Management and Conservation Article

Occupancy of Mountain Plover and Burrowing Owl in Colorado

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ABSTRACT Concern over the decline of grassland birds has spurred efforts to increase understanding of grassland bird–habitat relationships. Previous studies have suggested that black-tailed prairie dogs (*Cynomys ludovicianus*) provide important habitat for shortgrass prairie avifauna, such as mountain plover (*Charadrius montanus*) and western burrowing owl (*Athene cunicularia hypugaea*), although such studies are lacking in Colorado (USA). We used methods to estimate occupancy (ψ) of mountain plover and burrowing owl on prairie dog colonies and other shortgrass prairie habitats in eastern Colorado. Mountain plover occupancy was higher on prairie dog colonies ($\psi = 0.50$, 95% CI = 0.36–0.64) than on grassland ($\psi = 0.07$, 95% CI = 0.03–0.15) and dryland agriculture ($\psi = 0.13$, 95% CI = 0.07–0.23). Burrowing owl occupancy was higher on active prairie dog colonies ($\psi = 0.80$, 95% CI = 0.66–0.89) compared with inactive colonies ($\psi = 0.23$, 95% CI = 0.07–0.53), which in turn was much higher than on grassland ($\psi = 0.01$, 95% CI = 0.00–0.07) and dryland agriculture ($\psi = 0.00$, 95% CI = 0.00–0.00). Mountain plover occupancy also was positively correlated with increasing amounts of prairie dog colony in the landscape. Burrowing owl occupancy was negatively correlated with increasing amounts of prairie dog colony in the surrounding landscape. Our results suggest that actions to conserve mountain plovers and burrowing owls should incorporate land management to benefit prairie dogs. Because managing for specific colony attributes is difficult, alternative management that promotes heterogeneity may ensure that suitable habitat is available for the guild of grassland inhabitants. (JOURNAL OF WILDLIFE MANAGEMENT 72(4):1001–1006; 2008)

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Grassland birds have exhibited steeper, more consistent, and more widespread declines than any other avian guild in North America (Knopf 1994, Brennan and Kuvlesky 2005). These declines are likely because of the anthropogenic transformation of grassland ecosystems within the last 2 centuries. Native grasslands have been altered to a greater extent than any other biome in North America, resulting in the conversion of the once-diverse prairie landscape into a collection of homogenous grassland fragments interspersed with agricultural fields (Samson et al. 2004, Smith and Lomolino 2004, Brennan and Kuvlesky 2005). Part of this alteration has been caused by the attempted eradication of the black-tailed prairie dog (*Cynomys ludovicianus*; hereafter prairie dog).

Prairie dogs create large areas of grazed vegetation, bare soil, and burrows—essential components of breeding habitat for grassland birds such as mountain plover (*Charadrius montanus*; Knopf and Wunder 2006) and western burrowing owl (*Athene cunicularia hypugaea*; Dechant et al. 2003). In Montana (USA), mountain plovers are strongly associated with prairie dog colonies (Knowles et al. 1982, Dinsmore et al. 2005). Elsewhere, this relationship is not yet well understood (Dreitz et al. 2005, Knopf and Wunder 2006). Similarly, studies have suggested higher burrowing owl counts on prairie dog colonies than other habitats (Barko et al. 1999, VerCauteren et al. 2001, Smith and Lomolino 2004). Burrowing owls also are highly associated with active prairie dog colonies compared with inactive colonies (Desmond et al. 2000, Sidle et al. 2001).

Methodologies widely used to estimate grassland bird population parameters have lacked ≥ 1 of 2 important considerations—a probability-based sampling scheme and incorporation of detection probability into parameter estimates (Williams et al. 2002). Previous surveys of grassland birds have used a convenience sampling scheme by collecting data along roads or trails (e.g., Conway and Simon 2003, Sauer et al. 2003). Such approaches have limited value because evaluating bias of such estimates is difficult, and problems arise when extrapolating these estimates to larger areas of interest. Bias also arises from failure to detect occupied sampling units and the subsequent failure to adjust the count statistic accordingly (Williams et al. 2002).

