2003

Effects of fire and grazing on breeding birds in a mixed-grass prairie

Renae A. Schmitt

The University of Montana

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Author's Signature: [Signature]

Date: June 6, 2003

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The Effects of Fire and Grazing on Breeding Birds in a
Mixed-Grass Prairie

by

Renae A. Schmitt

B.S. Creighton University, 2001

presented in partial fulfillment of the requirements
for the degree of

Master of Science

The University of Montana

May 2003

Approved by:

Chairperson

Dean, Graduate School

Date
Disturbance can alter the availability of foraging and nesting sites of breeding birds and in turn can change the suitability of habitats and the reproductive success of birds. In mixed-grass prairie, numerous studies of fire and grazing effects on breeding birds have taken place, but clear, consistent patterns of species responses to disturbance have not emerged. The measurement of quantitative vegetation features associated with species presence, models of species presence, and data on nesting success would better enable managers to evaluate the effects of disturbance on grassland birds. In 2001 and 2002, I studied the impacts of fire and grazing on mixed-grass vegetation and breeding birds. In 2002, I also monitored nest success of three dominant bird species. Vegetation differed relative to disturbance type. Grasshopper Sparrow (Ammodrammus savannarum) and Western Meadowlark (Sturnella neglecta) appeared to have avoided areas that were burned and grazed. These species, as well as Vesper Sparrow (Pooecetes gramineus) did not appear to be affected by fire and grazing in 2002. Models of species presence did not have high strength of evidence in either year of the study. Nesting success for the three dominant bird species was low and I found little relationship between nest success and vegetation features at nests. I also did not find differences in nest site vegetation between species. Fire and grazing appeared to have created habitat with homogeneous, simple vegetation structure.
Acknowledgements

I would like to first thank my advisor, Joe Ball, and my committee members, Dick Hutto and Tom Martin, for helping me finish my degree in an extremely rushed manner. Joe was extremely patient with the thesis process and I am truly grateful for his help. I learned much from Dick’s graduate courses and Tom’s teas and I hope I can apply what I learned to my work in the future.

I am very grateful for the research opportunity and advice given to me by Doug Johnson from Northern Prairie. I also appreciate the help I received from Larry Igl and Toni Hanson from Northern Prairie who helped me with logistics before and during the field season. Vanetta Burton has been the best source of help for me during the last two years and I only hope to meet someone as helpful and humorous at my next school. I did not take advantage of the knowledge of other graduate students as much as I should have, but when I did, I learned many things from them, especially from those in Tom Martin’s lab.

I am extremely grateful for my field assistants, Rana Swistak and Nick VanLanen. Rana always looked forward to working and escaping the boredom of our summer establishment and Nick kept a positive attitude despite the horribly long hours he worked with me. Andie Lueders and Marissa Alhering also helped me during the beginning of my first field season and provided helpful advice and entertainment.

I am happy to have been friends with Flo Gardipee and Christina Kracher, who were supportive and understanding during the last couple of semesters. I could always count on them for much needed stress relief. Not only did I enjoy being friends with them, but also I enjoyed working with them to reorganize the UM Student Chapter of the American Indian Science and Engineering Society. I thank Don Christian and Penny Kukuk for supporting this organization and understanding its importance to Native American students.

Although they were far away, my parents’ support was always felt and I am sure that they were more excited about my education than I was. I also knew that Tami Buffalohead-McGill’s support is still there although she is far away as well and I rarely see her. She is one of the few people who did not question my goals but believed that I could accomplish them.
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Introduction

Disturbance increases habitat heterogeneity and diversity in all ecosystems (Ricklefs 1987). Disturbance can affect diversity by changing resource availability (Vinton and Collins 1997). For breeding birds, foraging and nesting sites are important resources that affect reproductive success and changes of the vegetation at these sites can affect species composition and abundance, such that decreases in vegetation density and complexity decreases diversity (Wilson 1974, Parker 1986). Studies of breeding birds in several habitats show that species composition and abundance can change in relation to disturbance (e.g. Hutto 1995, Johnson 1997). Reproductive success can also relate positively with vegetation density and complexity (Martin 1993). In grassland habitats, where vertical structure and complexity are low, disturbance is important for structuring vegetative heterogeneity across the landscape. Without a variety of disturbance regimes that increase heterogeneity across prairie landscapes, bird diversity and reproductive success can decrease (Herkert 1994, Rohrbaugh et al. 1999, Shriver and Vickery 2001).

Many studies of the effects of fire and grazing disturbance on breeding birds have taken place in the Great Plains. General patterns of the effects of disturbance on breeding birds have emerged, but the patterns are inconsistent in studies of mixed-grass and short-grass prairies (Madden et al. 2000). Furthermore, most of these studies lack demographic data that could indicate how fire and grazing affect reproductive rates (Rohrbaugh et al. 1999, Shriver and Vickery 2001). The need for better data on the relationship between habitat change and breeding birds is important for two reasons. Grasslands are the most endangered habitats in North America and much of what remains of short- and mixed-grass prairies is fragmented and degraded (Samson and Knopf 1994). In addition, bird
populations associated with grasslands exhibit more consistent, long-term declines than other bird populations (Knopf 1994, Herkert 1995). Quantitative habitat data, models of species presence, and data on nesting success would provide better information to managers intending to conserve bird populations and species (Rohrbaugh et al. 1999, Madden et al. 2000, Shriver and Vickery 2001).

Although studies on the effects of disturbance on grassland bird abundance are numerous (e.g. Kantrud 1981, Renken and Dinsmore 1987, Dale et al. 1997), few have provided quantitative data on vegetation associated with breeding birds (Madden et al. 2000). Such measurements are necessary because the effects of disturbance vary both spatially and temporally. The response of bird species to specific types of disturbance varies within prairie types because birds respond to vegetation and not to fire and grazing per se (Wiens and Rotenberry 1981, Herkert 1994), such that variation in vegetation response increases the variation in bird response. Quantitative, rather than qualitative, measurements of vegetation could potentially explain the amount of variation in species response within the same prairie type (Madden et al. 2000).

Models created with quantitative data would also be of more use to managers who need to know what features are most important to bird species (Madden et al. 2000). Managers consider the costs and risks of management decisions, and only knowing that vegetation differs significantly between undisturbed and disturbed areas does not help to determine the possible implications of management (Johnson 1999). Models that include variables that are most associated with the presence of a species may be more useful to managers who are attempting to manage landscapes for many bird species. Simple
models that include only the variables most likely to increase the likelihood of species presence could allow managers to focus on a few important vegetation features.

Quantitative data and models of species presence are important to understanding how species composition and abundance change, but do not reveal how fire or grazing affect nesting success (Rohrbaugh et al. 1999, Shriver and Vickery 2001). Fire and grazing can reduce litter, reduce standing crop vegetation, and alter plant diversity in grasslands (Collins and Barber 1985, Wilson and Shay 1990, Willms et al. 1993, Vinton and Collins 1997). Interactions between disturbance types decrease vegetation density and litter accumulation further, making habitats unsuitable for all but a few grassland birds (Temple et al. 1999). Because intensive grazing by domestic livestock occurs on most remaining grasslands, landscape heterogeneity as well as diverse bird habitat have decreased (Fleischner 1994, Knopf 1994). Birds may benefit from selecting nest sites that differ from those of other species because predators are less likely to form search images (Martin 1993). Although bird species use burned or grazed prairies, nesting success could be lower because changes in vegetation can force species to use similar nest sites or nest sites with unsuitable vegetation (Martin 1988, Rohrbaugh et al. 1999, Logan 2001, Shriver and Vickery 2001). Increased vegetation density also can conceal nests and create more potential sites for predators to search (Martin 1993, 1996). However, chronically disturbed or homogeneous grasslands have inadequate vegetation cover or structure to reduce the risk of predation.

Opportunities to study wildfire and its interaction with grazing seldom occur in mixed-grass prairie. An uncontrolled fire on the Little Missouri National Grassland in western North Dakota created an opportunity to study the influence of fire and grazing on
breeding bird abundance and nesting success. The purpose of this study was to 1) determine if vegetation differed between areas with different disturbance treatments, 2) determine if relative abundance of dominant bird species differed between treatments, 3) determine if models of vegetation features could predict the presence of dominant bird species, 4) determine nesting success of three dominant bird species, 5) characterize the vegetation at nest sites of these species, and 6) determine if nesting success was related to vegetation features.

Study Area

The study took place on the McKenzie Ranger District of the Little Missouri National Grasslands in western North Dakota. The entire area is comprised of 1,028,000 acres of mixed-grass prairie and badlands and the McKenzie Ranger District makes up the northern half of the grassland (Fig. 1; Macek-Rowland 2002). Dominant grasses in the area include Western wheatgrass (*Agropyron smithii*), Blue grama (*Bouteloua gracilis*), and Needle grasses (*Stipa* spp.). Common shrub species include Silver sagebrush (*Artemisia cana*), Western snowberry (*Symphoricarpos occidentalis*), and Buffaloberry (*Shepherdia argentea*). Crested wheatgrass (*Agropyron cristatum*) and Kentucky bluegrass (*Poa pratensis*) are common exotic grasses.

The majority of the area is leased for cattle grazing and over 190 ranching operations use the grasslands from late spring to early autumn. Fire is usually suppressed in the areas, but a human-caused fire burned over 60,000 acres of the grasslands in October 1999 (Macek-Rowland 2002). Intensity of the fire varied: 4% high, 26% moderate, 50% low, and 20% unburned (Oberbillig 2001). Cattle grazing was suspended in the burned area in 2000 but resumed in 2001.
Figure 1. Little Missouri National Grassland is one of three grasslands in North Dakota. The McKenzie Ranger District, where the study took place, is marked with diagonal lines.
Chapter 1. Effects of Fire and Grazing on Vegetation and Relative Abundances of Grassland Birds in Mixed-Grass Prairie

Methods

Vegetation Measurements and Bird Surveys

Grassland bird and plant communities were surveyed at 263 (2001) and 347 (2002) points that were equally distributed between burned and unburned areas (Table 1). Birds were surveyed on 200 (2001) and 250 (2002) transects. I did not have information on cattle grazing schedules so I could not divide surveys equally among four treatments (undisturbed, burned, grazed, burned-grazed). I used a random number generator to pick coordinates of a start point in burned and unburned areas and then used a GPS unit to locate coordinates in the field. After locating the starting point, I chose a random direction and walked in that direction for 250 m. There I marked another point and recorded the coordinates. I followed the same angle and marked points every 250 m until I encountered unsuitable areas (i.e. private property, roads, or water). I re-visited the points on approximately the same dates in 2002 as in 2001.

I categorized survey points as grazed or burned-grazed if cattle were present or if I found evidence of recent grazing. I measured vegetation in four 5m radius plots that were 50 m in each cardinal direction from the point center. I measured horizontal litter depth and estimated vertical obstruction according to Robel et al. (1970) 4m from the plot center in each cardinal direction such that there were four measurements of litter depth and vertical obstruction per vegetation plot. Dead plant material lying horizontal on the ground was considered litter. I also estimated the three most abundant plant species in each plot. The procedure was the same in both years except I also estimated
Table 1. Number of point count and transect surveys in each treatment. Points were evenly distributed between burned and unburned areas, but not between grazed and ungrazed areas.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Point Count</th>
<th>Transect</th>
<th>Point Count</th>
<th>Transect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undisturbed</td>
<td>29</td>
<td>23</td>
<td>77</td>
<td>51</td>
</tr>
<tr>
<td>Burned</td>
<td>34</td>
<td>22</td>
<td>43</td>
<td>39</td>
</tr>
<tr>
<td>Grazed</td>
<td>103</td>
<td>79</td>
<td>109</td>
<td>76</td>
</tr>
<tr>
<td>Burned-grazed</td>
<td>97</td>
<td>73</td>
<td>118</td>
<td>82</td>
</tr>
</tbody>
</table>
percent ground covers in 2002. Ground covers included bareground, cactus, clubmoss, forb, grass, standing dead vegetation (residual), sedge, and shrub. I pooled percent grass, forb, and sedge cover to form total green cover (green). Measurements from the four vegetation plots were averaged to create a single estimate for each vegetation variable for each point count circle.

