Evaluation of point counts and prediction of Golden-cheeked Warbler density on the Balcones Canyonlands Preserve, Travis County, Texas

Preliminary report

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Background

This is the preliminary report for collection agreement #18-CO-11242311-001 between the City of Austin, the U.S. Forest Service, and the University of Missouri. The objectives of this report are to estimate detectability and density of male Golden-cheeked Warblers (*Setophaga chrysoparia*) using the most supported model used to estimate the population size of male Golden-cheeked Warblers on the Balcones Canyonlands National Wildlife Refuge (BCNWR; hereafter "BCNWR model"; Sesnie et al. 2016). We chose to evaluate this model because it was shown to perform well when compared to 6 intensive monitoring plots located within the BCNWR and we were interested in evaluating model performance on an independent dataset from another location, the Balcones Canyonlands Preserve (BCP), Travis County, Texas.

In the original agreement, we proposed to analyze point count data collected by the City of Austin and Travis County biologists in April 2017. After preliminary analysis and exploration of the data, we decided the data were too sparse to produce meaningful density estimates and agreed to use the point count data collected in 2011-2014 across the BCP to evaluate the BCNWR model. We predicted abundance on 18 intensive monitoring plots with mostly color-marked birds (70%) using this model to determine how well it predicted plot density compared to actual density calculated from territory monitoring.

Methods

Study area-The BCP is a 12,294 ha discontinuous preserve located in western Travis County and protects ~11,250 ha of juniper (*Juniperus ashei*) and oak (*Quercus* spp.) woodland. It is the largest protected area in recovery region 5 of the USFWS recovery plan (Groce et al. 2010). The dominant canopy species are Ashe juniper (*Juniperus ashei*), Texas red oak (*Quercus buckleyi*), plateau live oak (*Q. fusiformis*), shin oak (*Q. sinuata*), and cedar elm (*Ulmus crassifolia*).

Avian surveys-We conducted single observer, unlimited radius point surveys across the BCP during early April and mid-May, 2011-2014 (Figure 1). Point locations were created from a random grid with 250-m spacing over the BCP. Points were surveyed once for 5-mins beginning ~10 mins post-sunrise until ~1120 during good weather conditions (>50°, <12 mph winds, no or light precipitation). For each survey, observers recorded the time of, and distance and direction to initial detections of singing Golden-cheeked Warblers. Observers measured the distance between themselves (at points) and singing males using a laser range-finder or estimated distance when using a laser range-finder was not possible. Additionally, observers recorded weather information and UTM coordinates. Observers were trained in and tested for species song identification and distance estimation prior to beginning surveys.

Monitoring plots-We monitored Golden-cheeked Warblers on 18 study plots, ranging in size from 27 to 180 ha, to determine plot density and territory success from March-June 2011-2014. These study plots included 11 plots that had been monitored for several years prior to 2011; 7 additional plots were added to capture a greater diversity of local habitat conditions. We monitored territories 2-3 times per week to resight color-marked birds, delineate territories, and determine reproductive success. We calculated plot density as the sum of the total number of territories fully within the plot boundaries and 0.5 of the number of territories partially within plot boundaries.

Remotely-sensed habitat covariates-Following methods described in Sesnie et al. (2016), we developed covariates from remotely sensed data. We obtained LiDAR data gathered during 2012 and NAIP aerial imagery layers from 2014-2015. We scaled these data layers to a 10-m pixel and then calculated the focal mean of each variable for the 100-m radius around each point, which was the radius used in the BCNWR model (Sesnie et al. 2016). We created a digital terrain model from the LiDAR layer (see Sesnie et al. 2016 for full details on the process) to calculate 2 variables that represented terrain and ruggedness (roughness and solar radiation). We combined the NAIP and LiDAR layers to calculate 3 variables meant to capture woodland composition (canopy cover, juniper cover, and juniper composition, defined as juniper cover/canopy cover).