Our objective was to address these 2 considerations by applying the occupancy methods of MacKenzie et al. (2002, 2006) over a large area, the shortgrass prairie in eastern Colorado, to increase our understanding of grassland bird ecology. Specifically, we tested hypotheses concerning variation in occupancy and detection of mountain plover and burrowing owl across 3 shortgrass prairie habitat strata: prairie dog colonies, native grassland not occupied by prairie dogs (hereafter, grassland), and dryland agriculture. Our habitat-association measures included our habitat strata at our sampling plot and surrounding landscape at multiple spatial scales. We hypothesized that mountain plover occupancy would be similar on prairie dog colony and dryland agriculture

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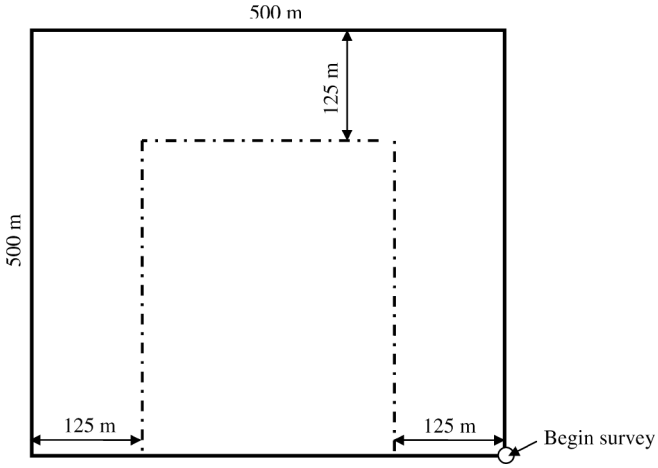

Figure 1. Diagram of transect walked by observers during occupancy surveys of mountain plover and burrowing owl conducted on randomly selected 500-m × 500-m plots in eastern Colorado, USA, in 2005.

plots and that both would be much higher than occupancy on grassland plots. For burrowing owl, we hypothesized that occupancy would be higher on active prairie dog colony plots than on inactive plots and that both would be much higher than occupancy on grassland or dryland agricultural plots. Based on species' breeding ecologies and habitat preferences as suggested from previous research (Dechant et al. 2003, Dreitz et al. 2005, Hamer et al. 2006), we hypothesized that increasing amounts of prairie dog colony and grassland in the landscape would have a positive effect on occupancy probabilities for both species.

STUDY AREA

Our study area was located in eastern Colorado, USA, on private and public lands approximately 48 km east of Interstate 25 (to exclude urban and exurban areas) and encompassed approximately 81,200 km^2 in 20 counties. Within the study area, approximately 48.8% was characterized as native shortgrass, 21.7% as dryland agriculture, and 2.3% as prairie dog colony. The remaining 27.2% was primarily characterized as native shrubland, wetland, irrigated agriculture, or Conservation Reserve Program lands. Native shortgrass was primarily vegetated by low-growing, perennial grasses, such as buffalograss (*Buchloe dactyloides*) and blue grama (*Bouteloua gracilis*), and was grazed to varying degrees. Dryland agriculture fields were either fallow or unirrigated crops, such as wheat and millet.

METHODS

Sampling Design

We determined land cover types using available data as described by Tipton (2007). The sampling frame consisted of 500-m × 500-m (25-ha) grid cells categorized as prairie dog colony, grassland, or dryland agriculture. We based plot size on the minimum mountain plover brood-rearing territory (28 ha; Knopf and Rupert 1996), which is considerably larger than burrowing owl nesting territory (4–6 ha; Dechant et al. 2003).

For each stratum, we chose sample plots from the sampling frame using a spatially balanced sampling design (SBS) using the SBS tool in ArcGIS 9.0 (Stevens and Olson 2004, Theobald 2004, Theobald et al. 2007). The SBS design maximized spatial coverage of sample plots and mimicked spatial patterns of our selected land cover layers: prairie dog, grassland, and dryland agriculture. The SBS design also avoids the potential problem of coinciding with an underlying periodicity in the response variables that is inherent in a systematic sampling design. In addition, SBS can result in more precise estimates.

