Grass Begets Quail: A Population Assessment of Northern Bobwhite and Other Grassland Birds on Mesquite-managed Lands at Matador WMA

Final Report April 28, 2020

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March 2020

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Executive Summary

This study describes a habitat-focused sampling effort for northern bobwhite (bobwhite) and other grassland birds conducted at Matador Wildlife Management Area (Matador) in Texas Bird Conservation Region (BCR) 19. In the 2019 season, Playa Lakes Joint Venture (PLJV) partnered with Texas Parks and Wildlife Department (TPWD) staff to design a study to monitor the post-treatment efficacy of chemical removal efforts for mesquite conducted at Matador between 2003 and 2018. Using treatment delineation data collected by TPWD at Matador and ground-based vegetation and avian point count data collected in May of 2019, we evaluated the effects of treatment on bobwhite and on a grassland bird guild (Cassin's sparrow, dickcissel, grasshopper sparrow, lark sparrow), separately. We demonstrate: (1) that the grassland bird guild which co-occur with bobwhite strongly benefit from mesquite removal work done at Matador, and (2) that there is an ideal window of 5-10 years of elapsed time since treatment that the grassland bird guild responds to. We used data from the Rocky Mountain Avian Data Center to compare the bird communities found at Matador and within Texas BCR19. Densities at Matador appear to be higher with a greater number of grassland birds detected with high frequency.

We found that the chemical treatments that have been applied to reduce mesquite cover at Matador have had a positive effect on grassland bird habitat. On average, following chemical treatment at sites, herbaceous cover increases, bare-ground decreases, and vertical structure that leads to the exclusion of grassland birds is reduced for both mesquite trees and shrubs at the station scale (250 m X 250 m). Over post-treatment periods greater than 15 years, canopy height for shrubs and trees both advance sufficiently to lead to declines in carrying capacity for grassland birds, suggesting that managers should re-treat a site every 5-10 years, but not sooner. Neither the grassland bird guild nor bobwhite had a strong response to standing dead mesquite or juniper stems sampled at post-treatment sites. The grassland bird guild selected for a patchy mosaic of ground-cover, preferring sites with bare-ground intermixed with herbaceous cover at small spatial scales. The grassland bird guild appeared tolerant of low residual shrub cover at sites intermixed with other vegetation. However, as shrub cover, tree cover, and bare-ground increased and became dominant at the transect scale (1 km^2), the grassland bird guild was excluded. We were unable to detect any significant relationships of bobwhite density to vegetation variables, this was likely because bobwhite was ubiquitous across the transects we sampled at Matador in 2019. In comparison to the broader Texas BCR 19 region, grassland bird densities appear higher. We conclude that the treatments used to manage mesquite for bobwhite are successful in creating habitat to support high densities of bobwhite and other grassland birds.

Introduction

Bird Conservation Region (BCR) 19 is the central mixed-grass prairie ecoregion of the United States, which contains important habitat for game birds and a number of priority species. Over the course of the last century, grassland ecosystems in BCR 19 have experienced stark losses. Recent mapping efforts document that 70% of the central mixed-grass prairie has been lost (Comer et al. 2018, World Wildlife Fund 2016). Historically, the bulk of habitat loss has been due to agricultural conversion, particularly in mixed-grass prairie ecosystems in BCR 19. As a result of this conversion to agriculture grassland birds have declined (Murphy 2003, Brennan and Kuvlesky, Jr. 2005, Quinn et al. 2017, Veech 2006, Vickery et al. 1995). Habitat loss, combined with increased trends in urbanization and the expanded use of pesticides and a subsequent decline in insect populations, have dramatically increased the rate of decline of grassland birds in the central Great Plains over the last 30 years (Rosenberg et al. 2019). Bird conservation efforts in the south Great Plains are distinct from those in the central and northern Great Plains due to differences in land use stemming from drier climate conditions, less water for agricultural development, and an expanded footprint for energy development (summarized in Ojima et al. 2015).

In the semi-arid grasslands of the southern Great Plains, honey mesquite (mesquite, *Prosopis glandulosa*) encroachment has been of concern for over 130 years (Fredrickson et al. 2006). It is hypothesized that a combination of land-use change after European settlement and high-intensity cattle production starting in the late 19th century contributed to the expansion of mesquite woodlands where it was once a minor component of the landscape (Fredrickson et al. 2006). With continued shifts in agricultural land-use and climate change, we predict that mesquite encroachment will continue to play a significant role in grassland habitat fragmentation and decline in the future (Archer et al. 2017, Ojima et al. 2015, Sleeter et al. 2012). Rates of mesquite encroachment in the southern Great Plains range from 0.2 to 2.3 % per year (Barger et al. 2011). Targeting work done for grassland-obligate game birds, such as lesser prairie-chicken, suggests the species avoids areas where mesquite is a small component of the landscape (Hagen et al. 2019). We think that woody species encroachment, specifically by mesquite and eastern redcedar (*Juniperus virginiana*), is an important factor contributing to recent declines for other grassland species as well (Scholtz et al. 2017). Over the course of the 21st century, we expect shifts in agricultural practices and land use change in the Great Plains to further intensify woody species spread (Engle et. al. 2008, Sohl et al. 2019).

The National Bobwhite Conservation Initiative (National Bobwhite Technical Committee 2011) describes Northern bobwhite (bobwhite*,* scientific names for bird species can be found in Appendix A) status and conservation needs. Biologists working across BCR 19 have identified 51.9 million acres as having a high probability for successful bobwhite conservation (Terhune and Palmer 2011). The list of management actions recommended for bobwhite includes prescribed fire, management of agricultural field borders, brush management, and grassland restoration. Given the rate of woody encroachment in BCR 19, management of these woody invasives has become a focal point for conservation. Though a suite of restoration practices to reduce woody species cover and restore native prairie habitat has been developed, few studies have demonstrated the population response by bobwhite and other grassland birds.

The multi-year tracking of chemical removal of mesquite done at Matador Wildlife Management Area (Matador) represents an opportunity to evaluate bobwhite and grassland bird response to management of mesquite over a 15 year time period. We anticipate these results will have important management implications beyond the extent of Matador.

Objectives

In this study, we explore three objectives related to grassland habitat conditions and bird abundance in the landscape in and around Matador:

1. Do grassland birds co-occur with bobwhite and do they benefit from grassland habitat restoration work conducted for bobwhite?
2. Is there an optimal treatment return interval for treatment to benefit grassland birds that can inform habitat work at Matador?
3. Is there a difference in the abundance of grassland birds at Matador compared to other landscapes sampled in Texas BCR 19?

Methods

Study Site Description and Sample Design

Matador Wildlife Management Area is located in north-central Texas (Figure 1). Major vegetation communities include shinnery oak (*Quercus havardii*) prairies, mixed shrubland of redberry juniper (*Juniperus coahuilensis*) and mesquite and invasive mesquite shrublands. Managers at Matador have been managing to improve habitat for bobwhite for 15 years through chemical treatment to kill mesquite and convert the land back to native prairie.

We designed the sampling stratification at Matador to allow comparisons between population densities of grassland birds across treatment levels. We allocated 20 1 km^2 sample grids (transects) across three treatment levels based on time since chemical treatment: (1) 1-5 years since treatment, (2) 5-10 years since treatment, and (3) 10-15 years since treatment (Table 1, Figure 2). We then used generalized random tessellation stratification (GRTS, Stevens & Olsen 2004) to randomly place bird and vegetation transects within treatment areas at Matador using the 1-km^2 US National Grid as a frame of reference (fgdc.gov/usng).

To compare densities of birds found at Matador to the Texas BCR 19 region, we queried the Rocky Mountain Avian Data Center and report densities extracted there for comparison. The grids included in this database are part of the broader Integrated Monitoring in Bird Conservation Regions (IMBCR) program in the Playa Lakes Joint Venture. In 2019, field crews sampled 18 grids in Texas BCR 19 across three strata playas, rivers, and all other lands. Because each 1 km^2 grid could include grassland and for purposes of sample size, we used all 18 grids in our ocular comparison. Densities and estimated population size values from the Rocky Mountain Avian Data Center are presented with a % Coefficient of Variation as an error estimate. As a general rule of thumb, a value <50% indicates high confidence in the calculated values.

Grassland Bird Data Collection

To sample birds at Matador, we used the Integrated Monitoring in Bird Conservation Regions protocol for data collection (Pavlacky et al. 2017). IMBCR transects were arrayed within a 1 X 1 km grid cell (transect). Within a transect, technicians conducted point counts at 16 stations spaced 250 m apart and 125 m from the edge of the grid cell (Figure 3). During each 6-minute point count, technicians recorded all birds seen and heard and measured the distance to each using a laser range-finder. Sampling was conducted with removal across minute periods.

