roads and recently built ones because some of the roads were cut off in the GIS layers.

Limitations and Future Directions

With a better comprehensive GIS data on woody vegetation cover and changes in road construction and removal, a more accurate result is achievable. Future studies should include analysis of habitat areas that contain roads with fences to determine the relationship of WEME presence and distance to roads with fencing. Also, future projects on suitable grassland bird habitat should encompass additional landscape variables such as land use and topography (slope, aspect, elevation), and other factors that describe the landscape structure.

Conclusions

This study found positive associations between increased presence of Western Meadowlark and increased distance to woody vegetation. Although no significant correlation was found between Western Meadowlark occurrence and distance to roads, edge effects played a critical role in determining habitat suitability of Western Meadowlark and potentially for other grassland bird species as well. This project highlights the importance of restricting woody plant encroachment in grassland management practices to prevent the consistent declines in grassland bird populations. To minimize possible effects of roads, dirt trails or fire roads should be used instead of widely paved roads near grassland habitats. Edge environments should be studied and taken into account in Western Meadowlark conservation and management plans to increase suitable habitats for them and other grassland bird species.

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APPENDIX A

Table 2: Presence and Absence of Western Meadowlarks from 2004 to 2011 in selected EBRPD parks.

Park (Plot)	2004	2005	2006	2007	2008	2009	2010	2011
BP								
(1)	NS	NS	NS	NS	NS	NS	NS	NS
(2)	NS	NS	NS	NS	NS	NS	NS	NS
(3)	NS	NS	NS	NS	NS	NS	NS	NS
(4)	0	1	0	1	1	NS	1	1
(5)	1	0	0	0	1	NS	1	1
(6)	1	0	1	1	1	NS	1	1
(7)	1	0	1	1	1	NS	1	1
(8)	0	0	0	0	1	NS	1	1
(9)	1	0	0	1	0	NS	0	1
MT								
(1)	0	0	1	0	0	1	0	0
(2)	1	0	0	0	0	0	0	0
(3)	0	0	0	0	0	0	0	0
(4)	1	0	1	0	0	0	0	1
(5)	1	0	0	0	0	0	0	0
(6)	0	0	0	0	0	0	0	0
(7)	0	1	1	0	0	0	0	0
(8)	0	0	0	0	0	0	0	0
(9)	0	0	0	0	0	0	0	0
(10)	0	0	0	0	0	0	0	0
PR								
(1)	NS	NS	NS	NS	NS	NS	NS	NS
(2)	NS	NS	NS	NS	NS	NS	NS	NS
(3)	NS	NS	NS	NS	NS	NS	NS	NS
(4)	0	1	0	0	0	1	0	1
(5)	1	1	0	0	1	0	1	1
(6)	0	1	0	0	0	0	1	1
(7)	1	0	0	0	0	1	0	1
(8)	0	0	0	0	0	0	0	0
(9)	0	0	0	0	0	0	0	0
SV								
(1)	0	0	0	0	0	0	0	0
(2)	0	0	0	0	0	0	0	0
(3)	0	0	1	0	0	1	0	0
(4)	1	1	0	0	1	1	1	1
(5)	1	1	1	1	1	1	1	1
(6)	1	1	1	0	1	0	1	1
VC								
(1)	1	0	0	0	0	1	1	1
(2)	1	1	0	1	1	0	1	1
(3)	1	0	1	1	1	1	1	1

(4)	1	1	1	1	1	1	1	1
(5)	1	1	1	0	1	1	1	1
(6)	1	1	1	0	1	1	1	0
(7)	1	1	1	1	1	1	1	1
(8)	0	1	1	0	0	1	1	1
(9)	0	1	1	1	0	1	1	1
(10)	1	1	1	1	1	1	1	1
(15)	NS	NS	NS	NS	NS	1	0	1

Legend:

1 = presence of Western Meadowlark(s)
0 = absence of Western Meadowlark(s)
NS = Not Sampled
BP = Brushy Peak
MT = Morgan Territory
PR = Pleasanton Ridge
SV = Sycamore Valley
VC = Vasco Caves