We selected plots using equal sample allocation (i.e., our 3 strata received equal survey effort regardless of the area of each stratum within the study area) to ensure sufficient sample sizes to test habitat-related hypotheses. We based sample-size calculations on data from a 2004 pilot study using optimization methods described by MacKenzie and Royle (2005; H. C. Tipton, Colorado State University, unpublished data). Although we intended to survey approximately 134 plots in each stratum, we initially selected more than this (e.g., 268 grassland plots) to account for plots that could not be surveyed because of nonresponse issues, such as incorrect strata or inability to obtain access. For plots where we obtained access, we based final plot selection on qualitative habitat assessments determined in the field. Our strata criteria were as follows: 1) grassland and dryland agricultural plots had 100% coverage of the appropriate cover type, and 2) prairie dog colony plots had ≥25% coverage by an active or inactive prairie dog colony. We classified colony activity status based on site observations of prairie dogs or prairie dog sign (e.g., fresh scat). Because we were primarily interested in the effect of habitat provided by prairie dogs, we only surveyed plots with inactive colonies (i.e., no evidence of prairie dogs) if aboveground conditions were not visibly different from those of active colonies (e.g., short vegetation, moderate amounts of bare ground, and relatively intact, clean burrows). Plot boundaries could go up to, but not overlap, major roads to allow for safety considerations.

Field Data Collection

We conducted up to 4 occupancy surveys of each plot: 1 May to 16 May, 17 May to 6 June, 7 June to 16 June, and 17 June to 30 June in 2005. Although we could not survey some plots all 4 times because of logistical constraints, the model we used in our analysis accommodates unequal numbers of surveys (MacKenzie et al. 2006). Because phenology of avian breeding activity is believed to begin earlier at lower latitudes, we surveyed plots from south to north during each survey period. We conducted morning and evening surveys primarily between sunrise and 1100 hours and between 1830 hours and sunset, respectively. We generally did not conduct surveys under unacceptable weather conditions, which included temperatures >27° C, wind speeds >6.0 m per second, and fog or precipitation that reduced visibility to <125 m.

We conducted surveys of each plot using 1 or 2 individuals who walked a transect such that the observer(s) was ≤125 m from any location in the study plot (Fig. 1), an assumed

maximum distance for positive species identification. We recorded all observations of mountain plovers and burrowing owls within the plot boundary. We recorded auditory-only observations when the species was thought to be well within plot boundaries (5.7% of observations). Surveys lasted 20–50 minutes. At the beginning and end of each survey, we recorded time and weather conditions with a digital temperature and wind meter.

Covariate Data Collection

We recorded prairie dog colony activity status (active or inactive) within the plot during each survey using the aforementioned criteria. We used digital aerial photography taken during the field season to identify prairie dog colonies within 2,250 m of surveyed plot boundaries (Tipton 2007). We digitized these data and combined the resulting prairie dog colony layer with existing land cover data to obtain 6 landscape-level variables representing percentage of cover by prairie dog colony and grassland at 3 spatial scales: a plot plus its 500-m, 1,500-m, or 2,250-m buffer, hereafter called landscape 1 (203.48 ha), landscape 2 (1,031.35 ha), and landscape 3 (2,064.30 ha), respectively (Tipton 2007). Buffer distances we targeted were 10×, 50×, and 100× the plot size. However, because of the raster cell size of our land-cover layers in ArcGIS, our buffer distances reduced to approximately 8×, 41×, and 82× the plot size.

Model Set and Selection

We modeled detection (p) and occupancy (ψ) probabilities using individual covariates representing visit-specific or habitat effects. For all variables of interest, we examined both variance and correlations with other variables. We excluded one of each pair of highly-correlated variables ($R > 0.40$, Tipton 2007).