I conducted surveys within 1 to 5 days of the vegetation measurements. Bird surveys were performed from 10 minutes before sunrise until 0830 and discontinued during high winds (>15 mph), rain, or fog. I visited each point for 5 minutes and recorded all birds seen or heard. I recorded the species and sex of the birds when possible and the distance of the birds from the center. After finishing a point count, I walked along a 250-m line transect to the next point, recording all birds seen or heard. Transect surveys lasted 5-8 minutes, depending on terrain. I recorded flyovers both years and birds outside of the survey areas in 2002, but I did not use these detections in the analyses. I did not double counts birds in 2001, such that birds detected on a transect and detected again within 100m of following point count center were ignored. I recorded birds that were detected on previous points and transects in 2002 so that I could compare results of transect and point count surveys. Bird surveys lasted from June 1 to July 7 in 2001 and May 15 to July 6 in 2002.

Statistical Analysis

Data analyses were performed with SPSS v10.1 (SPSS, Inc., Norrisus 2000). I began my analysis by determining whether to pool data between years. Paired t-tests of vegetation data revealed changes in vegetation between years. In addition, there was evidence that some birds used the same territories both years, making it likely that I
would create pseudoreplication by pooling detection results. Therefore, I did not pool
data and I analyzed the data within years. To determine if litter depth and vertical
obstruction changed as the field season progressed, I performed linear regression with
date as the independent variable.

I used two-way ANOVA to determine if mean vertical obstruction, mean litter
depth, and mean percent ground cover differed between treatments. I used Type III sum
of squares because the number of samples per treatment were unequal (Shaw and

Because it is recommended that only species that occur on >10% of surveys
should be used (Madden et al. 1999), I only compared relative abundance of Grasshopper
Sparrow, Vesper Sparrow, and Western Meadowlark across treatments. I used Kruskal-
Wallis tests to determine if differences in relative abundance between treatments were
significant. I believed that disturbance affected vegetation and therefore bird abundance,
but I did not know if differences in vegetation actually existed. Therefore, I predicted
that the number of detections of all three species would vary across treatment. To further
determine if the territory selection of the dominant species were random, I performed
Chi-square tests of species presence with the prediction that species presence was
independent from the presence of other species (α = 0.05).

I used independent t-tests to determine if vegetation differed between points used
and unused by the dominant species. I used logistic regression to create models of
species presence for the three dominant species. I began with a global model that
contained several variables that were expected to affect habitat selection of these species.
For instance, Grasshopper Sparrow is associated with low vertical obstruction,
intermediate to deep litter, and low bareground cover (Whitmore 1979, Madden et al.
2000). Presence of each species was then regressed against smaller versions of the global
model. I used point count survey data for the independent t-tests and models because
vegetation was measured 50 m from the center of point count circles. I also included
birds double counted in 2002 in order to increase sample size.

I used Akaike’s Information Criterion (AIC) to determine what the best models
were of all the models I created. AIC adjusts the log likelihood from logistic regression
with the number of parameters in the model. The model with the lowest AIC value is
considered the best parsimonious model given the data. There is substantial empirical
support for models that are within two AIC values of the best model as well (Burnham
and Anderson 2002). I assessed the fit of the models and compared the models to each
other by calculating AIC weights ($w_i$). AIC weights are the probability that the model
with the lowest AIC value is the best model relative to other models considered
(Burnham and Anderson 2002). AIC weights are scaled from 0 to 1 and models with
high $w_i$'s have a higher probability of being the best model.

Results

*Effects of Disturbance on Vegetation*

Neither litter depth nor vertical obstruction were related to date in either year
(2001: litter depth, $R = 0.17$, vertical obstruction, $R = 0.23$; 2002: litter depth, $R = 0.37$,
vertical obstruction, $R = 0.37$). Mean litter depth and vertical obstruction differed
between treatments in 2001 (Table 2; Fig. 2). Both variables decreased with fire, with
and without grazing. Significant differences between mean litter depth occurred in 2002.

<table>
<thead>
<tr>
<th></th>
<th>Undisturbed</th>
<th>Burned</th>
<th>Grazed</th>
<th>Burned-grazed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>x (SD)</td>
<td>x (SD)</td>
<td>x (SD)</td>
<td>x (SD)</td>
</tr>
<tr>
<td>Litter depth</td>
<td>1.93 (1.01)</td>
<td>1.27 (0.85)</td>
<td>2.09 (1.17)</td>
<td>0.64 (0.44)</td>
</tr>
<tr>
<td>Vertical obstruction</td>
<td>0.91 (0.24)</td>
<td>0.67 (0.26)</td>
<td>0.82 (0.30)</td>
<td>0.76 (0.30)</td>
</tr>
<tr>
<td>F</td>
<td>46.62</td>
<td></td>
<td></td>
<td>4.08</td>
</tr>
<tr>
<td>p</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

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Figure 2. Mean litter depth and vertical obstruction in 2001. Vegetation varied significantly between treatments. Both litter depth and vertical obstruction were highest in undisturbed and grazed areas. Vertical obstruction was converted from decimeters to centimeters.
and litter depth was lowest in burned-grazed areas (Table 3; Fig. 3). Mean vertical obstruction did not differ significantly between treatments in 2002 although it was numerically lower in burned and burned-grazed areas (Table 3).

Differences in ground cover were apparent in 2002 (Table 3). Bareground, green, and residual covers differed significantly in relation to treatment. Bareground cover was highest in burned and burned-grazed, green cover was highest in grazed areas, and residual cover was lowest in burned and burned-grazed areas (Fig. 4). Grass and forb cover did not differ between treatments. Clubmoss cover varied significantly between treatments and was highest in burned and burned-grazed areas (Fig. 5). Cactus and shrub cover did not vary significantly, although cactus cover was highest in burned areas and shrub cover was lowest in burned areas (Fig. 5).

The area was dominated by native grasses in 2001 and 2002. Non-native grasses (*Agropyron cristatum*, *Poa pratensis*) and native forbs were also common. Western wheatgrass was dominant in 2001 and Blue grama was dominant in 2002.

*Effects of Disturbance on Breeding Birds*

The total number individuals detected during point count and transect surveys varied between treatments but no pattern emerged suggesting that treatment affected total number of detections. The number of birds detected per point count and transect survey did not vary between treatments in 2001 (Table 4). However, average number of birds detected per point was highest on burned areas and lowest in burned-grazed areas in 2002. Average number of detections per transect was highest in grazed areas and lowest in burned areas. Total detections per species was less than ten for most species (Appendices A-D).
Table 3. Mean vegetation variables in 2002. Half the variables measured in 2002 varied significantly between treatments. Variables with significant differences are in bold.

<table>
<thead>
<tr>
<th></th>
<th>Undisturbed x (SD)</th>
<th>Burned x (SD)</th>
<th>Grazed x (SD)</th>
<th>Burned-grazed x (SD)</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Litter depth (cm)</td>
<td>2.03 (1.28)</td>
<td>1.46 (0.95)</td>
<td>1.83 (1.65)</td>
<td>1.13 (0.75)</td>
<td>15.60</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Vertical obstruction (dm)</td>
<td>0.95 (0.29)</td>
<td>0.85 (0.33)</td>
<td>0.86 (0.27)</td>
<td>0.86 (0.29)</td>
<td>1.83</td>
<td>0.14</td>
</tr>
<tr>
<td>Bareground</td>
<td>14.04 (10.94)</td>
<td>21.03 (10.54)</td>
<td>13.56 (8.88)</td>
<td>21.80 (11.50)</td>
<td>15.80</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cactus</td>
<td>0.42 (1.61)</td>
<td>0.29 (1.00)</td>
<td>0.45 (1.43)</td>
<td>0.21 (0.67)</td>
<td>0.82</td>
<td>0.49</td>
</tr>
<tr>
<td>Clubmoss</td>
<td>0.05 (0.32)</td>
<td>0.87 (3.73)</td>
<td>0.02 (0.17)</td>
<td>0.54 (2.42)</td>
<td>3.07</td>
<td>0.03</td>
</tr>
<tr>
<td>Forb</td>
<td>13.56 (7.28)</td>
<td>14.51 (6.02)</td>
<td>14.65 (6.70)</td>
<td>13.68 (6.63)</td>
<td>0.60</td>
<td>0.62</td>
</tr>
<tr>
<td>Grass</td>
<td>33.86 (10.40)</td>
<td>32.53 (10.92)</td>
<td>37.19 (11.57)</td>
<td>34.33 (10.78)</td>
<td>2.59</td>
<td>0.053</td>
</tr>
<tr>
<td>Green</td>
<td>51.57 (10.69)</td>
<td>49.54 (11.06)</td>
<td>56.69 (11.20)</td>
<td>53.96 (12.09)</td>
<td>5.82</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Residual</td>
<td>34.38 (11.98)</td>
<td>29.42 (9.26)</td>
<td>29.21 (9.95)</td>
<td>26.50 (9.81)</td>
<td>9.12</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Shrub</td>
<td>0.42 (1.61)</td>
<td>1.98 (5.38)</td>
<td>4.19 (6.74)</td>
<td>3.39 (5.42)</td>
<td>1.48</td>
<td>0.22</td>
</tr>
</tbody>
</table>

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Figure 3. Mean litter depth and vertical obstruction in 2002. Litter depth varied significantly between treatments but vertical obstruction did not although it continued to be lower in burned and burned-grazed areas. Vertical obstruction was converted from decimeters to centimeters.
Figure 4. Ground covers that covered > 5%. Bareground was highest in disturbed areas. Other covers were highest in undisturbed or grazed areas or varied very little between treatments.
Figure 5. Ground covers that covered < 5%. Clubmoss cover was significantly different between treatments and was higher in burned and burned-grazed areas. Cactus and shrub cover did not vary significantly between treatments.
Table 4. Number of birds detected and birds per point count survey and transect survey in each treatment.

<table>
<thead>
<tr>
<th>Year</th>
<th>Undisturbed</th>
<th>Burned</th>
<th>Grazed</th>
<th>Burned-grazed</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Birds at Point Counts</td>
<td>83</td>
<td>73</td>
<td>288</td>
<td>279</td>
</tr>
<tr>
<td>Birds/Point</td>
<td>2.86</td>
<td>2.15</td>
<td>2.8</td>
<td>2.88</td>
</tr>
<tr>
<td>Total Birds at Transects</td>
<td>35</td>
<td>26</td>
<td>88</td>
<td>67</td>
</tr>
<tr>
<td>Birds/Transect</td>
<td>1.52</td>
<td>1.18</td>
<td>1.11</td>
<td>0.92</td>
</tr>
<tr>
<td>2002</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Birds at Point Counts</td>
<td>186</td>
<td>130</td>
<td>252</td>
<td>151</td>
</tr>
<tr>
<td>Birds/Point</td>
<td>2.42</td>
<td>3.82</td>
<td>2.45</td>
<td>1.56</td>
</tr>
<tr>
<td>Total Birds at Transects</td>
<td>34</td>
<td>7</td>
<td>90</td>
<td>82</td>
</tr>
<tr>
<td>Birds/Transect</td>
<td>0.67</td>
<td>0.18</td>
<td>1.18</td>
<td>1.00</td>
</tr>
</tbody>
</table>
Relative abundance of Grasshopper Sparrow and Western Meadowlark at point count surveys differed significantly between treatments in 2001 (Table 5; Fig. 6): Grasshopper Sparrow abundance also differed significantly at transect surveys (Fig. 7). Relative abundance of Vesper Sparrow did not differ between treatments during point count or transect surveys. Only the relative abundance of Western Meadowlark at transects differed significantly in 2002 (Table 5, Figure 8-9).