Vegetation Sampling

Prior to beginning each point count, technicians collected vegetation data using ocular estimation methods. Percent cover of herbaceous vegetation, shrubs, and tree cover was estimated within a 50 m radius of each point count station. The technicians used a laser rangefinder to estimate the canopy height of trees and shrubs and counted the number of standing-dead mesquite and juniper stems within a 50-meter radius as well.

Although the information provided is useful for bird modeling work, ocular vegetation estimates of vegetation cover are notoriously imprecise, particularly for estimating herbaceous cover (Brown & Marsden 1976). We randomly selected a subset of 15 of the IMBCR transects across treatments at Matador to collect more detailed estimates of vegetation cover. Within the 15 selected IMBCR transects, we used 100-meter belt transects and the Daubenmire quadrat method to sample broad plant functional types (bareground, herbaceous, shrub, and tree cover) at a subset of point count stations (5/16 stations). At each station, a technician set a 100-meter transect tape in the North / South direction such that the 50 meters point was centered at the station. Every three meters, a 50 cm x 20 cm quadrat frame was placed 25 cm from the measuring tape and percent cover of vegetation was estimated. Ordinal cover-classes for bareground and herbaceous plant functional types estimated using the quadrats were consistent with classes sampled in the standard IMBCR protocol (0%, 1%, 1-3%, 3-5%, 5-10%, 20-30%, 30-40%, …90-100%). To sample woody species within each quadrat, we used point-intercept sampling and determined if shrub and tree canopy cover intercepted the center point of the quadrat frame (1 = present, 0 = absent). We then took the sum of point-intercept values across the entire belt transect to estimate percent cover for shrubs and trees at the station scale (250 m X 250 m). The three meters of separation between quadrats we selected to ensure independent sampling of pixels in 1 m resolution remotely-sensed imagery. Each vegetation belt transect contained 34 replicate cover estimates, which we aggregated to the station scale. We designed the vegetation sampling to be spatially-consistent with the standard IMBCR protocol so that we could extrapolate vegetation data across the extent of Matador in a format that was consistent with our bird sampling.

Land Cover Modeling

We used the detailed belt transect vegetation data to train a computer to map vegetation percent cover estimates to remotely sensed imagery from the USDA's National Agriculture Imagery Program (NAIP, *sensu* Davies et al. 2010) available between 2003-2016 (Figure 4). To predict land cover composition across the extent of Matador, we used a Generalized Linear Model with a binomial 'logit' link-function fit to principal components of Red, Blue, Green, and Near-infrared bands in the NAIP imagery. NAIP band data were re-scaled to the 250 m x 250 m station scale, using the latest time period of NAIP imagery for Matador's boundary (*sensu* Homer et al. 2012). After fitting models to the vegetation belt-transect data, we then ran the models across the extent of Matador to estimate vegetation cover at sites that were not directly sampled in the field (Appendix B).

Grassland Bird Guild and Population Modeling

A key component of the IMBCR design is the ability to make inferences about bird habitat selection across spatial scales, from management units to entire states and BCRs. This is accomplished through hierarchical (nested) stratification, which allows data from smaller order strata to be combined to make inferences about higher order strata. An IMBCR transect (Figure 3) contains 16 individual point-count stations. The combination of distance and removal counts allows for statistically robust estimates of bird occupancy and density at both the station (250 m x 250 m) and transect (1 km x 1 km) scales. We used the detection histories across all stations in a transect to estimate occupancy and the distance observations across all stations in a transect to estimate density for the most common birds sampled at Matador using the methods of Chandler et al. (2011). We then estimated bird population sizes at Matador by taking the mean density of birds sampled at Matador and extrapolated the estimates (with standard error) across the entire wildlife management area using the unmarked package in R.

We used general linear models with a poisson distribution to evaluate the relative importance of various vegetation types and time since treatment on density of bobwhite and the grassland bird guild. We defined the grassland bird guild as the four grassland bird species with the highest detections that were not bobwhite. The species included in the grassland bird guild were Cassin's sparrow, dickcissel, lark sparrow, and grasshopper sparrow. Data were analyzed at both the station and the transect scales. A full list of the variables used in the models can be found in Appendix C. We used a correlation plot to investigate relationships between bobwhite presence and presence of the top ten species detected at Matador.

Table 1. The number of transects sampled within each stratum (time since chemical treatment of mesquite) in the project region during the 2019 season.

Stratum Treatment Years (# years post-treatment)	Transects Sampled
2015-19 (1-5 years)	8
2010-14 (6-10 years)	7
2005-09 (11-15 years)	5

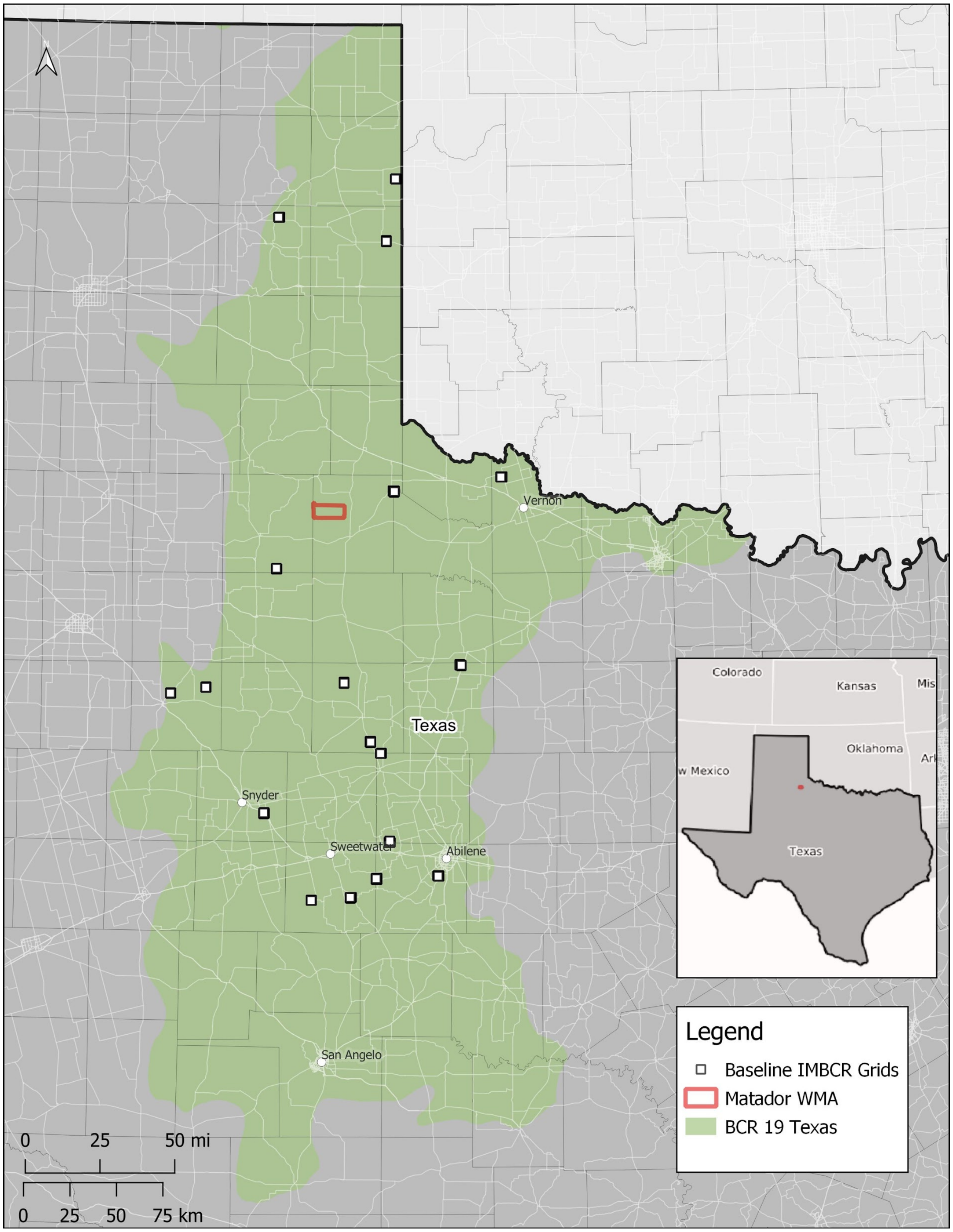


Figure 1. Region overview of Matador WMA with a delineation of the ecoregions of Texas east of the Llano Estacado caprock. The white squares are the 18 IMBCR baseline transects, transects sampled as a part of the overall IMBCR monitoring effort. These transects will be used for regional comparisons of bird density with the Matador WMA dataset. The Texas ecoregions depicted here straddle the southern boundary of Bird Conservation Region 19.