We modeled p as either constant or as a function of survey period (time), selected visit-specific covariates (day, average temp, average wind speed, no. of observers), plot stratum, or an additive or multiplicative combination of these variables. Because of the large numbers of observers relative to number of detections per species, we were unable to investigate individual observer effect on detection probability. We modeled ψ as either constant or as a function of survey period, selected plot- and landscape-level covariates, or an additive or multiplicative combination of these variables, with the exception that only one landscape-scale covariate (described above) could be included in a model. Plot-level variables consisted of stratum, plot northing, and, for prairie dog colony plots, prairie dog activity status and amount of prairie dog colony inside plot boundaries. We did not examine the effect of prairie dog activity status on mountain plover occupancy because our definition of inactive status included above-ground burrow characteristics and vegetation height that did not differ from active colonies. Burrows may have been filled when inactive, potentially influencing occupancy of owls. However, plovers do not use burrows for nesting. Although there may be some behavioral response in why plovers chose to breed on an active or inactive prairie dog colony, our interest was in examination of habitat provided by prairie dogs.

We estimated plot-level detection (p) and occupancy (ψ) probabilities using Program MARK (White and Burnham 1999). Before running the models, we tested for goodness of fit using a parametric bootstrap (MacKenzie and Bailey 2004). When running candidate model sets, we used Akaike's Information Criterion adjusted for small sample size (AIC_c) to rank models (Burnham and Anderson 2002). We considered models with ΔAIC_c values (the difference in AIC_c units from the highest-ranking model) ≤ 2 to have strong support. In addition, we computed cumulative AIC_c weights ($0 \leq \Sigma\, w_i \leq 1$), or importance values, to evaluate strength of evidence for each occupancy-modeled covariate.

RESULTS

We surveyed 282 plots, consisting of 90 in prairie dog colonies, 100 in grasslands, and 92 in dryland agriculture. Approximately 92% of surveyed plots were located on privately owned land for which we obtained access from approximately 450 owners and lessees. We detected mountain plovers on 59 plots: 40 prairie dog colony plots, 7 grassland plots, and 12 dryland agriculture plots. We detected burrowing owls on 59 plots: 58 prairie dog colony plots, one grassland plot, and zero dryland agriculture plots. Because of low numbers of burrowing owl detections on grassland and agriculture plots, models in which p varied by stratum were not possible. Goodness-of-fit simulations provided no evidence of overdispersion.

Mountain Plover

Models in which p was modeled as constant (·) consistently ranked higher than models where p was allowed to vary by any effect ($\hat{p} = 0.43$, 95% CI = 0.36–0.51 from top model). Models incorporating stratum, proportion of landscape 1 covered by prairie dog colony, and proportion of landscape 3 covered by grassland into ψ estimates consistently ranked high ($\Delta AIC_c < 2.50$). These 3 covariates had the highest cumulative AIC_c weights (Table 1). In addition, modeling a stratum-specific effect of amount of grassland in landscape 3 on ψ was always selected over models assuming an additive effect.

Mountain plover occupancy was higher on prairie dog colony plots ($\psi = 0.50$, 95% CI = 0.36–0.64) than on grassland ($\psi = 0.07$, 95% CI = 0.03–0.15) or dryland agriculture plots ($\psi = 0.13$, 95% CI = 0.07–0.23; Fig. 2). The covariate point estimate ($\hat{\beta}$) from the top model ($p{\cdot}\psi_{stratum \times grass_landscape3 + pd_landscape1}$) suggested a positive relationship ($\hat{\beta} = 3.89$, 95% CI = 1.32–6.46) between mountain plover occupancy and amount of prairie dog colony in landscape 1, regardless of plot stratum. However, the effect of amount of grassland in landscape 3 on mountain plover occupancy varied by stratum, showing a positive effect for prairie dog colony ($\hat{\beta} = 4.25$, 95% CI = 1.20–7.30) and dryland agriculture plots ($\hat{\beta} = 2.73$, 95% CI = −0.81 to 6.26) and some evidence for a negative effect for grassland plots ($\hat{\beta} = -2.35$, 95% CI = −7.13 to 2.42).