Presence of the dominant species was significantly dependent on the presence of the other two species in 2001 and 2002. In 2001, Western Meadowlark was present more often when Grasshopper Sparrow was absent although Grasshopper Sparrow was present more often with Western Meadowlark than without ($\chi^2 = 83.9, p << 0.001$). The same pattern was apparent for Grasshopper Sparrow in 2002 but Western Meadowlark was detected on an equal number of surveys with and without Grasshopper Sparrow ($\chi^2 = 10.6, p < 0.025$). The relation between Western Meadowlark and Vesper Sparrow presence was similar both years. Western Meadowlark was detected more without Vesper Sparrow and Vesper Sparrow was detected more without Western Meadowlark (2001: $\chi^2 = 83.9, p << 0.001$; 2002: $\chi^2 = 150, p << 0.001$). The relationship between Vesper and Grasshopper Sparrows revealed a similar species interaction, in which both species were detected more at points in the absence of the other (2001: $\chi^2 = 205, p << 0.001$; 2002: $\chi^2 = 144, p << 0.001$).

Vegetation at Points Used by the Dominant Species and Models of Species Presence

In 2001, mean litter depth and vertical obstruction were higher at points used Grasshopper Sparrow than at unused points (Table 6). Litter depth was also higher at
Table 5. Relative abundance of 3 dominant species in 2001 and 2002. Differences in relative abundance of Grasshopper Sparrow and Western Meadowlark across treatments were significant in 2001 but not in 2002 (highlighted in bold text). Relative abundance of Vesper Sparrow did not differ significantly either year.

<table>
<thead>
<tr>
<th></th>
<th>Undisturbed</th>
<th>Burned</th>
<th>Grazed</th>
<th>Burned-grazed</th>
<th>X²</th>
<th>P</th>
</tr>
</thead>
<tbody>
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<td><strong>2001 Point Counts</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grasshopper Sparrow</td>
<td>0.52</td>
<td>0.15</td>
<td>0.36</td>
<td>0.06</td>
<td>9.74</td>
<td>0.002</td>
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<tr>
<td>Vesper Sparrow</td>
<td>0.21</td>
<td>0.12</td>
<td>0.23</td>
<td>0.16</td>
<td>0.92</td>
<td>0.34</td>
</tr>
<tr>
<td>Western Meadowlark</td>
<td>0.79</td>
<td>0.53</td>
<td>0.53</td>
<td>0.34</td>
<td>4.71</td>
<td>0.03</td>
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<tr>
<td>Total Points</td>
<td>29</td>
<td>34</td>
<td>103</td>
<td>97</td>
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<table>
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<th>Undisturbed</th>
<th>Burned</th>
<th>Grazed</th>
<th>Burned-grazed</th>
<th>X²</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2001 Transects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grasshopper Sparrow</td>
<td>0.30</td>
<td>0.09</td>
<td>0.18</td>
<td>0.00</td>
<td>20.34</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Vesper Sparrow</td>
<td>0.17</td>
<td>0.23</td>
<td>0.11</td>
<td>0.15</td>
<td>1.95</td>
<td>0.58</td>
</tr>
<tr>
<td>Western Meadowlark</td>
<td>0.48</td>
<td>0.45</td>
<td>0.30</td>
<td>0.37</td>
<td>3.29</td>
<td>0.35</td>
</tr>
<tr>
<td>Total transects</td>
<td>23</td>
<td>22</td>
<td>79</td>
<td>73</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Undisturbed</th>
<th>Burned</th>
<th>Grazed</th>
<th>Burned-grazed</th>
<th>X²</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2002 Point Counts</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grasshopper Sparrow</td>
<td>0.51</td>
<td>0.60</td>
<td>0.44</td>
<td>0.42</td>
<td>1.06</td>
<td>0.30</td>
</tr>
<tr>
<td>Vesper Sparrow</td>
<td>0.16</td>
<td>0.07</td>
<td>0.20</td>
<td>0.21</td>
<td>1.85</td>
<td>0.17</td>
</tr>
<tr>
<td>Western Meadowlark</td>
<td>0.65</td>
<td>0.77</td>
<td>0.55</td>
<td>0.48</td>
<td>1.79</td>
<td>0.18</td>
</tr>
<tr>
<td>Total Points</td>
<td>77</td>
<td>43</td>
<td>109</td>
<td>118</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Undisturbed</th>
<th>Burned</th>
<th>Grazed</th>
<th>Burned-grazed</th>
<th>X²</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2002 Transects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grasshopper Sparrow</td>
<td>0.30</td>
<td>0.14</td>
<td>0.24</td>
<td>0.00</td>
<td>0.91</td>
<td>0.83</td>
</tr>
<tr>
<td>Vesper Sparrow</td>
<td>0.17</td>
<td>0.23</td>
<td>0.14</td>
<td>0.15</td>
<td>6.02</td>
<td>0.11</td>
</tr>
<tr>
<td>Western Meadowlark</td>
<td>0.57</td>
<td>0.45</td>
<td>0.37</td>
<td>0.41</td>
<td>10.64</td>
<td>0.01</td>
</tr>
<tr>
<td>Total transects</td>
<td>51</td>
<td>39</td>
<td>76</td>
<td>82</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Figure 6. Confidence intervals for the relative abundance of dominant species at point counts in 2001: Grasshopper Sparrow (■), Vesper Sparrow (•), and Western Meadowlark (●).
Figure 7. Confidence intervals for the relative abundance of dominant species at transects in 2001: Grasshopper Sparrow (■), Vesper Sparrow (•), and Western Meadowlark (○).
Figure 8. Confidence intervals for the relative abundance of dominant species at point counts in 2002: Grasshopper Sparrow (■), Vesper Sparrow (•), and Western Meadowlark (●).
Figure 9. Confidence intervals for the relative abundance of dominant species at transects in 2002: Grasshopper Sparrow (■), Vesper Sparrow (•), and Western Meadowlark (●).
Table 6. Mean vegetation at points used and unused by the three dominant bird species. Significant differences are in bold.

<table>
<thead>
<tr>
<th>Year</th>
<th>Grasshopper Sparrow</th>
<th>Vesper Sparrow</th>
<th>Western Meadowlark</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Used</td>
<td>Unused</td>
<td>t</td>
</tr>
<tr>
<td>2001</td>
<td>Litter depth (cm)</td>
<td>2.00 (1.20)</td>
<td>1.26 (1.03)</td>
</tr>
<tr>
<td></td>
<td>Vertical Obstruction (dm)</td>
<td>0.87 (0.32)</td>
<td>0.76 (0.29)</td>
</tr>
<tr>
<td>2002</td>
<td>Litter depth (cm)</td>
<td>1.40 (1.54)</td>
<td>1.65 (1.54)</td>
</tr>
<tr>
<td></td>
<td>Vertical Obstruction (dm)</td>
<td>0.91 (0.26)</td>
<td>0.85 (0.31)</td>
</tr>
<tr>
<td></td>
<td>Bareground</td>
<td>16.40 (10.37)</td>
<td>18.75 (11.81)</td>
</tr>
<tr>
<td></td>
<td>Forb</td>
<td>13.26 (6.48)</td>
<td>14.74 (6.82)</td>
</tr>
<tr>
<td></td>
<td>Grass</td>
<td>38.46 (10.28)</td>
<td>31.33 (10.68)</td>
</tr>
<tr>
<td></td>
<td>Residual</td>
<td>28.41 (8.91)</td>
<td>30.66 (12.31)</td>
</tr>
<tr>
<td></td>
<td>Total green cover</td>
<td>55.07 (10.27)</td>
<td>50.49 (12.67)</td>
</tr>
</tbody>
</table>
points used by Western Meadowlark. Vegetation did not differ between points used and unused by Vesper Sparrow. In 2002, vertical obstruction, grass cover, and total green cover were significantly higher while litter depth, bareground cover, forb cover, and residual cover were significantly lower at points used by Grasshopper Sparrow. Both litter depth and residual cover were significantly lower at points used by Vesper Sparrow. Western Meadowlark had higher litter depth, grass cover, and forb cover and lower bareground.

Evaluation of AIC values and their corresponding $w_i$'s showed that the evidence for the models of Grasshopper Sparrow and Western Meadowlark presence was strong in 2001 (Table 7). Presence of both species was positively correlated with litter depth, and Grasshopper Sparrow was also positively correlated with vertical obstruction (Table 8). Vesper Sparrow was negatively associated with litter depth, but the model for this species did not have a high weight.

In 2002, the Grasshopper Sparrow model included grass cover, residual cover, and date (Table 8). Species presence correlated positively with all variables (Table 9). The best model for Western Meadowlark included mean litter depth, grass cover, forb cover and vertical obstruction (Table 8). Western Meadowlark presence was positively correlated with all three variables. The Vesper Sparrow model included mean litter depth and vertical obstruction, and presence was negatively associated with litter but positively associated with vertical obstruction. Weights were low for models of all three species.
Table 7. AIC values, likelihood, and weights of models created with 2001 data. The best most often have the highest $w$. However, low $w$ indicates that there is not sufficient evidence for the model given the data. The best model for Vesper Sparrow has a $w$ and should be interpreted with caution.

<table>
<thead>
<tr>
<th>Species</th>
<th>Model*</th>
<th>-2logLL</th>
<th>K</th>
<th>AIC</th>
<th>AIC Diff</th>
<th>likelihood</th>
<th>$w$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grasshopper Sparrow</td>
<td>L Vo</td>
<td>266.16</td>
<td>4</td>
<td>274.16</td>
<td>0</td>
<td>1.00</td>
<td>0.68</td>
</tr>
<tr>
<td>Vesper Sparrow</td>
<td>L</td>
<td>255.66</td>
<td>3</td>
<td>261.66</td>
<td>0</td>
<td>1.00</td>
<td>0.42</td>
</tr>
<tr>
<td>Western Meadowlark</td>
<td>L</td>
<td>352.63</td>
<td>3</td>
<td>358.63</td>
<td>0</td>
<td>1.00</td>
<td>0.73</td>
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</tbody>
</table>

*L = litter depth, Vo = vertical obstruction*
Table 8. AIC values, likelihood, and weights of best models created with 2002 data. Models for all three species were low, indicating models are weak.