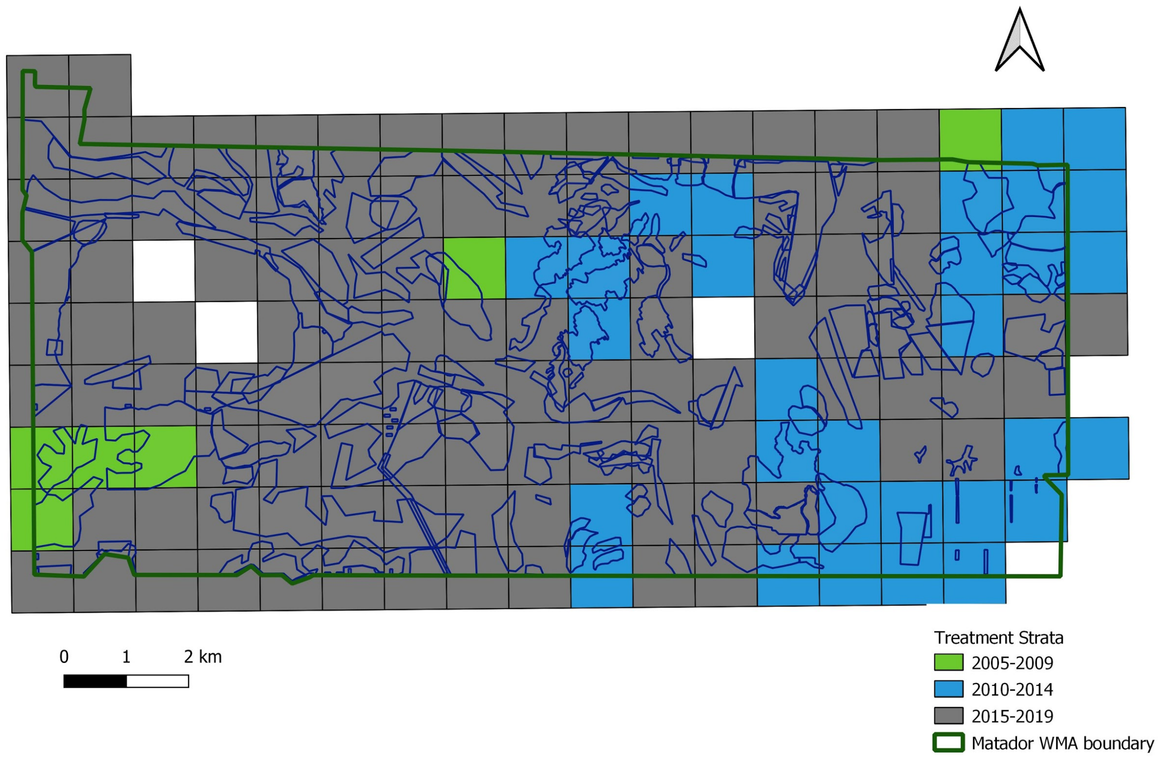


Figure 2. A stratification overview for the sampling conducted at Matador Wildlife Management Area in 2019. The US National Grid units are colored based on their stratum prefix. The blue polygons are the treatment boundaries.

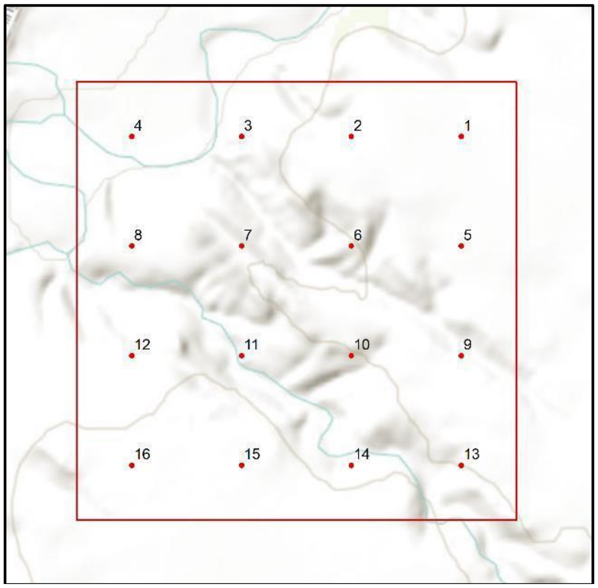


Figure 3: An example of standard 16 point-count stations placed within a 1 km² US National Grid unit using the Integrated Monitoring in Bird Conservation Regions design.

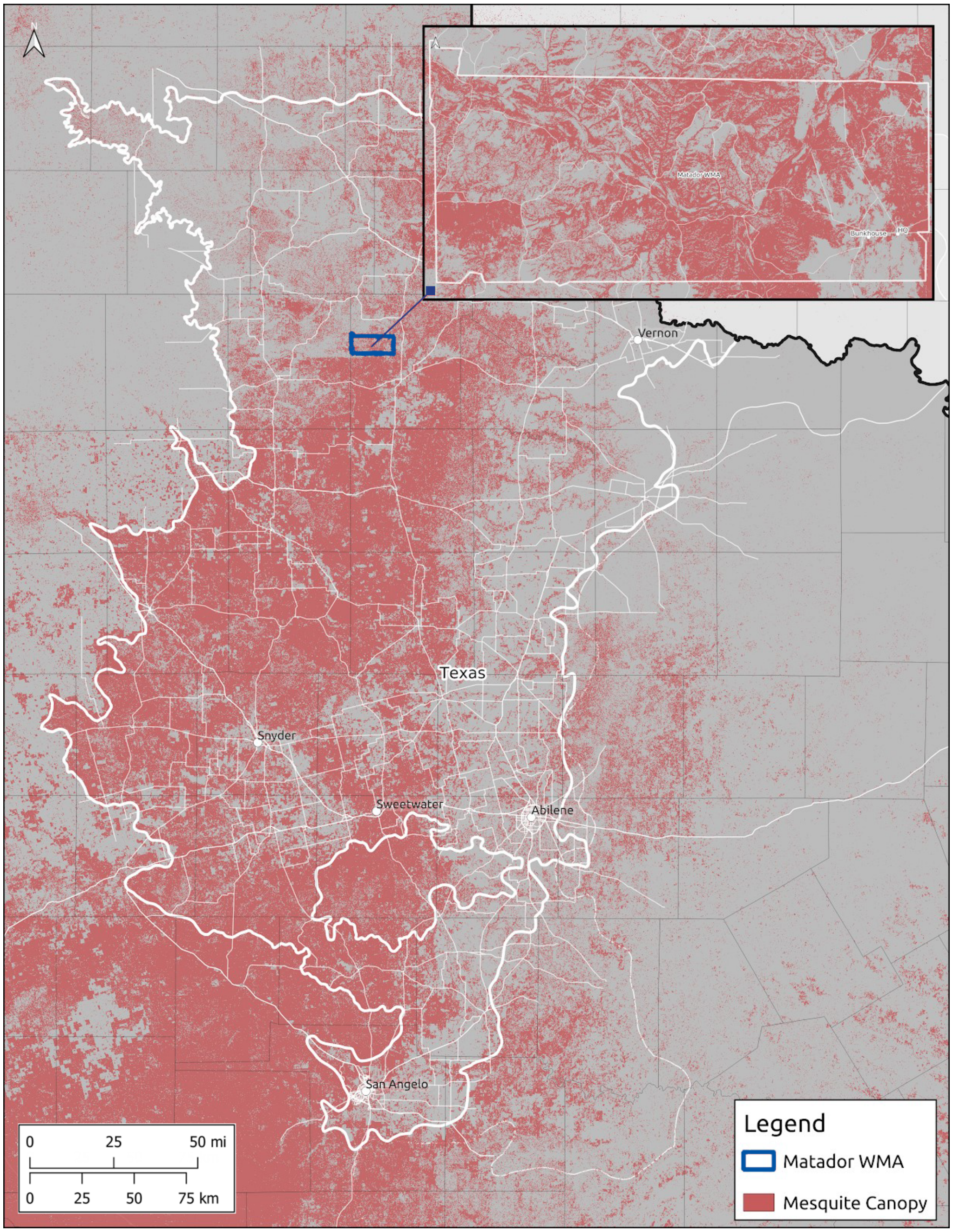


Figure 4. Regional overview of Matador Wildlife Management Area with the most recent classified NAIP imagery showing predicted mesquite canopy cover at 10 m resolution. An inset in the upper-right demonstrates the predicted distribution of mesquite canopy within the Matador Wildlife Management Area boundary.

Results

Across Matador, we had a total of 4,037 bird detections sampled across 20 transects (Table 2; Appendix B has a complete list of species detected). This is a more than adequate sample size for reliably estimating population size and density for the most common species at Matador. Grassland associated species like Cassin's sparrow, bobwhite, and dickcissel were the most common birds sampled at Matador. There were also a number of birds with high detections, including Bewick's wren, painted bunting, and northern cardinal, that prefer woody vegetation cover. Of the 22 most abundant species found at Matador, we estimate a total population size of 132,492 individuals.