Table 1. Cumulative Akaike's Information Criterion weights ($\Sigma\ w_i$) of occupancy (ψ) model parameters for mountain plover and burrowing owl in eastern Colorado in 2005.

	$\Sigma\ w_i$	
Model parameter[a]	Mountain plover	Burrowing owl
$\psi_{stratum}$	1.00	1.00
$\psi_{northing}$	0.00	NA
$\psi_{pd_activity}$	NA	1.00
ψ_{pd_plot}	0.00	0.00
$\psi_{pd_landscape1}$	0.80	0.27
$\psi_{pd_landscape2}$	0.19	0.34
$\psi_{pd_landscape3}$	0.00	0.36
$\psi_{grass_landscape1}$	0.00	0.09
$\psi_{grass_landscape2}$	0.10	0.11
$\psi_{grass_landscape3}$	0.87	0.18

[a] We defined model parameters as follows: *stratum* = categorical designation of plot stratum (prairie dog colony, grassland, or dryland agriculture); *northing* = latitude of plot center as represented by North American Datum 1927, Universal Transverse Mercator Zone 13 North; *pd_activity* = indicator variable representing prairie dog activity within a plot (1 = active, 0 = inactive or not applicable if grassland or dryland agriculture); *pd_plot* = proportion of plot occupied by prairie dog colony; *pd_landscape* = proportion of landscape (1, 2, or 3) occupied by prairie dog colony; *grass_landscape* = proportion of landscape (1, 2, or 3) occupied by grassland; NA = not applicable.

Burrowing Owl

Similar to our mountain plover results, models in which p was modeled as constant for burrowing owl ranked higher than models where we allowed p to vary by any effect ($\hat{p} = 0.55$, 95% CI = 0.47–0.62 from top model). Models incorporating stratum, presence of active prairie dogs on the plot, and proportion of prairie dog colony in surrounding landscapes (at all scales) into ψ estimates consistently ranked high ($\Delta AIC_c \leq 3.00$). Both stratum and prairie dog activity model parameters had cumulative AIC_c weights of 1.00 (Table 1). Among prairie dog colony landscape variables, models incorporating landscape 3 were always selected over models with an effect of landscape 1 or landscape 2. Cumulative AIC_c weights also support this relationship (Table 1).

Burrowing owl occupancy was higher on active prairie dog colony plots ($\psi = 0.80$, 95% CI = 0.66–0.89) compared with inactive plots ($\psi = 0.23$, 95% CI = 0.07–0.53), which in turn was much higher than on grassland ($\psi = 0.01$, 95% CI = 0.00–0.07) or dryland agriculture plots ($\psi = 0.00$, 95% CI = 0.00–0.00; Fig. 2). The $\hat{\beta}$ from the top model ($p \cdot \psi_{stratum+pd_activity+pd_landscape3}$) also suggested a positive relationship ($\hat{\beta} = 2.59$, 95% CI = 1.07–4.12) between burrowing owl occupancy and activity status of the prairie dog colony. However, amount of area covered by prairie dog colony in the surrounding landscape (at all scales) had a negative effect ($\hat{\beta} = -5.18$, 95% CI = −9.37 to −0.99 from top model) on burrowing owl occupancy, regardless of plot stratum.

DISCUSSION

Our results suggest that occupancy methods are feasible to monitor and address biological questions on mountain plovers and burrowing owls over large areas (MacKenzie et al. 2006). Results of numerous studies indicate that detection probability is usually <1 (Williams et al. 2002). Our study supports this assertion for mountain plovers and burrowing owls. Incorporation of methodologies that estimate detection probabilities is essential for monitoring programs, and our estimated stratum-specific detection and occupancy probabilities (further details in Tipton 2007) can be used to optimize future occupancy study designs.