<table>
<thead>
<tr>
<th>Species</th>
<th>Model*</th>
<th>-2logLL</th>
<th>K</th>
<th>AIC</th>
<th>AIC Diff</th>
<th>likelihood</th>
<th>w</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grasshopper Sparrow</td>
<td>GreD</td>
<td>412.18</td>
<td>5</td>
<td>422.18</td>
<td>0</td>
<td>1.00</td>
<td>0.52</td>
</tr>
<tr>
<td>Vesper Sparrow</td>
<td>LVo</td>
<td>317.21</td>
<td>4</td>
<td>325.21</td>
<td>0</td>
<td>1.00</td>
<td>0.23</td>
</tr>
<tr>
<td>Western Meadowlark</td>
<td>VoLGF</td>
<td>458.29</td>
<td>6</td>
<td>470.29</td>
<td>0</td>
<td>1.00</td>
<td>0.32</td>
</tr>
</tbody>
</table>

* D = date, G = grass cover, F = forb cover, L = litter depth, Re = residual cover, Vo = vertical obstruction

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<table>
<thead>
<tr>
<th>Year</th>
<th>Species</th>
<th>Model Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>Grasshopper sparrow</td>
<td>( Y(\text{grasshopper sparrow}) = -2.74 + 0.53 \times \text{litter} + 0.92 \times \text{vertical obstruction} )</td>
</tr>
<tr>
<td></td>
<td>Vesper sparrow</td>
<td>( Y(\text{vesper sparrow}) = -1.36 - 0.06 \times \text{litter} )</td>
</tr>
<tr>
<td></td>
<td>Western meadowlark</td>
<td>( Y(\text{western meadowlark}) = -0.60 + 0.396 \times \text{litter} )</td>
</tr>
<tr>
<td>2002</td>
<td>Grasshopper sparrow</td>
<td>( Y(\text{grasshopper sparrow}) = -5749 + 5.70 \times 10^7 \times \text{date} + 0.61 \times \text{grass} + 0.25 \times \text{residual} )</td>
</tr>
<tr>
<td></td>
<td>Vesper sparrow</td>
<td>( Y(\text{vesper sparrow}) = -1.63 - 0.46 \times \text{litter} + 0.84 \times \text{vertical obstruction} )</td>
</tr>
<tr>
<td></td>
<td>Western meadowlark</td>
<td>( Y(\text{western meadowlark}) = -1.56 + 0.03 \times \text{grass} + 0.05 \times \text{forb} + 0.16 \times \text{litter} - 0.10 \times \text{vertical obstruction} )</td>
</tr>
</tbody>
</table>
Discussion

Litter depth was lowest in burned areas, with and without grazing, for both years of the study, and vertical obstruction was lowest in grazed and burned-grazed areas in 2001. Both fire and grazing in can reduce litter depth (Hulbert 1988). The occurrence of grazing after fire can prolong recovery of grassland areas such that vegetation growth can be inhibited (Gartner et al. 1984, Pfeiffer and Steuter 1994). Vertical obstruction, which relates to vegetation density (Robel et al. 1970), was lowest in burned and burned-grazed areas in 2001 and lowest in grazed and burned-grazed in 2002. The presence of grazing in burned-grazed two years after the fire could have prevented vegetation from recovering at the same rate as vegetation in areas that were only burned. Although grazing did not occur in the burned areas in 2000, heavy grazing before the fire in 1999 could have also negated recovery efforts after the fire. Stock densities and precipitation can affect recovery as well (Gartner et al. 1984).

The differences in bareground and clubmoss cover are not surprising because both increase with heavy disturbance (Renken and Dinsmore 1984). The decrease in residual cover in relation to disturbance is similar to the reduction in horizontal litter (Hulbert 1988). Although vertical obstruction decreased with disturbance, green vegetation cover was highest in grazed areas. Green vegetation cover, which is primary composed of grasses, can increase with grazing although density of the grasses may not (Vinton and Collins 1997). This may explain why vertical obstruction was low and green cover was high in grazed areas.

Bird species abundance can decrease significantly after fire due to the decrease in vegetation litter, and residual cover (Pylypec 1991, Johnson 1997). No apparent changes
in relative abundance in relation to treatment occurred in the study site in 2001. In 2002, number of birds detected per survey point was lowest in burned-grazed areas. The increase in bareground and clubmoss cover in these areas could have decreased the number of territories that were suitable for species requiring high amounts of residual and vegetation cover.

The three dominant species in my study were also dominant in survey studies conducted in the McKenzie District before 2000 (Freed and Nordsven, unpublished data; Young and Hutto, unpublished data). The lack of independence in species presence suggests that these species are selecting different habitat features and therefore disturbance would affect each species differently.

The higher relative abundance of Grasshopper Sparrow in undisturbed areas corresponds to results of other studies in which the species was more abundant in mixed-grass prairie that was lightly grazed or unburned (Kantrud 1981, Kantrud and Kologiski 1983, Forde 1984, Huber and Steuter 1984, Johnson 1997). Whitmore (1979) also found the species preferred areas with higher residual and litter cover and low bareground. The species has occurred in areas of low vertical obstruction and litter depth (Madden et al. 2000). Madden et al. (2000) noted that Grasshopper Sparrow responded positively to fire but my study showed that the species was in burned less than unburned areas. Differences in the detected response of this species emphasizes the need for quantitative rather than qualitative habitat measurements.

Total detection per survey of Grasshopper Sparrow increased in mid-June in 2002. The species increased in burned areas of other studies by mid-July (Huber and Steuter 1984), indicating that it was responding to the re-growth of burned vegetation.
is unclear if the species was responding to plant re-growth in this study. I found no correlation between time and vegetation probably because grazing restricted spring growth. However, date was often in the most parsimonious models of Grasshopper Sparrow presence.

The response of Western Meadowlark to disturbance is comparable to that of Grasshopper Sparrow (Huber and Steuter 1984, Pylypec 1991, Johnson 1997). Pylypec (1991) noted that Western Meadowlark abundance was similar between unburned and unburned areas, a result similar to mine. Sutter and Brigham (1998) found that Western Meadowlark numbers were correlated with high percent grass cover, high vegetation height, and low litter depth. Western Meadowlark was often associated with higher forb cover (Madden et al. 2000, Logan 2001). The species was correlated with litter in my study than in other studies, but the species was positively associated with forb and grass cover as in other studies.

The lack of response to disturbance by Vesper Sparrows is documented in other studies (Kantrud 1981). Camp and Best (1994) found that the species was common in row-crops, suggesting that the species is a generalist. Vesper Sparrows were associated with grazed and burned mixed-grass prairie in several other studies (Dale 1984, Pylypec 1991). Nest sites of this species were positively correlated with bareground and negatively correlated with vegetation height and vertical density (Camp and Best 1994), which may explain why the species is detected more in burned and grazed habitats when vegetation is sparse. Shrub cover also could be important to the species since it uses them for singing posts (Risling 1996), but shrub cover was not an important variable in my study. Models of presence for Vesper Sparrow were not strong, which could indicate
that the species was not selecting specific vegetation characteristics or important characteristics were not measured.

The results of my study should be accepted with reservations. Pseudoreplication was present in the study design because there was one burned area of mixed-grass prairie (Hurlbert 1984). Therefore, the inference of the results is very low. The design of the study was a static group comparison, which has low causal internal validity and small external inference (James and McCulloch 1995). I had no pre-fire data to use in the analysis to determine if the fire truly affected vegetation and bird species abundance. Although several differences in vegetation features suggest that fire had an impact even three years after it occurred, whether the differences are actually due to the fire alone will never be known for sure. Pre-fire conditions influence the effects of fire and its interactions with grazing (Gartner et al. 1984). Site-specific information and more formal replication of disturbance are necessary to understand the effects of fire and grazing on bird habitat (Madden et al. 2000).

The results of this study show more research is needed to fully understand the impacts of disturbance on grassland birds. Controlled, replicated studies of disturbance would provide useful information to managers trying to manage for grassland birds. Disturbance is the only source of habitat renewal for many grassland birds and understanding of disturbance will allow managers to maintain habitat for a large number of species.
Appendix A. Species list for point counts in 2001

<table>
<thead>
<tr>
<th>Species</th>
<th>Undisturbed</th>
<th>Burned</th>
<th>Grazed</th>
<th>Burned-grazed</th>
<th>Total/Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Crow</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>American Kestrel</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>American Robin</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Baird's Sparrow</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Black-billed Magpie</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Bobolink</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Brown-headed Cowbird</td>
<td>1</td>
<td>0</td>
<td>8</td>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td>Brewer's Blackbird</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Brown Thrasher</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Chestnut-collared Longspur</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Chipping Sparrow</td>
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<td>0</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Clay-colored Sparrow</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Common Flicker</td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>5</td>
<td>13</td>
</tr>
<tr>
<td>Common Grackle</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Common Yellow-throat</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
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Appendix B. Species list for transects in 2001.

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Appendix C. Species list for point counts in 2002.

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Appendix D. Species list for transect surveys in 2002.

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<td>0</td>
<td>6</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Vesper Sparrow</td>
<td>8</td>
<td>1</td>
<td>15</td>
<td>29</td>
<td>53</td>
</tr>
<tr>
<td>Western Kingbird</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Western Meadowlark</td>
<td>12</td>
<td>0</td>
<td>17</td>
<td>5</td>
<td>34</td>
</tr>
<tr>
<td>Yellow Warbler</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total Detections/Treatment</strong></td>
<td><strong>34</strong></td>
<td><strong>7</strong></td>
<td><strong>90</strong></td>
<td><strong>82</strong></td>
<td></td>
</tr>
</tbody>
</table>
Appendix E. Candidate models for Grasshopper Sparrow presence in 2002.

<table>
<thead>
<tr>
<th>Model</th>
<th>-2logLL</th>
<th>K</th>
<th>AIC</th>
<th>AIC Diff</th>
<th>Likelihood</th>
<th>w</th>
</tr>
</thead>
<tbody>
<tr>
<td>GReD</td>
<td>412.18</td>
<td>5</td>
<td>422.18</td>
<td>0</td>
<td>1.00</td>
<td>0.52</td>
</tr>
<tr>
<td>GD</td>
<td>415.97</td>
<td>4</td>
<td>423.97</td>
<td>1.79</td>
<td>0.41</td>
<td>0.21</td>
</tr>
<tr>
<td>LVoGReD</td>
<td>410.68</td>
<td>7</td>
<td>424.68</td>
<td>2.50</td>
<td>0.29</td>
<td>0.15</td>
</tr>
<tr>
<td>BLVoGReD</td>
<td>410.24</td>
<td>8</td>
<td>426.24</td>
<td>4.06</td>
<td>0.13</td>
<td>0.07</td>
</tr>
<tr>
<td>LVoGD</td>
<td>415.55</td>
<td>6</td>
<td>427.55</td>
<td>5.37</td>
<td>0.07</td>
<td>0.04</td>
</tr>
<tr>
<td>BLVoGFSReD</td>
<td>409.72</td>
<td>10</td>
<td>429.72</td>
<td>7.54</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td>VReD</td>
<td>430.74</td>
<td>5</td>
<td>440.74</td>
<td>18.56</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>LVoG</td>
<td>435.22</td>
<td>5</td>
<td>445.22</td>
<td>23.04</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>LVoGRe</td>
<td>434.24</td>
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<td>446.24</td>
<td>24.05</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>BLVoGRe</td>
<td>433.70</td>
<td>7</td>
<td>447.70</td>
<td>25.52</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>VoeD</td>
<td>440.65</td>
<td>4</td>
<td>448.65</td>
<td>26.47</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>BLVoGFRe</td>
<td>433.70</td>
<td>8</td>
<td>449.70</td>
<td>27.52</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>LVoD</td>
<td>441.53</td>
<td>5</td>
<td>451.53</td>
<td>29.35</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>BLVoGFSRe</td>
<td>433.65</td>
<td>9</td>
<td>451.65</td>
<td>29.47</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>BLVoRe</td>
<td>456.40</td>
<td>6</td>
<td>468.40</td>
<td>46.22</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>LVoV</td>
<td>459.36</td>
<td>5</td>
<td>469.36</td>
<td>47.18</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>LVo</td>
<td>470.00</td>
<td>4</td>
<td>478.00</td>
<td>55.82</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>LVoRe</td>
<td>469.51</td>
<td>5</td>
<td>479.51</td>
<td>57.33</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

* B = bareground, D = date, G = grass cover, F = forb cover, L = litter depth, Re = residual cover, S = shrub cover, Vo = vertical obstruction

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Appendix F. Candidate models for Vesper Sparow presence in 2002.