The grassland bird guild had a small, positive correlation value with bobwhite (Figure 7) and were strongly negatively correlated with Bewick's wren, painted bunting, and northern cardinal at matador. Bobwhite were positively correlated with mourning doves (Figure 7).

*Table 2. Summary population statistics for the 22 most abundant species found at Matador Wildlife Management Area (scientific names can be found in Appendix B) and the Texas BCR 19 region. Density estimates for Matador are presented with a Standard Error (SE), D represents detections, %CV is the Coefficient of Variation. In general a %CV <50 indicates high confidence in the estimates. An * indicates an obligate grassland bird and a + indicates a facultative grassland bird (Vickery and Herkert 1999).*

	Matador Wildlife Management Area			Texas BCR 19		
Species	**D**	**Density (SE) (birds/km^2)**	**Population Size (SE)**	**D**	**Density (%CV) (birds/km^2)**	**Estimated Population Size**
Cassin's Sparrow*	667	127.93 (12.57)	18,387 (1,807)	58	8.42 (23)	751,833
Northern Bobwhite +	552	113.69 (14.04)	16,340 (2,018)	59	3.80 (13)	339,471
Dickcissel*	445	90.98 (13.37)	13,076 (2,008)	58	27.00 (13)	2,409,666
Northern Mockingbird	386	69.33 (12.59)	9,964 (1,810)	67	4.77 (21)	426,006
Mourning Dove +	365	109.01 (13.91)	15,668 (1,999)	91	11.21 (59)	1,000,026
Bewick's Wren	181	43.41 (11.34)	6,239 (1,630)	73	29.33 (15)	2,617,874
Lark Sparrow +	171	52.54 (12.08)	7,551 (1,736)	30	11.42 (42)	1,019,137
Painted Bunting	149	59.87 (14.06)	8,605 (2,021)	66	11.28 (25)	1,006,199
Grasshopper Sparrow*	118	27.19 (7.74)	3,908 (1,112)	29	18.58 (22)	1,657,748
Northern Cardinal	108	26.88 (8.36)	3,863 (1,202)	114	27.98 (18)	2,496,619
Scissor-tailed flycatcher +	86	40.24 (13.54)	5,784 (1,946)	45	16.76 (33)	1,495,690

Golden-fronted woodpecker	80	24.27 (9.24)	3,488 (1,328)	16	1.27 (36)	113,416
Brown-headed Cowbird +	75	18.96 (7.67)	2,725 (1,102)	48	13.82 (95)	1,233,030
Rufous-crowned Sparrow +	72	26.39 (10.11)	3,793 (1,453)	ND		
Bullock's Oriole	67	19.30 (8.24)	2,774 (1,184)	9	0.89 (74)	79,119
Ash-throated Flycatcher +	63	26.99 (11.95)	3,879 (1,718)	29	6.23 (33)	555,637
Blue Grosbeak	54	11.24 (5.25)	1,615 (755)	21	3.12 (26)	277,964
Red-winged Blackbird +	38	7.34 (2.64)	1,015 (379)	102	12.76 (49)	1,138,518
Ladder-backed woodpecker	35	14.23 (8.47)	2,045 (1,217)	7	1.17 (43)	104,619
Greater Roadrunner	28	2.90 (2.14)	417 (308)	ND		
Western Meadowlark*	24	6.65 (2.86)	956 (411)	47	0.05 (100)	4,393
Field Sparrow	24	2.78 (1.34)	400 (193)	27	5.51 (26)	491,427

Figure 5. Correlation matrix of the abundance among the ten most common species and the grassland bird guild sampled at Matador Wildlife Management Area. The grassland bird guild is composed of the sum counts for the four most abundant other grassland species sampled (Cassin's sparrow, dickcissel, lark sparrow, and grasshopper sparrow).

We observed the highest herbaceous cover, lowest cover of bareground, and lowest shrub cover at sites last treated between 2010-2014 (5-10 years post-treatment, Figure 6). As elapsed time since treatment succeeds into 10-15 years (the 2005-2009 treatment stratum), bareground increases, herbaceous cover is reduced, and shrub cover marginally increases. In general, there is a reduction in bareground and an increase in herbaceous cover immediately after treatment, but the magnitude of this change is less than what we observed at 2010-2014 stratum transects. Boxplots for tree cover were omitted from this figure, because there were no appreciable differences in tree cover among strata.

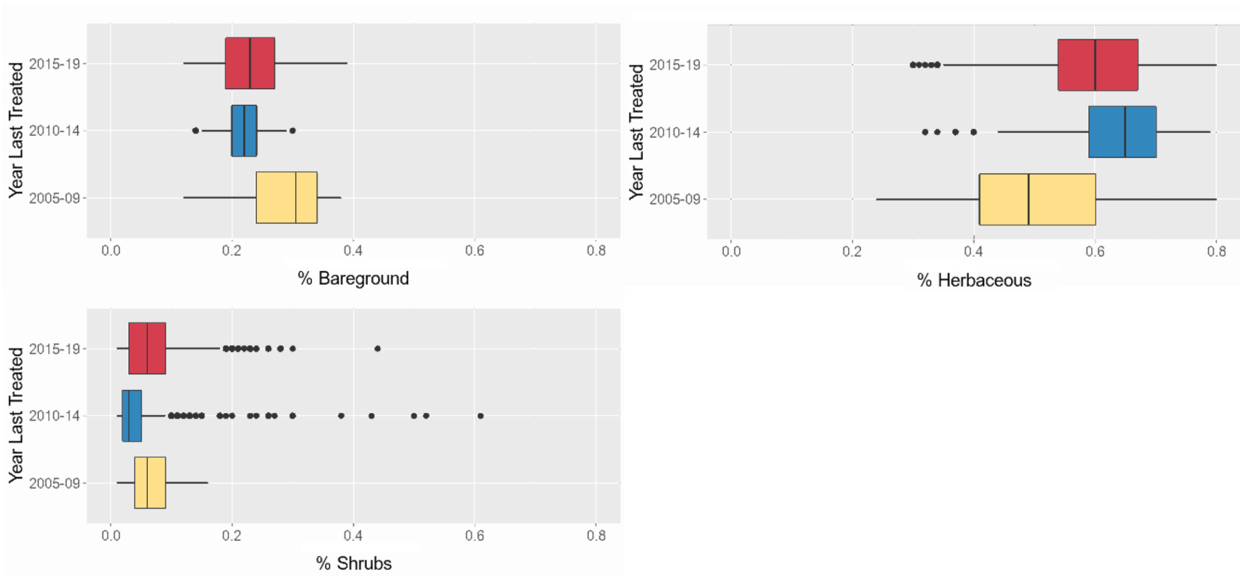
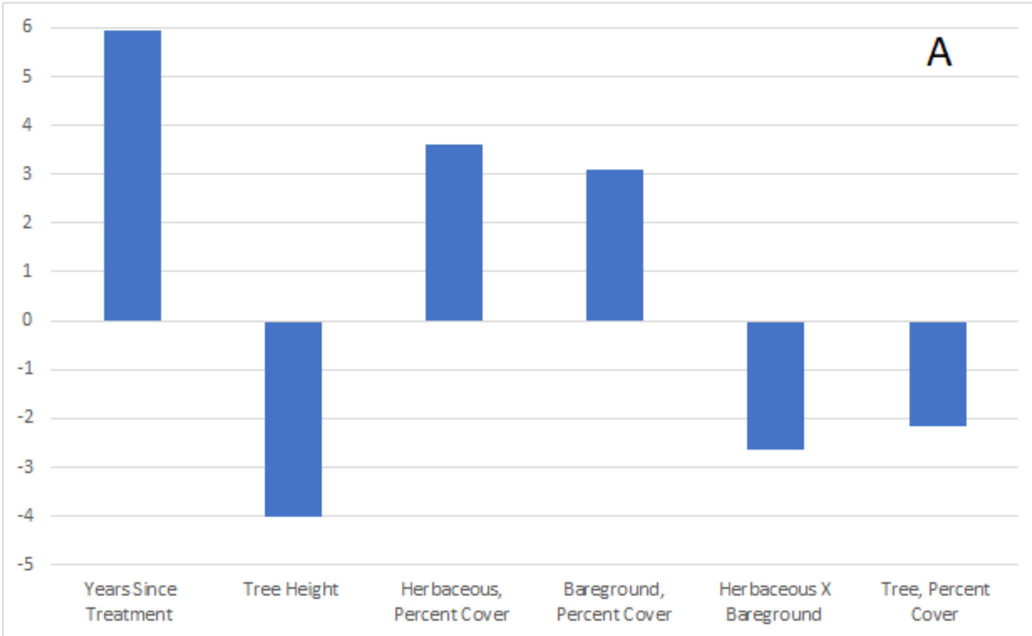


Figure 6. Summary vegetation boxplots for the three time-since-treatment conditions sampled at Matador Wildlife Management Area demonstrating differences in percent cover of bareground, herbaceous, and shrub canopy among each of the treatment strata at the station (250 m X 250 m) scale. Shrub composition is almost exclusively associated with mesquite in this landscape.