Density analysis-We predicted density of Golden-cheeked Warbler males and modeled relationships between density and woodland structure and terrain features using distance-based models in the R package, unmarked (Fiske et al. 2011). We included only detections within the first 3 min of the survey (Sesnie et al. 2016). We truncated detections at 115 m for the 2011-2014 data, which eliminated the largest 10% of detections (Buckland et al. 2001), and grouped the remaining detections into 4 unequal distance bins with approximately equal number of detections. We scaled all covariates prior to analysis to simplify model convergence (mean = 0, standard deviation = 1). We evaluated correlations

between variables prior to model building; all included variables had correlations < 0.40. We then estimated detectability using the half-normal detection model and the variables surface roughness and canopy cover and estimated density with the variables juniper composition (quadratic form), canopy cover, and solar radiation (quadratic form); these were the most supported detection function and covariates for detectability and density from the BCNWR model. We then used the relationships between density and habitat variables to predict density across the BCP for every 10-m pixel in GIS. To determine densities for each monitoring plot, we summed the predicted densities for each pixel within the plot. We report the detection probability and overall and plot-level density estimates.

To assess the predictive accuracy of the model, we then compared predicted plot densities to actual densities determined from intensive monitoring plots. We first calculated Pearson correlation coefficients (r) between predicted and actual densities. We plotted the regression points and conducted a 2-tailed t-test to assess whether the slope (m) differed significantly from 1 at $\alpha=0.05$, with 1 defining a perfect fit between predicted and actual densities. We assessed error by calculating the difference in the predicted and actual density for each plot and then calculated the Pearson's correlation coefficient to determine if there was a pattern in the errors. Last, we examined the magnitude of error by plotting the predicted density/actual density ratios against actual density.

Results

Eight observers (two per year) surveyed 1507 points across the BCP during 2011-2014 (Figure 1). Observers detected 484 singing Golden-cheeked Warblers at 408 points during the first 3 mins of surveys (77% of total detections for the 5-min survey). Covariates at the points were representative of the overall BCP (Table 1). Goodness-of-fit tests showed the model fit the data adequately ($P > 0.40$ for chi-square test and Freeman-Tukey test).

With the half-normal detection function and the covariates canopy cover and surface roughness, the overall detection probability was 0.26. Canopy cover had a positive effect on detectability ($\beta = 0.19$, 95% CI: 0.15, 0.24), whereas surface roughness had no effect on detectability ($\beta = -0.01$, 95% CI: -0.05, 0.32). The mean density from the model {canopy cover + juniper composition + canopy cover*juniper composition + solar radiation} was 0.28 (0.18 SD) males/ha, respectively. Predicted density was 0.80-35 times actual density for the 18 monitoring plots (Table 3).

Density increased with increasing canopy cover, peaked when juniper was ~80% of the canopy cover and across all levels of canopy cover, and was lowest at the mid-range of solar radiation values (Table 2).

Predicted and actual densities on 18 plots were highly correlated ($r = 0.70$; Fig. 2). However the slope differed significantly from 1 ($m = 0.46$, $P < 0.001$; Fig 2). We found a strong negative relationship in errors between predicted and actual density ($r = -.076$) and the slope differed from 1 ($m = -0.54$; Fig. 3). The model tended to overpredict across the range of densities (Fig. 3), but the magnitude of error was larger for plots with very low densities (Fig. 4).

Conclusions and Recommendations

We were able to fit the BCNWR model (Sesnie et al. 2016) to the BCP data collected during 2011-2014. However, the variables used to model detectability did not support the same relationships, e.g., we found no support for an effect of roughness and a positive effect of canopy cover, whereas BCNWR found a strong positive effect of surface roughness and negative effect of canopy cover (Sesnie et al. 2016). The detection probability for the BCNWR model applied to the BCP data was substantially lower than the BCP detection model applied in Reidy et al. (2017) (0.26 versus 0.56). Because the density estimate is directly linked to the detection probability, it is not surprising that this model overpredicted substantially more than the model in Reidy et al. (2017).