<table>
<thead>
<tr>
<th>Model^</th>
<th>-2logLL</th>
<th>K</th>
<th>AIC</th>
<th>AIC Diff</th>
<th>Likelihood</th>
<th>w</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lvo</td>
<td>317.21</td>
<td>4</td>
<td>325.21</td>
<td>0</td>
<td>1.00</td>
<td>0.23</td>
</tr>
<tr>
<td>VoLRe</td>
<td>316.78</td>
<td>5</td>
<td>326.78</td>
<td>1.58</td>
<td>0.45</td>
<td>0.11</td>
</tr>
<tr>
<td>VoLV</td>
<td>316.82</td>
<td>5</td>
<td>326.82</td>
<td>1.61</td>
<td>0.45</td>
<td>0.10</td>
</tr>
<tr>
<td>BLVo</td>
<td>316.95</td>
<td>5</td>
<td>326.95</td>
<td>1.75</td>
<td>0.42</td>
<td>0.10</td>
</tr>
<tr>
<td>VL</td>
<td>319.07</td>
<td>4</td>
<td>327.07</td>
<td>1.87</td>
<td>0.39</td>
<td>0.09</td>
</tr>
<tr>
<td>VoLG</td>
<td>317.11</td>
<td>5</td>
<td>327.11</td>
<td>1.90</td>
<td>0.39</td>
<td>0.09</td>
</tr>
<tr>
<td>BL</td>
<td>319.84</td>
<td>4</td>
<td>327.84</td>
<td>2.63</td>
<td>0.27</td>
<td>0.06</td>
</tr>
<tr>
<td>VoLReG</td>
<td>316.55</td>
<td>6</td>
<td>328.55</td>
<td>3.35</td>
<td>0.19</td>
<td>0.04</td>
</tr>
<tr>
<td>VoLVRe</td>
<td>316.70</td>
<td>6</td>
<td>328.70</td>
<td>3.49</td>
<td>0.17</td>
<td>0.04</td>
</tr>
<tr>
<td>BLVoG</td>
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<td>6</td>
<td>328.76</td>
<td>3.55</td>
<td>0.17</td>
<td>0.04</td>
</tr>
<tr>
<td>BLVoS</td>
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<td>6</td>
<td>328.82</td>
<td>3.61</td>
<td>0.16</td>
<td>0.04</td>
</tr>
<tr>
<td>Bvo</td>
<td>321.85</td>
<td>4</td>
<td>329.85</td>
<td>4.64</td>
<td>0.10</td>
<td>0.02</td>
</tr>
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<td>BLVoGS</td>
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<td>7</td>
<td>330.71</td>
<td>5.50</td>
<td>0.06</td>
<td>0.01</td>
</tr>
<tr>
<td>VoV</td>
<td>324.21</td>
<td>4</td>
<td>332.21</td>
<td>7.00</td>
<td>0.03</td>
<td>0.01</td>
</tr>
<tr>
<td>BLVoGSC</td>
<td>316.42</td>
<td>8</td>
<td>332.42</td>
<td>7.21</td>
<td>0.03</td>
<td>0.01</td>
</tr>
<tr>
<td>BLVoGSReC</td>
<td>315.64</td>
<td>9</td>
<td>333.64</td>
<td>8.43</td>
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<td>0.00</td>
</tr>
<tr>
<td>BLVoGFSReC</td>
<td>315.42</td>
<td>10</td>
<td>335.42</td>
<td>10.21</td>
<td>0.01</td>
<td>0.00</td>
</tr>
</tbody>
</table>

\^B = bareground, C = cactus cover, D = date, G = grass cover, F = forb cover, L = litter depth, Re = residual cover, S = shrub cover, Vo = vertical obstruction
Appendix G. Candidate models for Western Meadowlark presence in 2002.

<table>
<thead>
<tr>
<th>Model</th>
<th>-2logLL</th>
<th>K</th>
<th>AIC</th>
<th>AIC Diff</th>
<th>likelihood</th>
<th>w</th>
</tr>
</thead>
<tbody>
<tr>
<td>VoLGF</td>
<td>458.29</td>
<td>6</td>
<td>470.29</td>
<td>0</td>
<td>1.00</td>
<td>0.32</td>
</tr>
<tr>
<td>VoLGFS</td>
<td>457.11</td>
<td>7</td>
<td>471.11</td>
<td>0.82</td>
<td>0.66</td>
<td>0.21</td>
</tr>
<tr>
<td>VoLGFR</td>
<td>457.70</td>
<td>7</td>
<td>471.70</td>
<td>1.41</td>
<td>0.49</td>
<td>0.16</td>
</tr>
<tr>
<td>VoLGVoSRe</td>
<td>457.00</td>
<td>8</td>
<td>473.00</td>
<td>2.72</td>
<td>0.26</td>
<td>0.08</td>
</tr>
<tr>
<td>VoLV</td>
<td>463.05</td>
<td>5</td>
<td>473.05</td>
<td>2.76</td>
<td>0.25</td>
<td>0.08</td>
</tr>
<tr>
<td>VoLVRe</td>
<td>462.32</td>
<td>6</td>
<td>474.32</td>
<td>4.03</td>
<td>0.13</td>
<td>0.04</td>
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<tr>
<td>VoLG</td>
<td>465.24</td>
<td>5</td>
<td>475.24</td>
<td>4.96</td>
<td>0.08</td>
<td>0.03</td>
</tr>
<tr>
<td>VoLB</td>
<td>465.32</td>
<td>5</td>
<td>475.32</td>
<td>5.04</td>
<td>0.08</td>
<td>0.03</td>
</tr>
<tr>
<td>L</td>
<td>470.37</td>
<td>3</td>
<td>476.37</td>
<td>6.08</td>
<td>0.05</td>
<td>0.02</td>
</tr>
<tr>
<td>VoLF</td>
<td>466.65</td>
<td>5</td>
<td>476.65</td>
<td>6.37</td>
<td>0.04</td>
<td>0.01</td>
</tr>
<tr>
<td>VoLGSRe</td>
<td>463.64</td>
<td>7</td>
<td>477.64</td>
<td>7.35</td>
<td>0.03</td>
<td>0.01</td>
</tr>
<tr>
<td>VoL</td>
<td>470.34</td>
<td>4</td>
<td>478.34</td>
<td>8.06</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td>Vo</td>
<td>472.70</td>
<td>3</td>
<td>478.70</td>
<td>8.42</td>
<td>0.01</td>
<td>0.00</td>
</tr>
</tbody>
</table>

*G = grass cover, F = forb cover, L = litter depth, Re = residual cover, S = shrub cover, Vo = vertical obstruction.
Chapter 2: Nest Site Vegetation and Nest Success of Three Grassland Bird Species

Methods

Nest searching and monitoring lasted from mid-May to mid-July, 2002. Two 40-ha nest plots were randomly placed in each of the burned and unburned areas. The plots were separated by 5 km or more and were greater than 0.5 km from the nearest road. Sparsely wooded draws bordered one plot in each burn treatment. I initially intended to use ungrazed plots, but cattle were placed on three of the plots in June. Only one unburned plot was not grazed during the study.

Nest searching began 0600 or 0900, depending on if I conducted bird surveys in the morning, and lasted until 1230. Nest searching on the plots consisted of both systematic searches (Martin and Geupel 1993) and rope dragging. I documented the amount of search time and search methods used each time a nest plot was searched. Nest densities were low in the plots so I also monitored nests found by chance off the plots. I searched for the nests of the three species that were most abundant in 2001 surveys: Grasshopper Sparrow (*Ammodramus savannarum*), Vesper Sparrow (*Pooecetes gramineus*), and Western Meadowlark (*Sturnella neglecta*). When I found a nest, I recorded its location with a GPS unit, its contents, the substrate in which the nest was located, and the orientation of the nest opening. I used this information primarily to help locate the nests later. Flagging was placed 50m or more from the nest in a cardinal direction. Because I monitored several nests in an area at once, I varied the direction and
distance of the flagging to prevent predators from using it to find the nests. I noted when
I found nests of other species although I did not mark or monitor these nests.

Nests were monitored every 2-4 days optimally, although the length of time
between nest checks was sometimes longer due to time constraints and weather. I
approached a nest from different directions during each check to prevent trails from
forming. I checked nest contents, noting the location and behavior of the parents, and
quickly left the nest site.

When a nest failed or fledged, I marked the exact nest site with flagging and
returned approximately two weeks later to conduct vegetation measurements of the nest
site. I used the BBird Protocol for Grassland Habitats (Martin et al. 1997) to measure
nest site vegetation. I centered a 5m-radius plot on the nest and divided the plot along the
cardinal directions into four equal segments. I measured grass height, vertical
obstruction, and litter depth at 0m, 1m, 3m and 5m from the nest in each cardinal
direction and I estimated percent ground cover in each segment. Ground covers included:
grass, forb, sedge, cactus, total green vegetation cover (green), bareground, and standing
dead vegetation (residual). To assess the available nesting habitat near each nest, I
performed the same measurement at a random site located 30m from the nest site.
Random sites were not exactly similar to nest sites, however I centered the 5m-radius plot
on the same substrate in which the adjacent nest was found. My field assistant and I took
turns measuring vegetation at nest sites and random sites to reduce observer bias.

Statistical Analysis

I calculated means and standard deviations for all nest site vegetation
measurements for each bird species. I calculated average litter depth and percent ground
covers by type in each nest and random plot. For each species, I used Student’s paired t-test to test whether grass height, vertical obstruction, and litter depth differed significantly between nest sites and random sites (Ott and Longnecker 2001). Data on percent ground covers were not distributed normally, therefore I used Wilcoxon signed rank test to determine if differences in ground covers between nest sites and random sites were significant. Vegetation can differ relative to distance from the nest (Logan 2001), so I used paired t-tests to compare grass height and vertical obstruction at 0m, 1m, 3m, and 5m for each nest site. I performed independent t-tests to test for differences in grass height, litter depth, and vertical obstruction and Mann-Whitney U to test for differences in percent ground covers between species (Ott and Longnecker 2001).

I calculated apparent nest success for all species and used the Mayfield method (Mayfield 1975, Johnson 1979) to estimate daily nest mortality rates and standard errors for species represented by >20 nests. I did not calculate Mayfield estimates for species represented by fewer than 20 nests because estimates become unreliable with small sample sizes (Hensler and Nichols 1981). I used independent t-tests do test for differences in vegetation between fledged and failed nests. I performed two-way factorial analysis to determine if treatment (undisturbed, burned, grazed, burned-grazed) affected nesting success.

Results

Nest Searching

Two hundred eighty-two person hours (2 people x 141 hours) were spent on nest searching in the four nest plots using systematic searches (110 hours) and rope dragging
(172 hours). I found 33 nests in the plots and spent 8.5 hrs/nest. I found 32 nests were in areas off nest plots bringing the total number of nests of to 65 (13 Grasshopper Sparrow, 32 Vesper Sparrow, and 20 Western Meadowlark). I also found eight nests of five other species, which I did not monitor (Table 2).