Grassland Bird Population and Habitat Modeling

In our guild level grassland bird abundance models, we observed that grassland birds prefer a mosaic of bareground mixed with herbaceous cover and strongly select for sites with high herbaceous cover at the station (250 m x 250 m) scale. At the transect scale (1 km^2), herbaceous cover becomes less important than avoiding sites that have acquired vertical structure from woody vegetation. (Figure 6, Appendix C). Notably, at both the station and transect scales, we observed a strong effect associated with time since treatment. At the transect scale, grassland bird response was greatest at the 5-10 years post-treatment stratum then declined in the 11-15 years post-treatment stratum. It is important to note that there are confounding changes in herbaceous cover and bareground associated with time since treatment, with higher herbaceous cover and lower bareground associated with 5-10 year elapsed treatment areas at Matador (Figure 7), notably, as site conditions at smaller-scales approach 15 years, the amount of bareground increases.

At the station scale, bobwhite had a positive response to years since treatment. No other variables were predictive of bobwhite abundance (Appendix C). At the 1 km^2 transect scale, no variables significantly predicted bobwhite abundance (Appendix C).



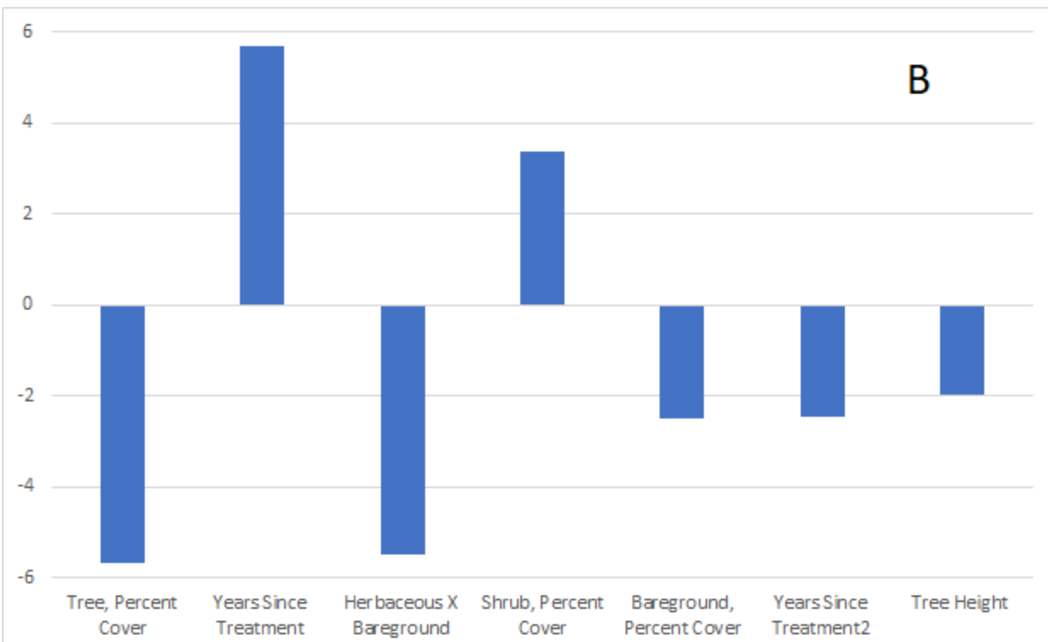


Figure 7. Standardized effect sizes for variables that were significant at α = 0.05 for grassland bird guild abundance given habitat conditions sampled at Matador Wildlife Management Area. The grassland bird guild includes Cassin's sparrow, dickcissel, grasshopper sparrow, and lark sparrow. Model effects are reported here at (A) the station scale (250 m x 250 m) and (B) the transect scale (1 km²).

Conclusions

Northern bobwhite were detected at all transects, in addition field technicians reported on the large number of bobwhite and their ubiquity across all treatment types. These high numbers resulted in difficulty modeling habitat relationships for bobwhite. However, we were able to model habitat relationships for the grassland bird guild, a group of birds correlated with bobwhite presence.

Most of the grassland species detected are species that are known to require more structure, and some small woody structure, in their habitat requirements, even among the obligate grassland bird species (Table 3, Dunning et al. 2020, Temple 2020, Vickery 2020, Martin and Parrish 2020). In Oklahoma, Crosby et al. (2015) demonstrated that bobwhite were correlated with several grassland and shrubland birds, including species of conservation concern, indicating that bobwhite can be used as umbrella species. However, they advise that the species for which bobwhite may act as an umbrella species will be region specific (Crosby et al. 2015). At the Matador Wildlife Management Area, bobwhite were correlated with several grassland species of concern; grasshopper sparrow and dickcissel are listed as Partners in Flight watch list species for BCR 19 and Cassin's sparrow and lark sparrow have experienced well-documented population declines (Rosenberg et al. 2016). Using chemical treatments at Matador to increase bobwhite populations may continue to support species like dickcissel and Cassin's sparrow.

At the station scale (250 m x 250 m), a scale that might represent a breeding territory for a grassland songbird, the grassland bird guild responded positively to time since treatment and selected for sites with more herbaceous cover and bare ground, although the data do indicate an interaction between those two variables so there is a trade-off occurring. The positive effect of time since treatment indicates that treatment effects of chemical removal of mesquite can have long lasting effects, at the smaller scale.

At the transect scale (1 km^2), or a landscape sale, the quadratic function of time since treatment was significant indicating that the grassland bird guild had higher abundances in the 2010-2014 time since treatment strata. At this scale, the interaction term for bareground and herbaceous cover was negatively related to density, however, shrub cover was positively related. This may reflect the habitat needs of the four species included in the guild. At a larger scale, the species are choosing areas that have some amount of shrub cover but at the smaller scale, the birds require herbaceous cover and bareground for nesting and foraging.

We were unable to determine any habitat relationships with Northern Bobwhite at either the station scale or the transect scale. This may be due to the high numbers of Northern Bobwhite at Matador, if the species has high detection across all transects, it is difficult for the models to resolve what the species is cueing in when selecting habitat. At the station scale, but not at the transect scale, we detected a positive effect of time since treatment on density. This may also reflect the territory scale needs of bobwhite, which we were unable to determine, and the long-lasting nature of the chemical treatments for providing suitable habitat at the station scale. However, no effect of time since treatment was determined at the transect scale. At this scale, bobwhite may respond to time since treatment at finer time-scale than was tested in this study. A five-year time scale may be too coarse to detect any changes.

Regardless, our results indicate that to maintain grassland bird guild densities at the landscape scale, retreatment should occur every 5-10 years. Retreatment in this timeframe will create a landscape at Matador that is suitable for grassland birds that require or prefer some woody structure in the landscape. Only one species that prefers shorter grasses and no structure, Western Meadowlark, was found at Matador and only at very low densities (Davis and Lanyon 2020), however, even that species is found at higher densities on Matador compared to the Texas BCR 19 region (Table 2). Therefore, the treatments being done at Matador to control mesquite for bobwhite will also have positive benefits for the grassland bird species found at Matador.

We used density estimates from the Rocky Mountain Avian Data Center (http://rmbo.org/v3/avian/Home.aspx) to compare the Texas BCR 19 region-wide density estimates to densities of birds found at Matador (Table 3). Direct statistical comparisons are not possible because these estimates do not include habitat covariates; however, we will make anecdotal comparisons. Densities of bobwhite at Matador are higher than the estimated densities in the broader Texas BCR 19 region. All of the four species included in our grassland bird guild appear to have higher densities at Matador than in the broader Texas BCR 19 region, as well. In addition, two of the top three species detected at Matador are grassland obligate species, while in the broader region, in what was once a prairie landscape, many of the highest detected birds are generalist species or shrubland species (Table 3). Broad-scale mesquite removal treatments like those applied at Matador may also have positive benefits for grassland birds across the broader region.

Prescribed fire is also used as a management tool at Matador. Due to sample size issues and limitations in study design, we were unable to evaluate the effectiveness of prescribed fire separately from chemical treatments. All the sampled grids, with one exception, have been burned between 2015-2019. In addition, mechanical treatments have also been applied to remove mesquite at Matador. The results presented here should be interpreted in that context; chemical treatments paired with other managements methods in other years may be necessary to manage for bobwhite and other grassland birds.