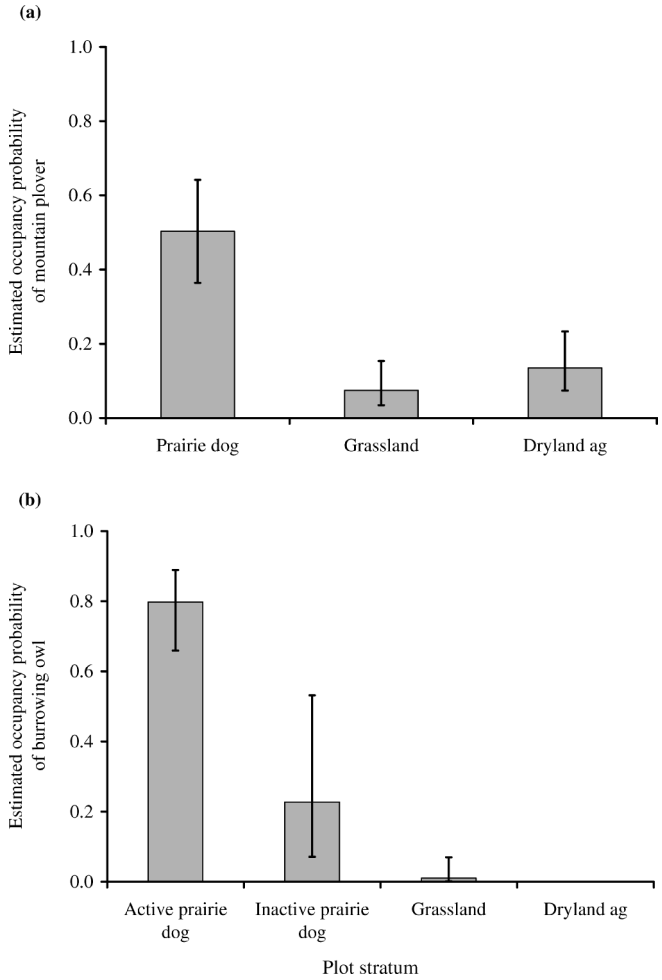

Figure 2. Estimated stratum-specific occupancy probabilities (ψ) for (a) mountain plover, and (b) burrowing owl in eastern Colorado in 2005. Estimates with 95% confidence intervals are shown for 3 plot strata: prairie dog colony, grasslands, and dryland agriculture (dryland ag). When modeling burrowing owl occupancy, we further characterized prairie dog colony plots as active or inactive. We calculated occupancy estimates under the highest-ranking model for each species (mountain plover: $p \cdot \psi_{stratum.\times grass_landscape3+pd_landscape1}$, burrowing owl: $p \cdot \psi_{stratum+pd_activity+pd_landscape3}$) using stratum-specific means for individual covariates.

Effects on Occupancy Probabilities

Plot-level effects.—Plot stratum had the most important effect on ψ for both species, with prairie dog plots being most highly occupied and the other strata occupied to lesser degrees. Our results correspond to those of Winter et al. (2003) for both species, and other studies have found similar results for burrowing owls (Barko et al. 1999, Smith and Lomolino 2004). In contrast, Barko et al. (1999) only found mountain plover on uncolonized shortgrass; however, sample size was small (n = 10 sites).

Burrowing owl occupancy probability showed a strong association with active colonies (approx. 82% of surveyed prairie dog colony plots) as also found by Desmond et al. (2000) and Sidle et al. (2001).

Our study was a single-year study, and we could not investigate effects of changing habitat conditions that would result from annual differences in precipitation and temperatures. In years with little precipitation and high temperatures, differences in vegetation height and cover will be less across all habitat types; in wetter, cooler years, the opposite is likely. Vegetative differences between colonized and uncolonized areas may be much greater in wet than in dry years (Barko et al. 1999, Winter et al. 2003). During our study, weather conditions were considered wet and cool, which resulted in increased vegetation height and cover in grassland and taller wheat in dryland agriculture fields. Under such conditions, prairie dog colony habitat may become more important to species such as the mountain plover that prefer low grass height and bare ground.