_Nest Site Vegetation of Each Species_

Although most means of vegetation variables were higher at nest sites than at random sites for all species, few of the differences were significant (Table 3). However, there were often significant differences in grass height and vertical obstruction at different distances from the nests (Table 4).

For the Grasshopper Sparrow, mean grass heights at 0m and 1m were lower at nest sites than at random sites. Vertical obstruction at 3m was significantly higher at nest sites than random sites but did not differ significantly at other distances. Litter was higher at nest sites, but not significantly so (Fig.1). Forb, grass, green, and shrub cover were numerically higher at nest sites than random nest sites (Fig.2). Random sites had higher bareground and sedge cover. Grass height and vertical obstruction were significantly higher at the nest (0m) than at 1m, 3m, or 5m. Vertical obstruction decreased with distance from the nest, but grass height showed no clear pattern (Fig.1).

Mean grass height was higher at Vesper Sparrow nest sites than at random sites. Vertical obstruction and litter depth differed very little between nest and random sites at any distance (Fig.3). Vesper Sparrow nest sites had higher cactus, sedge, and shrub cover but lower percentages of all other ground covers types (Fig.4). Grass height was significantly higher at 0m than at 5m but did not differ between 0m, 1m, and 3m. Vertical obstruction at 0m was significantly higher than at 1m, 3m, and 5m (Fig.3).
Table 1. Number of hours spent searching for nests of abundant species in nest plots using two different methods. Plots are named according to treatment (B = burned, N = Non-burned, G = Grazed, U = Ungrazed).

<table>
<thead>
<tr>
<th>Plot</th>
<th>Systematic search</th>
<th>Rope search</th>
<th>Total Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>BG1</td>
<td>18.5</td>
<td>15.25</td>
<td>33.75</td>
</tr>
<tr>
<td>BG2</td>
<td>34</td>
<td>8</td>
<td>42</td>
</tr>
<tr>
<td>NU1</td>
<td>19.5</td>
<td>15</td>
<td>34.5</td>
</tr>
<tr>
<td>NG1</td>
<td>14</td>
<td>16.75</td>
<td>30.75</td>
</tr>
</tbody>
</table>
Table 2. Number of nests found for each species and their location. Although search and monitoring efforts focused on Grasshopper Sparrow, Vesper Sparrow, and Western Meadowlark nests, locations of nests of other species were noted.

<table>
<thead>
<tr>
<th>Species</th>
<th>BG1</th>
<th>BG2</th>
<th>NU1</th>
<th>NG1</th>
<th>Off-Plot</th>
<th>Total/Nest Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grasshopper Sparrow (Ammodramus savannarum)</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>6</td>
<td>13</td>
</tr>
<tr>
<td>Vesper Sparrow (Pooecetes gramineus)</td>
<td>5</td>
<td>6</td>
<td>3</td>
<td>3</td>
<td>16</td>
<td>32</td>
</tr>
<tr>
<td>Western Meadowlark (Sturnella neglecta)</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Common Nighthawk (Chordeiles minor)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Eastern Kingbird (Tyrannus tyrannus)</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Lark Bunting (Calamospiza melanocorys)</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Morning Dove (Zenaida macroura)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Savannah Sparrow (Passerculus sandwichensis)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total Nests / Plot</td>
<td>8</td>
<td>14</td>
<td>8</td>
<td>8</td>
<td>36</td>
<td>46</td>
</tr>
</tbody>
</table>
Table 3. Differences between mean vegetation variables at nest sites and adjacent random sites for each species (grass height in cm, vertical obstruction in dm). Values for variables that were significantly different ($\alpha = 0.05$) are in bold.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Grasshopper Sparrow</th>
<th>Vesper Sparrow</th>
<th>Western Meadowlark</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nest (SD)</td>
<td>Random (SD)</td>
<td>Nest (SD)</td>
</tr>
<tr>
<td>Grass height 0m</td>
<td>35.00 (11.38)</td>
<td>35.36 (14.44)</td>
<td>-0.08</td>
</tr>
<tr>
<td>Grass height 1m</td>
<td>25.06 (7.89)</td>
<td>29.46 (6.93)</td>
<td>-1.85</td>
</tr>
<tr>
<td>Grass height 3m</td>
<td>27.58 (10.20)</td>
<td>24.13 (5.59)</td>
<td>1.20</td>
</tr>
<tr>
<td>Grass height 5m</td>
<td>24.65 (5.82)</td>
<td>20.50 (6.46)</td>
<td>1.91</td>
</tr>
<tr>
<td>Vertical obstruction 0m</td>
<td>1.55 (0.40)</td>
<td>1.26 (0.30)</td>
<td>2.29</td>
</tr>
<tr>
<td>Vertical obstruction 1m</td>
<td>1.28 (0.53)</td>
<td>1.28 (0.49)</td>
<td>0.02</td>
</tr>
<tr>
<td>Vertical obstruction 3m</td>
<td>1.19 (0.40)</td>
<td>0.93 (0.37)</td>
<td>3.57</td>
</tr>
<tr>
<td>Vertical obstruction 5m</td>
<td>1.16 (0.61)</td>
<td>0.88 (0.28)</td>
<td>1.64</td>
</tr>
<tr>
<td>Litter depth (mm)</td>
<td>6.48 (4.14)</td>
<td>5.58 (4.35)</td>
<td>0.75</td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th>Variable</th>
<th>Nest (SD)</th>
<th>Random (SD)</th>
<th>Z</th>
<th>p</th>
<th>Nest (SD)</th>
<th>Random (SD)</th>
<th>Z</th>
<th>p</th>
<th>Nest (SD)</th>
<th>Random (SD)</th>
<th>Z</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bareground</td>
<td>9.17 (5.33)</td>
<td>9.96 (4.97)</td>
<td>-0.90</td>
<td>0.37</td>
<td>0.24 (0.99)</td>
<td>0.94 (4.96)</td>
<td>0.02</td>
<td>0.91</td>
<td>10.17 (9.91)</td>
<td>9.44 (5.62)</td>
<td>-0.31</td>
<td>0.76</td>
</tr>
<tr>
<td>Cactus</td>
<td>0</td>
<td>0.04 (0.14)</td>
<td>-1.0</td>
<td>0.32</td>
<td>0.37 (0.93)</td>
<td>0.19 (0.94)</td>
<td>-1.44</td>
<td>0.15</td>
<td>0.56 (0.93)</td>
<td>0.10 (0.21)</td>
<td>-1.87</td>
<td>0.06</td>
</tr>
<tr>
<td>Forb</td>
<td>12.85 (6.40)</td>
<td>10.87 (5.18)</td>
<td>-0.87</td>
<td>0.38</td>
<td>14.58 (8.20)</td>
<td>15.07 (6.21)</td>
<td>-0.97</td>
<td>0.33</td>
<td>12.03 (7.37)</td>
<td>11.44 (7.47)</td>
<td>-0.18</td>
<td>0.86</td>
</tr>
<tr>
<td>Grass</td>
<td>64.12 (19.37)</td>
<td>63.48 (16.71)</td>
<td>0.11</td>
<td>0.92</td>
<td>54.91 (14.47)</td>
<td>58.61 (16.98)</td>
<td>-1.19</td>
<td>0.23</td>
<td>67.99 (18.17)</td>
<td>72.67 (13.32)</td>
<td>-1.29</td>
<td>0.2</td>
</tr>
<tr>
<td>Green</td>
<td>66.25 (14.28)</td>
<td>62.69 (11.82)</td>
<td>-0.91</td>
<td>0.36</td>
<td>63.89 (15.20)</td>
<td>64.36 (13.03)</td>
<td>-0.51</td>
<td>0.61</td>
<td>61.04 (14.45)</td>
<td>63.89 (13.40)</td>
<td>-1.25</td>
<td>0.21</td>
</tr>
<tr>
<td>Sedge</td>
<td>4.44 (10.65)</td>
<td>5.29 (9.66)</td>
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<td>0.80</td>
<td>15.98 (12.06)</td>
<td>12.33 (10.59)</td>
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<td>0.19</td>
<td>1.48 (3.02)</td>
<td>1.17 (2.05)</td>
<td>-0.70</td>
<td>0.48</td>
</tr>
<tr>
<td>Shrub</td>
<td>11.10 (18.00)</td>
<td>9.35 (14.97)</td>
<td>-0.66</td>
<td>0.51</td>
<td>2.62 (6.27)</td>
<td>3.79 (8.19)</td>
<td>-0.49</td>
<td>0.62</td>
<td>6.89 (14.01)</td>
<td>4.20 (9.40)</td>
<td>-1.96</td>
<td>0.05</td>
</tr>
</tbody>
</table>
Table 4. Differences relative to distance from the nest (0m). Mean grass height and mean vertical obstruction at the nest were often significantly higher than at 1m, 3m, and 5m for all species. Means at 1m were often significantly higher than at 3m and 5m as well. Significant values are in bold.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Grasshopper Sparrow</th>
<th>Vesper Sparrow</th>
<th>Western Meadowlark</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t</td>
<td>p-value</td>
<td>t</td>
</tr>
<tr>
<td>Grass height (cm) 0-1m</td>
<td>3.28</td>
<td>0.01</td>
<td>1.65</td>
</tr>
<tr>
<td>Grass height (cm) 0-3m</td>
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<td>0.20</td>
<td>-0.095</td>
</tr>
<tr>
<td>Grass height (cm) 0-5m</td>
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<td>0.73</td>
<td>1.10</td>
</tr>
<tr>
<td>Grass height (cm) 1-3m</td>
<td>1.72</td>
<td>0.12</td>
<td>1.32</td>
</tr>
<tr>
<td>Grass height (cm) 1-5m</td>
<td>3.35</td>
<td>0.01</td>
<td>2.15</td>
</tr>
<tr>
<td>Grass height (cm) 3-5m</td>
<td>1.43</td>
<td>0.18</td>
<td>1.15</td>
</tr>
<tr>
<td>Vertical obstruction (dm) 0-1m</td>
<td>2.72</td>
<td>0.02</td>
<td>4.21</td>
</tr>
<tr>
<td>Vertical obstruction (dm) 1-3m</td>
<td>0.97</td>
<td>0.35</td>
<td>0.34</td>
</tr>
<tr>
<td>Vertical obstruction (dm) 1-5m</td>
<td>0.93</td>
<td>0.37</td>
<td>1.26</td>
</tr>
<tr>
<td>Vertical obstruction (dm) 0-3m</td>
<td>3.25</td>
<td>0.01</td>
<td>4.64</td>
</tr>
<tr>
<td>Vertical obstruction (dm) 0-5m</td>
<td>2.69</td>
<td>0.02</td>
<td>5.86</td>
</tr>
<tr>
<td>Vertical obstruction (dm) 3-5m</td>
<td>0.22</td>
<td>0.83</td>
<td>1.20</td>
</tr>
</tbody>
</table>

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Figure 1. Means for vegetation variables at Grasshopper Sparrow nest sites and random sites. Vertical obstruction was converted from decimeters to centimeters. Most variables were higher at nest sites than random sites although differences were often non-significant.
Figure 2. Mean percent ground covers for Grasshopper Sparrow nest sites and random sites. Very few differences between sites exist. Cactus cover was omitted because it covered ≤ 1.0% and thus was too small to be adequately depicted on the graph.
All mean vegetation variables were higher at Western Meadowlark nest sites except for grass height at 5m (Fig. 5). Only grass height at 1m was significantly higher at nest sites. Nest sites had higher bareground, forb, cactus, sedge, and shrub cover. These sites also had lower grass and shrub cover (Fig. 6). Grass height did not differ greatly between 0m and 1m, but grass height at the nest and 1m was significantly higher than at 3m and 5m. Vertical obstruction was higher at the nest than at 1m and 5m (Fig. 5).