*Table 3. Summary population statistics for the top 22 species detected in the BCR 19 region of Texas (scientific names can be found in Appendix B, with the exception of three species noted here). In general a % Coefficient of Variation (%CV) <50 indicates high confidence in the estimates. An * indicates an obligate grassland bird and a + indicates a facultative grassland bird (Vickery and Herkert 1999).*

Species	Detections	Density (birds/km^2)	Estimated Population Size	% Coefficient of Variation
Great-tailed Grackle (*Quiscalus mexicanus*)	291	18.56	1,656,479	159
Northern Cardinal	114	27.98	2,496,619	18
Cliff Swallow	102	5.47	488,404	217
Red-winged Blackbird +	102	12.76	1,138,518	49
Mourning Dove +	91	11.21	1,000,026	59
Bewick's Wren	73	29.33	2,617,874	15
Northern Mockingbird	67	4.77	426,006	21
Painted Bunting	66	11.28	1,006,199	25
Northern Bobwhite +	59	3.80	339,471	13
Cassin's Sparrow *	58	8.42	751,833	23
Dickcissel *	58	27.00	2,409,666	13
Horned Lark * (*Eremophila alpestris*)	58	8.37	746,916	54
Common Grackle	53	32.29	2,881,344	146
Brown-headed Cowbird +	48	13.82	1,233,030	95
Western Meadowlark *	47	0.05	4,393	100
Scissor-tailed Flycatcher +	45	16.76	1,495,690	33
Black-crested Titmouse	35	7.16	639,393	23
Lark Sparrow +	30	11.42	1,019,137	42
Spotted Sandpiper	30	0	138	105
Ash-throated Flycatcher +	29	6.23	555,637	33
Grasshopper Sparrow *	29	18.58	1,657,748	22

Eastern Meadowlark *	28	3.41	304,103	22

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Appendices

Appendix A: Full list of species detected at Matador Wildlife Management Area in 2019

Common Name	Species Name
American Crow	*Corvus brachyrhynchos*
American Kestrel	*Falco sparverius*
Ash-throated Flycatcher	*Myiarchus cinerascens*
Barn Swallow	*Hirundo rustica*
Bell's Vireo	*Vireo bellii*
Bewick's Wren	*Thryomanes bewickii*
Black-chinned Hummingbird	*Archilochus alexandri*
Black-crested Titmouse	*Baeolophus atricristatus*
Blue Grosbeak	*Passerina caerulea*
Blue Jay	*Cyanocitta cristata*
Blue-gray Gnatcatcher	*Polioptila caerulea*
Brown-headed Cowbird	*Molothrus ater*
Bullock's Oriole	*Icterus bullockii*
Burrowing Owl	*Athene cunicularia*
Canyon Towhee	*Melozone fusca*
Carolina Wren	*Thryothorus ludovicianus*
Cassin's Sparrow	*Peucaea cassinii*
Cedar Waxwing	*Bombycilla cedrorum*
Chihuahuan Raven	*Corvus cryptoleucus*
Chipping Sparrow	*Spizella passerina*
Clay-colored Sparrow	*Spizella pallida*
Cliff Swallow	*Petrochelidon pyrrhonota*
Common Grackle	*Quiscalus quiscula*
Common Nighthawk	*Chordeiles minor*
Common Raven	*Corvus corax*
Dickcissel	*Spiza americana*

Eastern Kingbird	*Tyrannus tyrannus*
Eastern Meadowlark	*Sturnella magna*
Eastern Phoebe	*Sayornis phoebe*
Field Sparrow	*Spizella pusilla*
Golden-fronted Woodpecker	*Melanerpes aurifrons*
Grasshopper Sparrow	*Ammodramus savannarum*
Great Blue Heron	*Ardea herodias*
Great Horned Owl	*Bubo virginianus*
Greater Roadrunner	*Geococcyx californianus*
Green Heron	*Butorides virescens*
House Finch	*Haemorhous mexicanus*
House Wren	*Troglodytes aedon*
Indigo Bunting	*Passerina cyanea*
Killdeer	*Charadrius vociferus*
Ladder-backed Woodpecker	*Dryobates scalaris*
Lark Sparrow	*Chondestes grammacus*
Lazuli Bunting	*Passerina amoena*
Lesser Goldfinch	*Spinus psaltria*
Lincoln's Sparrow	*Melospiza lincolnii*
Loggerhead Shrike	*Lanius ludoviscianus*
MacGillivray's Warbler	*Geothlypis tolmiei*
Mississippi Kite	*Ictinia mississippiensis*
Mourning Dove	*Zenaida macroura*
Northern Bobwhite	*Colinus virginianus*
Northern Cardinal	*Cardinalis cardinalis*
Northern Flicker (Yellow-shafted)	*Colaptes auratus*
Northern Mockingbird	*Mimus polyglottos*
Orchard Oriole	*Icterus spurius*
Painted Bunting	*Passerina ciris*

Red-headed Woodpecker	*Melanerpes erythrocephalus*
Red-winged Blackbird	*Agelaius phoeniceus*
Rufous-crowned Sparrow	*Aimophila ruficeps*
Savannah Sparrow	*Passerculus sandwichensis*
Say's Phoebe	*Sayornis saya*
Scissor-tailed Flycatcher	*Tyrannus forficatus*
Swainson's Hawk	*Buteo swainsoni*
Turkey Vulture	*Cathartes aura*
Vesper Sparrow	*Pooecetes gramineus*
Warbling Vireo	*Vireo gilvus*
Western Kingbird	*Tyrannus verticalis*
Western Meadowlark	*Sturnella neglecta*
Western Wood-Pewee	*Contopus sordidulus*
Wild Turkey	*Meleagris gallopavo*
Yellow Warbler	*Setophaga petechia*
Yellow-billed Cuckoo	*Coccyzus americanus*
Yellow-breasted Chat	*Icteria virens*
Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*
Yellow-rumped Warbler	*Setophaga coronata*

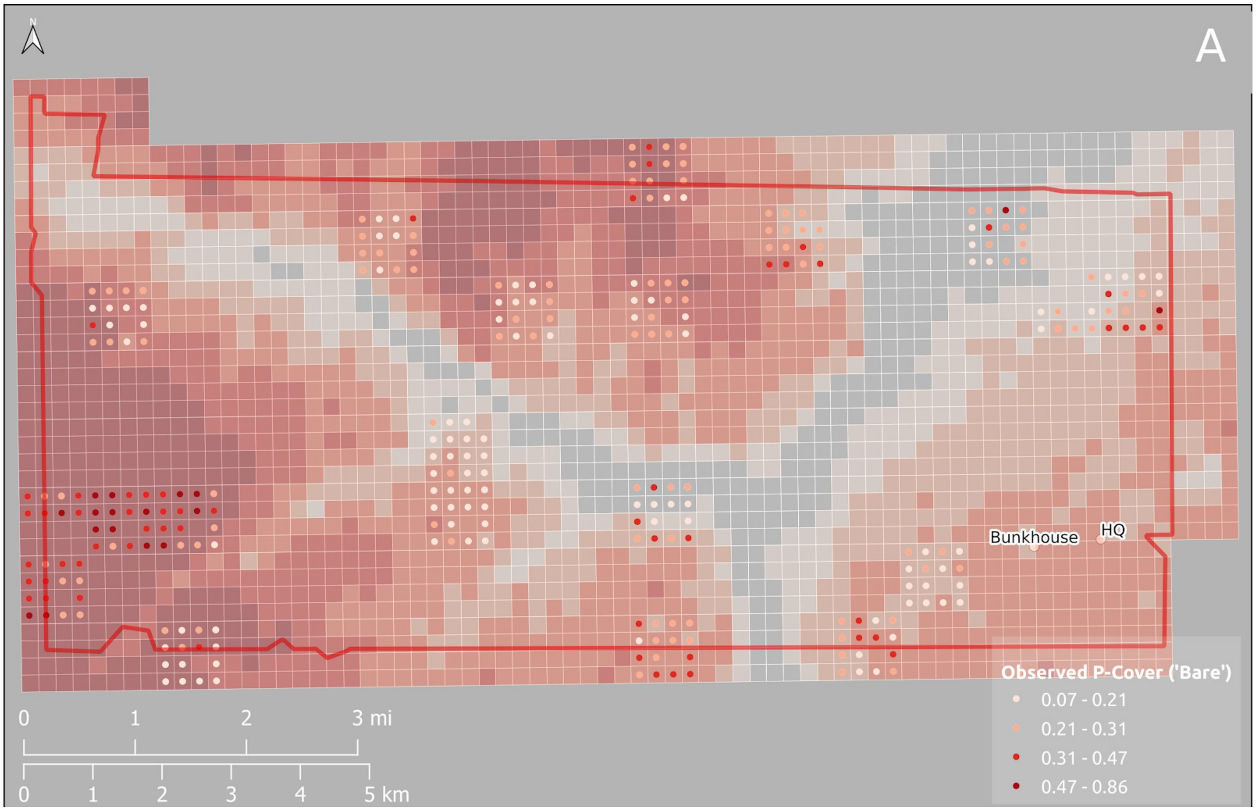
Appendix B: Vegetation and Land Cover Mapping