Landscape-level effects.—Our results indicate that among landscape variables, habitat characteristics at our largest spatial scale (landscape 3) had the greatest effect on occupancy probabilities. A mechanistic explanation for the importance of landscape habitat variables supports that species' habitat selection is often constrained by broadscale requirements, which act as a filter for local habitat requirements (Hamer et al. 2006).

The relationship between occupancy and large-scale habitat characteristics, as well as the magnitude of the effect, is related to species' breeding ecology and habitat preferences. Mountain plover occupancy was closely tied to plot stratum and amount of prairie dog colony in the immediate surrounding landscape (landscape 1), the area of which corresponds closely with average plover brood-rearing home-range size as observed by Dreitz et al. (2005), which ranged from 146.1 ha (± 101.5 SE) to 243.3 ha (± 366.3 SE). Occupancy probability also was affected by amount of grassland habitat at the largest spatial scale, although direction and magnitude of the effect differed with plot stratum. This stratum-specific response may be indicative of species that use one habitat type for nesting and another for brood rearing. Previous studies suggest such a relationship may exist for mountain plovers (Knopf and Rupert 1996), although this movement pattern was not observed in a recent study (Dreitz et al. 2005).

In addition to the effect of plot-level variables, burrowing owl occupancy was also negatively affected by amount of prairie dog colony in the surrounding landscape. Although this result may seem counterintuitive, the negative association at larger spatial scales may indicate a need for habitat heterogeneity, reflecting greater prey availability, effective over the large areas used for foraging (35–241 ha in southern Saskatchewan; Haug and Oliphant 1990, Orth and Kennedy 2001, Sissons et al. 2001).

For both species, landscape-level features were important in determining patterns of occupancy. If landscape factors are not considered, apparent avian–habitat relationships may be confounded by potential effects of differences in the landscapes surrounding plots (Rotenberry and Knick 1999). Little information exists on effects of landscape factors on shortgrass prairie avifauna, as most grassland bird studies examining avian–landscape associations have been conducted in mixed-grass and tallgrass prairies. Future studies investigating shortgrass prairie avifauna–habitat associations should include effects of patch size and shape and habitat arrangement within the landscape. In addition, our results are specific to the landscape sizes used in this analysis, and if different buffer distances are used, effects of landscape-scale features on plover or owl occupancy may vary from those we presented.

Limitations on Inference

Inference of our study results is limited by the proportion of plots that we could not include in our sampling frame. For example, of the 268 grassland plots we initially selected, we were not able to reach landowners of 113 plots and were denied access by another 34, which suggests we can only make inference to approximately 45% of our grassland habitat. This problem was accentuated because most of eastern Colorado is in private ownership, with little public land. The limited inference could be lessened in future studies by increasing collaboration with landowners and lessees or by including incentives for landowners.

Closure is an important assumption when estimating occupancy (MacKenzie et al. 2006). If temporary immigration or emigration occurs during the survey season, occupancy will be overestimated. Based on our plot size, length of our survey season, and nesting biology of our study species, especially mountain plovers, the closure assumption may have been violated. If the assumption of closure was not met, a more appropriate interpretation of occupancy data is resource use (MacKenzie et al. 2006).

MANAGEMENT IMPLICATIONS

Our results suggest that prairie dogs provide suitable breeding habitat within the shortgrass prairie ecosystem for mountain plovers and burrowing owls. Based on occupancy results, initial avian conservation efforts that incorporate land management to benefit prairie dogs should be considered. Management actions should promote ecosystem processes that produce natural variation within native shortgrass. Restoring the land's natural heterogeneity ensures that suitable habitat is available for not only mountain plovers and burrowing owls but a variety of grassland inhabitants, despite fluctuations in prairie dog populations.

Because >80% of eastern Colorado is in private ownership, a study of this scope will, by necessity, work on private lands. Private lands provide important habitat for endangered and threatened species, and we must be able to work with landowners if our conservation efforts are to be successful. Although gaining permission and working on private lands is not effortless, our results suggest that this can be achieved and that methodologies similar to ours may be successfully applied in other areas.

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