*Differences in Nest Site Vegetation Between Species*

There were negligible differences in grass height, vertical obstruction, and litter depth between species (Table 5). Both Grasshopper Sparrow and Western Meadowlark nests had higher means in most categories in comparison to Vesper Sparrow nests (Figs. 7-9). However, mean litter depth was the only variable that was significantly higher at Western Meadowlark nests than at Vesper Sparrow nests. The three species differed in percent ground covers (Table 5; Fig. 9). Vesper Sparrow had higher bareground and shrub cover than the other species. Grasshopper Sparrow and Western Meadowlark has higher grass cover than Vesper Sparrow, with a significant difference existing between Grasshopper and Vesper Sparrows.

I noted that Grasshopper Sparrow nests were often concealed with residual grasses and were in patches of dense litter and standing residual grass. Vesper Sparrow nests varied greatly in concealment. Some nests were concealed with residual grasses, but often the nest was under a living forb, grass clump, or shrub. In one instance, a successful Vesper Sparrow nest was found in a cactus patch and the nest was concealed by a single cactus pad on the south. Western Meadowlarks usually concealed their nests with a dome of residual grasses. As the nesting period progressed, nests became more
Figure 3. Mean vegetation variables at Vesper Sparrow nest sites and random sites. Mean grass height was higher at nest sites while vertical obstruction and litter depth varied little between sites. Grass height was significantly higher at 0m from the nest than at 5m and vertical obstruction was significantly higher at 0m than at other distances from the nest.
Figure 4. Mean percent ground covers at Vesper Sparrow nest sites and random sites. Few differences existed between sites and none were significant. Cactus cover was omitted because it covered ≤ 1.0%.
Figure 5. Mean vegetation variables at Western Meadowlark nest sites and random sites. The majority of vegetation variables were higher at nest sites with only grass height at 1m being significantly higher. Grass height and vertical obstruction decreased with distance from the nest, and many of the differences between distances from the nest were significant.
Figure 6. Mean percent ground covers at Western Meadowlark nest sites and random sites. Differences between sites was minimal and non-significant. Cactus cover was omitted because it covered ≤ 1.0%.
Table 5. Results of tests for differences between species. Despite observation of differences at nest sites between species, few differences emerged after statistical analysis. Significant differences are in bold.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Grasshopper Sparrow vs. Vesper Sparrow</th>
<th>Western Meadowlark vs. Grasshopper Sparrow</th>
<th>Vesper Sparrow vs. Western Meadowlark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass height (cm) 0m</td>
<td>0.995 0.33</td>
<td>-0.9 0.38</td>
<td>0.09 0.93</td>
</tr>
<tr>
<td>Grass height (cm) 1m</td>
<td>0.55 0.58</td>
<td>0.95 0.35</td>
<td>0.48 0.63</td>
</tr>
<tr>
<td>Grass height (cm) 3m</td>
<td>-0.17 0.87</td>
<td>-1.17 0.25</td>
<td>-1.25 0.22</td>
</tr>
<tr>
<td>Grass height (cm) 5m</td>
<td>0.09 0.93</td>
<td>-1.47 0.15</td>
<td>-1.48 0.16</td>
</tr>
<tr>
<td>Vertical obstruction (dm) 0m</td>
<td>-0.7 0.49</td>
<td>0.62 0.54</td>
<td>1.32 0.199</td>
</tr>
<tr>
<td>Vertical obstruction (dm) 1m</td>
<td>-0.95 0.35</td>
<td>-0.04 0.97</td>
<td>0.93 0.36</td>
</tr>
<tr>
<td>Vertical obstruction (dm) 3m</td>
<td>-0.65 0.52</td>
<td>0.41 0.69</td>
<td>0.91 0.37</td>
</tr>
<tr>
<td>Vertical obstruction (dm) 5m</td>
<td>-0.88 0.39</td>
<td>0.2 0.84</td>
<td>0.5 0.62</td>
</tr>
<tr>
<td>Litter depth (mm)</td>
<td>-0.69 0.49</td>
<td>1.16 0.26</td>
<td>2.35 0.02</td>
</tr>
<tr>
<td>Percent Ground Cover</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bareground</td>
<td>-2.47 0.01</td>
<td>-0.18 0.86</td>
<td>-1.75 0.08</td>
</tr>
<tr>
<td>Cactus</td>
<td>-1.84 0.07</td>
<td>-2.26 0.02</td>
<td>-0.85 0.39</td>
</tr>
<tr>
<td>Forb</td>
<td>-0.31 0.76</td>
<td>-0.44 0.66</td>
<td>-1.09 0.28</td>
</tr>
<tr>
<td>Grass</td>
<td>-1.66 0.097</td>
<td>-0.6 0.55</td>
<td>-2.28 0.02</td>
</tr>
<tr>
<td>Green</td>
<td>-0.37 0.71</td>
<td>-0.92 0.36</td>
<td>-0.88 0.38</td>
</tr>
<tr>
<td>Rock</td>
<td>-0.93 0.35</td>
<td>-1.22 0.22</td>
<td>-52 0.6</td>
</tr>
<tr>
<td>Sedge</td>
<td>-0.54 0.59</td>
<td>-6.8 0.5</td>
<td>-0.19 0.85</td>
</tr>
<tr>
<td>Shrub</td>
<td>-0.11 0.92</td>
<td>-1.66 0.097</td>
<td>-1.88 0.06</td>
</tr>
</tbody>
</table>
Figure 7. Differences in mean grass height between species.
Figure 8. Differences in mean vertical obstruction between species.

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Figure 9. Mean percent cover at nest sites for all species. Few differences existed between species. Grasshopper Sparrow and Western Meadowlark were more similar to each other than to Vesper Sparrow.
exposed as adults entered and left the nests. Western Meadowlark nests that were in Crested wheatgrass (*Agropyron cristatum*) were much more conspicuous than nests in native grasses because they lacked a dome of residual material.

**Nesting Success**

Apparent nesting success was low for the three species. Of 20 Western Meadowlark nests, 3 were abandoned and 13 depredated (80% failure). Of 32 Vesper Sparrow nests, 5 were abandoned and 19 were depredated (68.8% failure). Eight of 13 Grasshopper Sparrow were depredated (61.5%). One Western Meadowlark and two Vesper Sparrow nests were abandoned during the building stage because of observer presence. Cowbird parasitism was not evident in any nests. Daily nest success was lower for Western Meadowlark than for Vesper Sparrow (Table 6). Probability of nest success was 8.8% for Western Meadowlark and 16.9% for Vesper Sparrow.

**Characteristics of Fledged and Failed Nests**

There were few if any differences in vegetation variables between successful and failed nests (Table 7). Although many variables such as grass height, vertical obstruction, and litter depth were higher at successful nests, standard errors were high due to small sample sizes (Figs. 10-12). Mean litter depth was significantly greater at fledged Grasshopper Sparrow nests. Fledged Vesper Sparrow nests had higher cactus cover than depredated sites. Percent grass cover was lower at successful Western Meadowlark nests, but grass height was higher at 1m, 3m, and 5m. Fire and grazing disturbance had no apparent effect on success rates ($F = 0.94, p = 0.43$). A lower proportion of nests in burned areas fledged (25%) compared to the unburned areas (40%). Nest predation was the main cause of failure in all nest plots and off-plot areas (Table 8).
Table 6. Daily survival rates (DSR) and probabilities of success during each nesting stage for Vesper Sparrow and Western Meadowlark.

<table>
<thead>
<tr>
<th>Species</th>
<th>Laying N</th>
<th>DSR (SE)</th>
<th>Incubation DSR (SE)</th>
<th>Success</th>
<th>Nestling DSR (SE)</th>
<th>Success</th>
<th>Overall DSR (SE)</th>
<th>Success</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vesper Sparrow</td>
<td>32</td>
<td>0.33 (0.14)</td>
<td>0.91 (0.03)</td>
<td>0.31</td>
<td>0.94 (0.02)</td>
<td>0.55</td>
<td>0.91 (0.01)</td>
<td>0.169</td>
</tr>
<tr>
<td>Western Meadowlark</td>
<td>20</td>
<td>0.50 (0.25)</td>
<td>0.90 (0.03)</td>
<td>0.23</td>
<td>0.92 (0.02)</td>
<td>0.38</td>
<td>0.90 (0.01)</td>
<td>0.088</td>
</tr>
</tbody>
</table>

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Table 7. Difference in vegetation at fledged and failed nest sites (grass height in cm, vertical obstruction in dm). Few differences existed between fledged and failed nests and standard deviations were high due to the small number of fledged nests (5, 10, 4).

<table>
<thead>
<tr>
<th>Vegetation</th>
<th>Grasshopper Sparrow</th>
<th>Vesper Sparrow</th>
<th>Western Meadowlark</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fledged (SD)</td>
<td>Failed (SD)</td>
<td>t</td>
</tr>
<tr>
<td>Grass height 0m</td>
<td>37.60 (13.90)</td>
<td>32.83 (9.58)</td>
<td>-0.67</td>
</tr>
<tr>
<td>Grass height 1m</td>
<td>27.50 (8.63)</td>
<td>23.53 (7.57)</td>
<td>-0.87</td>
</tr>
<tr>
<td>Grass height 3m</td>
<td>28.15 (12.72)</td>
<td>27.22 (9.24)</td>
<td>-0.15</td>
</tr>
<tr>
<td>Grass height 5m</td>
<td>27.75 (7.11)</td>
<td>22.72 (4.25)</td>
<td>1.62</td>
</tr>
<tr>
<td>Vertical obstruction 0m</td>
<td>1.38 (0.25)</td>
<td>1.66 (0.46)</td>
<td>-1.25</td>
</tr>
<tr>
<td>Vertical obstruction 1m</td>
<td>1.28 (0.31)</td>
<td>1.28 (0.65)</td>
<td>0.02</td>
</tr>
<tr>
<td>Vertical obstruction 3m</td>
<td>1.30 (0.37)</td>
<td>1.13 (0.43)</td>
<td>-0.75</td>
</tr>
<tr>
<td>Vertical obstruction 5m</td>
<td>1.03 (0.27)</td>
<td>1.25 (0.75)</td>
<td>0.63</td>
</tr>
<tr>
<td>Litter depth (mm)</td>
<td>9.40 (2.99)</td>
<td>4.66 (3.80)</td>
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</table>