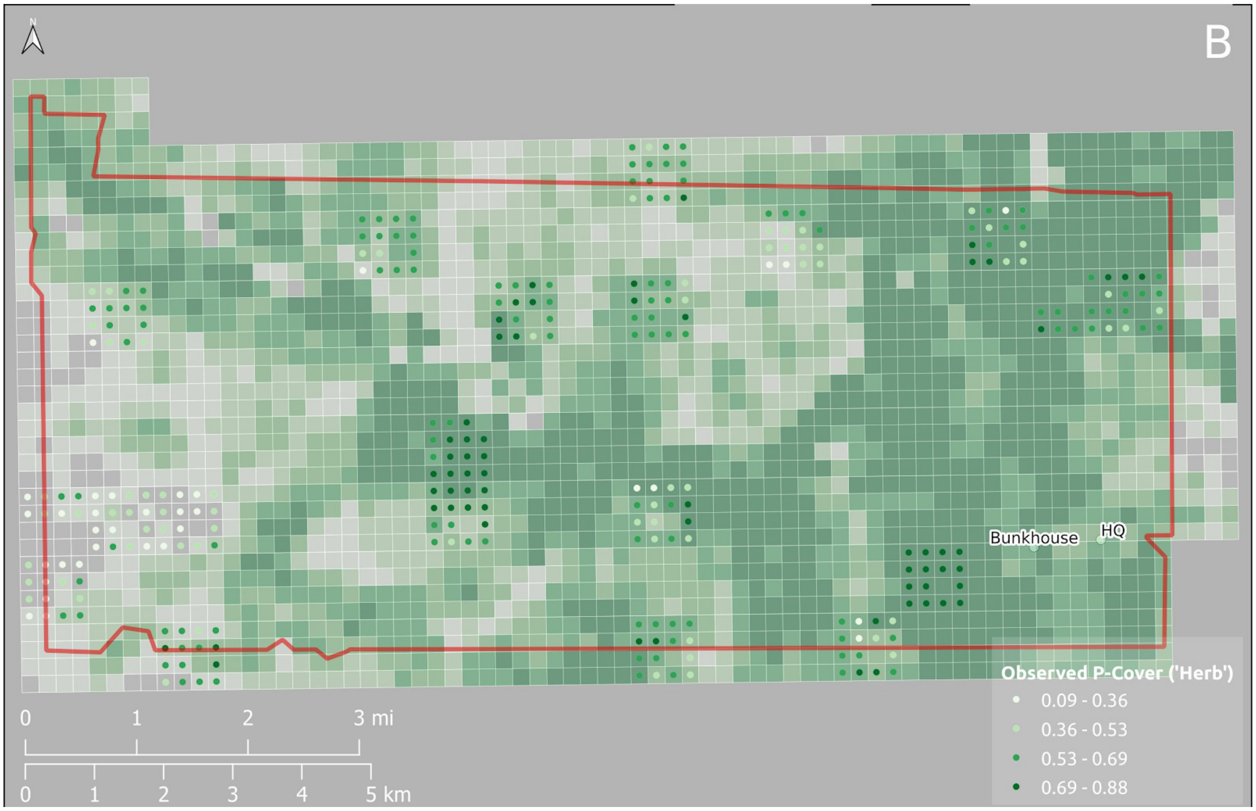
Station scale predictions of each vegetation cover type at Matador are shown in Figure B1. Vegetation cover estimates are juxtaposed with the fitted-values observed at individual IMBCR stations in this figure. The area sampled in 2019 for birds and vegetation at Matador covered 16% of the total area shown in the figures.

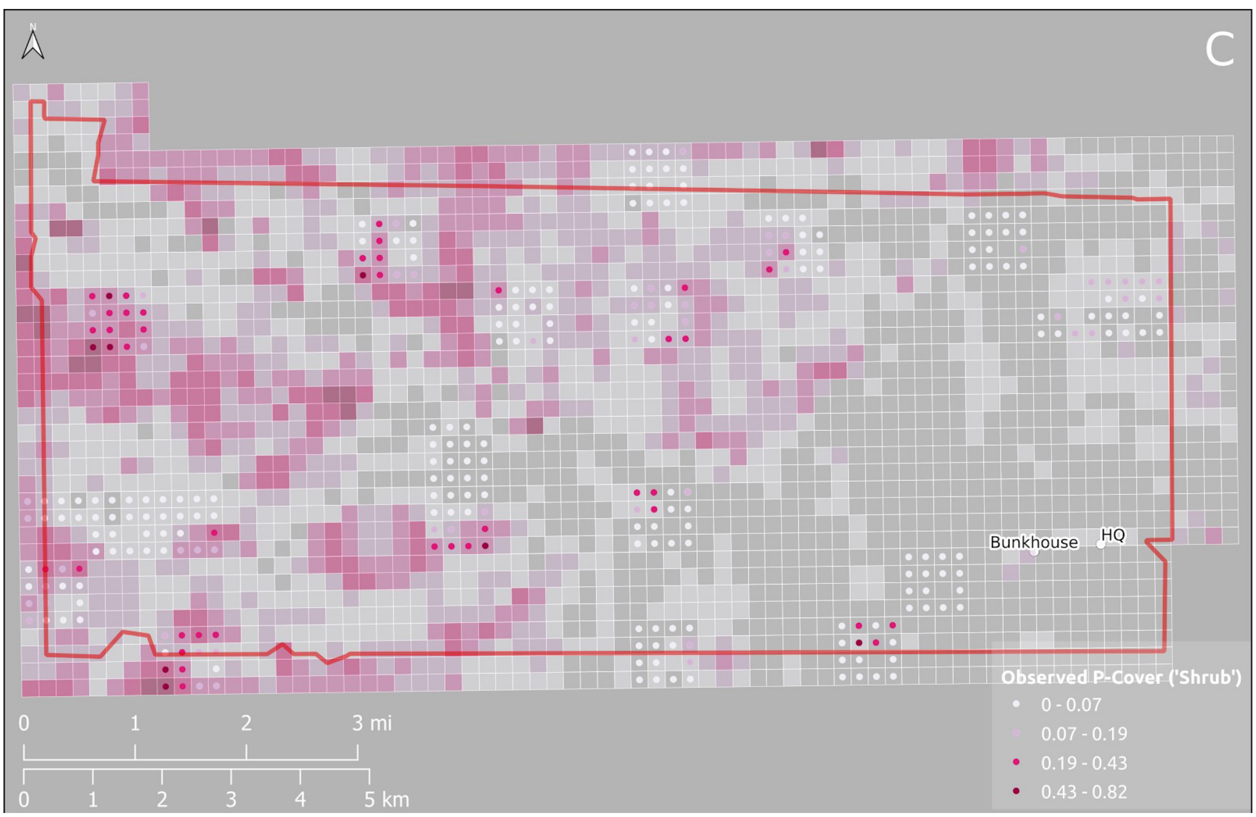
McFadden's specification states that models with an $R^2 > 0.3$ are good. The cross-validation procedure indicates correlation between observed and predicted values using RMSE and represents an absolute measure of model fit (Xu et al. 2005). The herbaceous and shrub land cover models were the optimal performing models considered in our analysis. Although the fit of the tree canopy cover model was high, this is an indication that the model is overfit. Because there were few vegetation belt transects that intersected tree canopy, we think that zero-inflation may be biasing model predictions for the tree canopy estimate (Table B1).

Table B1. Accuracy assessment of individual binomial land cover model predictions using a McFadden's R^2 and K=10 folds cross-validation.

Modeled Variable	**McFadden's R^2**	**10-Fold Cross Validation R^2**
Bareground (% Cover)	0.38	0.26
Litter (% Cover)	0.39	0.29
Herbaceous (% Cover)	0.75	0.42
Shrub (% Cover)	0.65	0.32
Tree (% Cover)	1.0	0.92


A
Bunkhouse
HQ
Observed P-Cover ('Bare')
0.07 - 0.21
0.21 - 0.31
0.31 - 0.47
0.47 - 0.86
0
1
2
3 mi
0
1
2
3
4
5 km


B
Bunkhouse
HQ
Observed P-Cover ('Herb')
0.09 - 0.36
0.36 - 0.53
0.53 - 0.69
0.69 - 0.88
0
1
2
3 mi
0
1
2
3
4
5 km


C
Bunkhouse
HQ
Observed P-Cover ('Shrub')
0 - 0.07
0.07 - 0.19
0.19 - 0.43
0.43 - 0.82
0
1
2
3 mi
0
1
2
3
4
5 km

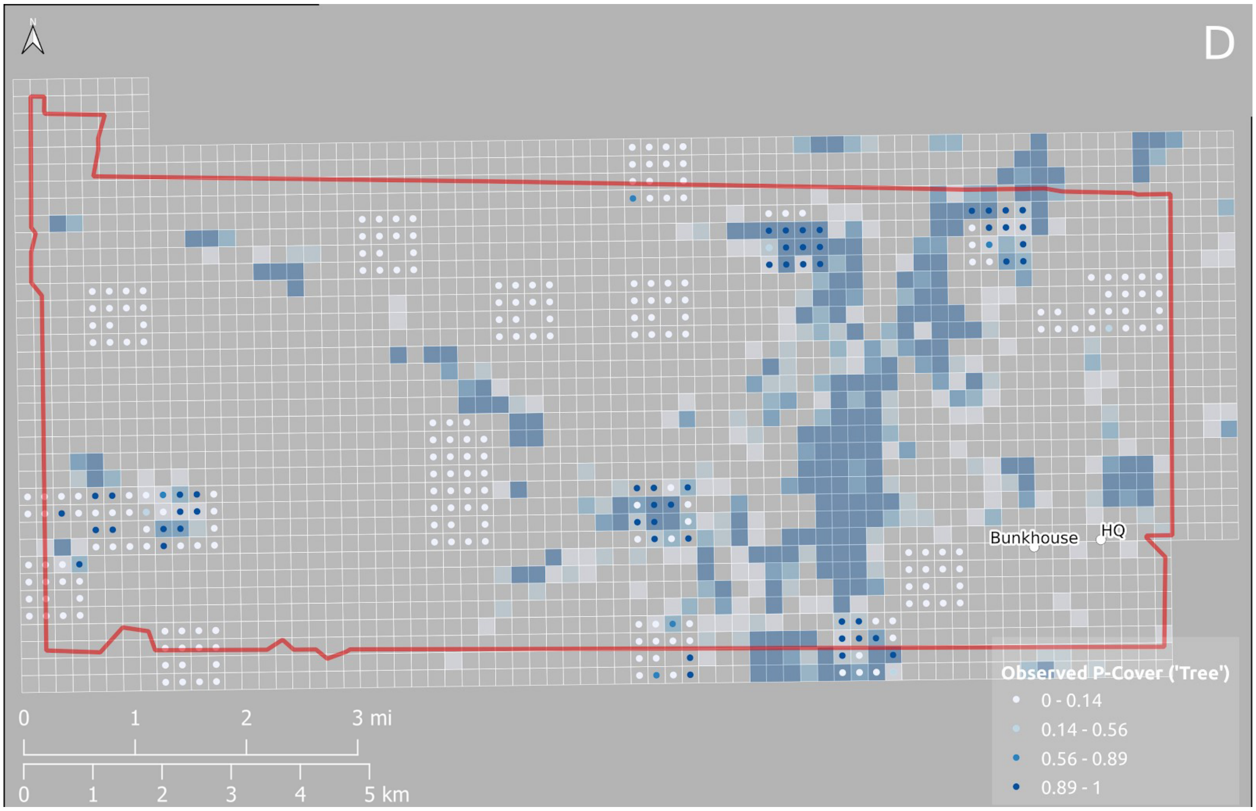


Figure B1. Vegetation mapping of predicted (A) bareground, (B) herbaceous, (C) shrub, and (D) tree cover across Matador Wildlife Management Area from the belt transect data. The small circles are the observed vegetation conditions at IMBCR stations grid stations sampled in 2019.

Appendix C: Model Fitting

We expressed bareground using a 2nd order polynomial and added an interaction term for percent cover herbaceous and percent cover bareground because we think there is an important interaction between the two covariates in describing habitat. We fit independent models at the station and grid scales (Table C1 A & B) to explore whether important habitat covariates change between scales. We observed strong selection against mesquite tree cover (i.e., stems taller than 2 meters) at both spatial scales. The influence of bareground is very different between scales, with grassland birds appearing to select for some bareground at finer spatial scales and select against bareground at larger (1 km^2) spatial scales. We think that the fit of the other grassland birds guild model is better than individual models fit for Northern bobwhite (Table C1 C & D) because bobwhite was ubiquitous across the sites sampled at Matador in 2019. Bobwhite were detected on all transects making defining limiting conditions challenging.

*Table C1. Standardized regression coefficients and error for optimal guild-level Poisson abundance models for birds sampled at Matador Wildlife Management Area. Grassland guild abundance was fit independently at A) 250 m x 250 m (station scale) and B) 1km² (transect scale). Northern bobwhite abundance was fit independently at the C) station and D) transect scales. Variables that are bolded with an * are significant at ⍰ = 0.05.*

A. Grassland Bird Guild 250 m x 250 m				
Variable	Estimate	Standard Error	z-value	Pr(>|t|)
Intercept *	**1.707**	**0.049**	**35.114**	**<2e-16**
Tree, Percent Cover *	**-0.071**	**0.033**	**-2.173**	**0.030**
Shrub, Percent Cover	1.213	0.714	1.699	0.089
Shrub, Percent Cover^2	-0.872	0.522	-1.670	0.095
Herbaceous, Percent Cover *	**0.254**	**0.070**	**3.620**	**0.0003**
Bareground, Percent Cover *	**2.917**	**0.948**	**3.078**	**0.002**
Bareground, Percent Cover^2	-1.108	0.878	-1.261	0.207
Shrub Height	-0.044	0.024	-1.794	0.073
Tree Height *	**-0.110**	**0.027**	**-4.017**	**5.9e-5**
Years Since Treatment *	**0.180**	**0.030**	**5.940**	**2.9e-9**
Herbaceous X Bareground *	**-0.127**	**0.048**	**-2.625**	**0.009**

B. Grassland Bird Guild 1 km x 1 km				
Variable	Estimate	Standard Error	z-value	Pr(>|t|)
Intercept *	**4.479**	**0.026**	**174.136**	**<2e-16**
Tree, Percent Cover *	**-0.229**	**0.040**	**-5.694**	**1.2e-8**
Shrub, Percent Cover *	**0.799**	**0.237**	**3.379**	**0.0007**
Shrub, Percent Cover^2	-0.135	0.138	-0.974	0.330
Herbaceous, Percent Cover	0.051	0.054	0.953	0.341
Bareground, Percent Cover *	**-0.182**	**0.072**	**-2.515**	**0.012**
Shrub Height	-0.010	0.042	-0.234	0.815
Tree Height *	**-0.089**	**0.045**	**-1.980**	**0.048**
Years Since Treatment *	**1.006**	**0.177**	**5.676**	**1.4e-8**
Years Since Treatment^2 *	**-0.354**	**0.143**	**-2.471**	**0.013**
Herbaceous X Bareground *	**-0.254**	**0.046**	**-5.497**	**3.9e-8**

C. Northern Bobwhite 250 m x 250 m				
Variable	Estimate	Standard Error	z-value	Pr(>|t|)
Intercept *	**0.532**	**0.090**	**5.926**	**3.1e-9**
Tree, Percent Cover	0.001	0.059	0.020	0.984
Shrub, Percent Cover	0.454	1.360	0.334	0.738
Shrub, Percent Cover^2	-0.929	0.974	-0.954	0.340
Herbaceous, Percent Cover	0.066	0.131	0.504	0.615
Bareground, Percent Cover	0.271	1.748	0.155	0.877
Bareground, Percent Cover^2	-1.271	1.669	-0.761	0.446
Shrub Height	-0.018	0.046	-0.396	0.692
Tree Height	-0.039	0.051	-0.775	0.438
Years Since Treatment *	**0.115**	**0.057**	**2.016**	**0.044**
Herbaceous X Bareground	-0.065	0.091	-0.705	0.481

D. Northern Bobwhite 1 km x 1 km				
Variable	Estimate	Standard Error	z-value	Pr(>|t|)
Intercept *	**3.279**	**0.047**	**70.131**	**<2e-16**
Tree, Percent Cover	-0.081	0.075	-1.082	0.279
Shrub, Percent Cover	0.251	0.423	0.593	0.553
Shrub, Percent Cover^2	-0.108	0.257	-0.421	0.674
Herbaceous, Percent Cover	0.133	0.104	1.280	0.201
Bareground, Percent Cover	-0.049	0.130	0.379	0.705
Shrub Height	-0.019	0.077	-0.244	0.808
Tree Height	-0.009	0.085	-0.102	0.917
Years Since Treatment	0.573	0.316	1.814	0.070
Years Since Treatment^2	-0.076	0.270	-0.282	0.778
Herbaceous X Bareground	-0.082	0.092	-0.892	0.373