<table>
<thead>
<tr>
<th>Percent ground cover</th>
<th>Fledged (SD)</th>
<th>Failed (SD)</th>
<th>Z</th>
<th>p</th>
<th>Fledged (SD)</th>
<th>Failed (SD)</th>
<th>Z</th>
<th>p</th>
<th>Fledged (SD)</th>
<th>Failed (SD)</th>
<th>Z</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bareground</td>
<td>6.70 (1.98)</td>
<td>9.09 (6.63)</td>
<td>0.0</td>
<td>1.0</td>
<td>11.30 (6.72)</td>
<td>18.20 (13.48)</td>
<td>-1.27</td>
<td>0.20</td>
<td>19.38 (14.67)</td>
<td>7.54 (6.72)</td>
<td>-1.65</td>
<td>0.09</td>
</tr>
<tr>
<td>Cactus</td>
<td>0.00 (4.59)</td>
<td>7.00 (2.47)</td>
<td>-1.25</td>
<td>0.21</td>
<td>13.53 (6.50)</td>
<td>15.08 (8.76)</td>
<td>-0.09</td>
<td>0.93</td>
<td>14.69 (5.59)</td>
<td>11.27 (8.08)</td>
<td>-1.28</td>
<td>0.20</td>
</tr>
<tr>
<td>Forb</td>
<td>10.00 (2.47)</td>
<td>7.00 (2.47)</td>
<td>-1.25</td>
<td>0.21</td>
<td>13.53 (6.50)</td>
<td>15.08 (8.76)</td>
<td>-0.09</td>
<td>0.93</td>
<td>14.69 (5.59)</td>
<td>11.27 (8.08)</td>
<td>-1.28</td>
<td>0.20</td>
</tr>
<tr>
<td>Grass</td>
<td>61.35 (16.33)</td>
<td>53.70 (18.05)</td>
<td>-0.74</td>
<td>0.46</td>
<td>53.44 (10.66)</td>
<td>72.14 (17.94)</td>
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<td>0.07</td>
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<td></td>
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<tr>
<td>Green</td>
<td>65.25 (14.80)</td>
<td>61.99 (16.83)</td>
<td>-0.76</td>
<td>0.45</td>
<td>60.00 (12.08)</td>
<td>61.34 (15.46)</td>
<td>-0.32</td>
<td>0.75</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sedge</td>
<td>7.55 (16.74)</td>
<td>2.38 (5.08)</td>
<td>0.17</td>
<td>0.86</td>
<td>0.17 (3.33)</td>
<td>1.91 (3.33)</td>
<td>-1.17</td>
<td>0.23</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shrub</td>
<td>1400 (25.81)</td>
<td>9.28 (12.84)</td>
<td>-0.07</td>
<td>0.94</td>
<td>14.33 (14.47)</td>
<td>9.44 (16.53)</td>
<td>-1.05</td>
<td>0.29</td>
<td>10.31 (18.21)</td>
<td>5.91 (13.25)</td>
<td>-0.76</td>
<td>0.45</td>
</tr>
</tbody>
</table>
Figure 10. Means and standard errors for grass height (cm), vertical obstruction (cm), and litter depth (mm) at Grasshopper Sparrow nests. High standard error negated differences between failed and fledged nests. Error at fledged nest sites was due to small sample size (=5).
Figure 11. Means and standard errors for grass height (cm), vertical obstruction (cm), and litter depth (mm) at Vesper Sparrow nests. High standard error negated differences between failed and fledged nests. Error at fledged nest sites was due to small sample size (n = 8).
Figure 12. Means and standard errors for grass height (cm), vertical obstruction (cm), and litter depth (mm) at Western Meadowlark nests. High standard error negated differences between failed and fledged nests. The higher error at fledged nest sites was due to small sample size ( = 4).
Table 8. Nest fates separated by location and treatment (B = burned, N = Non-burned, G = Grazed, U = Ungrazed). Nest numbers are too low for any effect of location and treatment to be apparent.

<table>
<thead>
<tr>
<th>Plot</th>
<th>Abandoned</th>
<th>Depredated</th>
<th>Observer</th>
<th>Fledged</th>
<th>Total</th>
</tr>
</thead>
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Discussion

Nest numbers appear to be low in comparison to numbers in other studies. The low number of nests may be caused by several factors. Our ability to search for nests continually throughout the day was impeded by the distance between nest plots, time spent monitoring nests far from roads, time spent on bird surveys, and our small field crew. While I spent 8.5 search hours per nest in the nest plots, a field crew in north-central Montana spent approximately 2.9 search hours per nest and found ≥ 300 nests (864 hours / 300 nests in 1998 and 1024 hours / 358 nests in 1999) (Logan 2001). An 8-person nest-searching crew in a Wisconsin tallgrass prairie found only 60 nests of several ground and shrub nesting species and spent approximately four person hours per nest (N. VanLanen, personal communication). Size of the search plot and nest densities also can affect the number of nests found.

Nest site characteristics at my study site were comparable to what was reported in other studies. Grasshopper Sparrows use more litter and require higher residual and living grass cover than other species in mixed-grass prairie. Vesper Sparrows use bare patches of ground within their territories and use a clump of vegetation for nest concealment (Rodenhouse and Best 1983). They often have lower residual and green cover relative to Western Meadowlark nests (Logan 2001). Western Meadowlark can have higher forb and shrub cover at their nests (Logan 2001), but Grasshopper Sparrow had higher shrub cover in my study. Vegetation at the nest (0m) was often more dense and taller than vegetation further from the nest. Vegetation > 1m from the nest can be more variable than vegetation at the nest (Logan 2001).
Differences between nest sites and random sites were seldom significant although most vegetation variables were higher at nest sites, but standard errors were high and differences might have been apparent with larger sample sizes. Greater than 35 samples per species are necessary to find significant differences ($\alpha = 0.05$) in used and unused habitat (Morrison 1984) and Johnson (1981) suggested that $> 20$ samples plus five samples for every variable considered. Only 19 Western Meadowlark nests and 13 Grasshopper Sparrow nests were used in analysis so interpretation of the results for these species must be conducted with caution.

Even with greater sample sizes and smaller standard errors, differences between nest sites and random sites could be minimal. Species could be choosing nest sites that are similar to available habitat in order to reduce predation. Territories with high vegetative density and diversity have higher numbers of potential nest sites, and therefore more areas that predators must search (Martin and Roper 1988, Martin 1993). The species in this study could have chosen nest sites within territories with high vegetative diversity, but the advantages of such selection are not apparent considering the low nesting success of all species.

Bird species may also decrease predation rates by selecting nest site features that are different from those of other species because predators may develop a search image for nests with certain characteristics and ignore nests without these characteristics (Martin 1996). However, vegetation differed little between the three bird species although they have been noted in other studies to prefer different nest site characteristics. Low vegetation density and diversity can contribute to low dissimilarity and perhaps nesting success. A study of grazing effects in mixed-grass prairie showed that nests in
grazed areas were more similar to each than in ungrazed areas (Logan 2001). Nest success was also lower in grazed areas (Logan 2001). As similarity between species increases, apparent density of nest sites increases, thereby increasing the chance that a predator will find a nest (Martin 1996). Fire and cattle grazing can reduce vegetative diversity and density (Vinton and Collins 1997) and potentially increase the similarity in nest sites between species. Decreases in vegetative diversity could force bird species to use similar nest sites or nest sites of poor quality, thereby decreasing nesting success (Martin 1993).

Nesting success of Grasshopper and Vesper Sparrows was low but was similar to nesting success in other studies that consider the effects of habitat change and fragmentation. Apparent success of Grasshopper Sparrow was 25% in Maine (Vickery et al. 1992), 52% in fragmented Nebraska tallgrass prairie (Delisle and Savidge 1996), and < 20% on undisturbed and less than < 10% in disturbed tallgrass prairie in Oklahoma (Rohrbaugh et al. 1999). Overall probability of nest success was 22% in fragmented Missouri tallgrass prairie (Winter and Faaborg 1999) and 30% in CRP fields (Patterson and Best 1996). Apparent nest success was low for Vesper Sparrows on reclaimed mines with only 38% of nests fledging (Wray and Whitmore 1979). On mixed-grass prairie, overall nesting success for Vesper Sparrows ranged from 22 to 41%, with the lowest success rate on grazed mixed-grass prairie (Logan 2001). Most of the nests in these studies were depredated as in my study.

Nest success of Western Meadowlark was usually lower than estimates in other studies. Estimates of nest success ranged from 7.0% and 44.4% in mixed-grass prairie (Logan 2001) and was approximately 23-24% in western Montana (Fondell 1997).
Western Meadowlark nest success in this study was also lower than that of Eastern Meadowlark, a similar species. Overall nest success of Eastern Meadowlark was 19.5% in fragmented tallgrass prairie (Winter and Faaborg 1999) and apparent success was < 20% on undisturbed and less than < 10% in disturbed tallgrass prairie (Rohrbaugh et al. 1999).

The low nest success of the three species in my study suggests that disturbance may influence predation. However, vegetation differed little between fledged and failed nests such that vegetation and disturbance may not have had direct impacts on nest predation rates. Predation is a main cause of nest failure for grassland birds and it may be incidental and density-independent (Wray at al. 1982, Zimmerman 1988, Vickery et al. 1992). If this is the case, nest concealment and nest site partitioning among species is unimportant in reducing predation risk (Holway 1991). In fact, predation is not correlated with vegetation variables in many studies of nesting success (Best 1978, Wray et al. 1982, Zimmerman 1984, Holway 1991, Filliater et al. 1994, Howlett and Stutchbury 1996, Braden 1999, Ricketts and Ritchison 2000). Wray et al. (1982) suggested that incidental predation was high for Grasshopper Sparrow although nests of this species appeared to be better concealed than Vesper Sparrow nests. Similarly, I found through data analysis and personal observations that Grasshopper Sparrow and Western Meadowlark nest were concealed by more vegetation than Vesper Sparrow nests, yet they suffered high predation rates.

There are several reasons why nest site vegetation does not appear to lower predation. Low sample size can prevent differences in nest sites to be revealed (Howard et al. 2001). Only four Grasshopper Sparrow nests and five Western Meadowlark nests
fledged and standard errors for the mean vegetation variables at these nest sites were high. Measurement of the wrong vegetation variables also can lead to the conclusion that no difference exists between successful and depredated nests (Schmidt and Whelan 1999).

Stochastic predation and variation in predator abundance could be a reason vegetation does not contribute to lower predation rates (Holway 1991). A diverse predator base could prevent bird species from evolving specific nest site features (Filliater et al. 1994, Ricketts and Ritchison 2000), and traits that prevent predation by one predator species may not deter others. Wray et al. (1982) concluded that Grasshopper Sparrow suffered more losses for predation than Vesper Sparrows because of opportunistic predators such as snakes negated nest site differences. I observed many snakes, small mammals, and raptors in the nest plots and observed snakes eating eggs on two occasions. The diverse predator taxa and high observations of predators could indicate that vegetation could not deter predation but without more observations of predation, it is difficult to determine how these predators affected nest site selection. Factors outside of the nest site or nest patch may also influence nest predation (Wray et al. 1982, Braden 1999). Winter and Faaborg (1999) suggested that higher predator abundance in forest edges increased nest failure for Dickcissels in prairie fragments although the prairies appeared to appropriate for the species. Influences beyond the grazed pastures in this study are unknown.

Despite the high numbers of Grasshopper Sparrow, Vesper Sparrow, and Western Meadowlark during 2001 and 2002 surveys, nesting success for these species was low. The low reproductive rates of these species emphasize the need for demographic data.
when determining the effects of habitat change and disturbance on grassland birds. As indicated by Van Horne (1983) and Mauer (1986), high density or numbers of individuals does not always indicate that reproductive success is high. Grassland birds continue to use this habitat although it is heavily grazed, may provide less diverse vegetation structure for nest sites. Altered landscapes may expose grassland birds to risks they have not coped with before (i.e. high incidental predation; Wray et al. 1982, Winter and Faaborg 1999). Determining the effects of habitat change and degradation on population numbers and species presence is not sufficient to understanding the impacts on reproductive success.


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