Predicted densities on BCP were closer to actual densities at high density plots (>0.30 males/ha). The model performed poorly at predicting density at low-density plots (<0.10 males/ha), which has been shown in other studies (O'Donnell et al. 2015, Reidy et al. 2016). We had a broader range of actual densities (0.01-0.49 males/ha on BCP; ~0.10-0.30 males/ha on BCNWR) and larger sample size (18 plots on BCP, 6 plots on BCNWR) to compare with predicted densities on BCP than on BCNWR. Because BCNWR did not have plots with actual densities <0.10 males/ha, the model's performance at these low densities on BCNWR is unknown. Possible reasons for poor performance at low densities is discussed in more detail in O'Donnell et al. (2015), but we will reiterate a few here. One often cited reason is survey duration, with longer surveys allowing for more possible movement of birds. However, we truncated the survey to 3-min, which performed well in Sesnie et al. (2016), and is only slightly longer than the 2-min duration recommended by Peak (2011). Another reason is if distances are systematically underestimated. Although observers spent significant field time estimating distances, observer bias was still present, as reported in Reidy et al. (2016), and this bias was not accounted for in the model we used herein. While Sesnie et al. (2016) also did not include observer, they surveyed each point four times by different observers and this approach may alleviate some observer effects. Besides survey duration and distance estimation, there are possibly biological reasons for the overprediction. Males at low density sites may sing more frequently if the pairing success is lower at low-density plots. Pairing success generally was high, but was lowest at the low density plots across the density gradient (City of Austin et al. 2014). Alternatively, males may sing more at higher density plots because they are defending their territory against more neighbors. Singing rates recorded by automatic recording units were shown to be higher on higher density plots (Warren et al. 2013). How changes in singing rates across the density spectrum affect density estimation remains an interesting avenue to explore.

Despite the overall poor predictive ability of the model, predicted relationships between Golden-cheeked Warbler density and habitat and terrain features were similar between the BCP and BCNWR. Golden-cheeked Warbler density was predicted to increase with increasing canopy cover for both BCNWR and BCP and peaked when the woodland composition was ~80% juniper on BCP, whereas as density peaked when juniper composition was ~70% on BCNWR (Sesnie et al. 2016). Density was lowest in the middle range of solar radiation values, similar to the pattern shown on BCNWR (Sesnie et al. 2016). We did have a wider range of solar radiation, including some extreme outliers, and predicted densities were unreasonably high at the low end of the values.

The pattern of overprediction we have observed now with multiple models fit to point counts on the BCP is common (Howell et al. 2004, Toms et al. 2006, Peak 2011) but problematic. For example, conservation and management goals often rely on identification of high-quality properties to prioritize use of limited resources, but results of multiple point count studies have shown that distinguishing high from low density sites may be hindered because the bias is often much greater for low density sites, making them appear like they support more birds than they do. Therefore, there is continued interest in closer examination of the modeling process, the design and covariates used, and underlying sources of error and bias that may be causing this pattern. Our large sample of point count data across the BCP (1507 points) and number of plots monitored between 2011-2014 (n = 18) provide a unique opportunity to explore what is happening at low densities and whether model performance can be improved to provide more accurate estimates across the density spectrum.

During Year 2 of our collection agreement, we will investigate fitting better-performing models by examining the effects of count duration, truncation distances or fixed radii for detections, and models based on time of detection and distance to detections, and further exploration of additional covariates to explain density relationships. We will develop a model using the model selection process based on the

full 5-min and unlimited radius surveys conducted during 2011 through 2014 using updated remotely sensed-based covariates to estimate male Golden-cheeked Warbler density. We will also develop models for 2-min and 3-min surveys (by truncating detections of singing to those within the first 2 or 3 min of the survey, respectively) and for 50-m and 100-m maximum radii to provide a deeper understanding of how design changes can influence the model's estimates. We will then predict density across the BCP using a 10-m grid and sum those pixel-level densities for the intensive monitoring plots to compare to actual densities from territory monitoring.

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Figure 1. Locations of Golden-cheeked Warbler surveys conducted in 2011-2014 (purple points) within Balcones Canyonlands Preserve (black outline), Travis County, Texas. Intensive monitoring plots are shown in yellow outline. Background is percent of canopy cover.

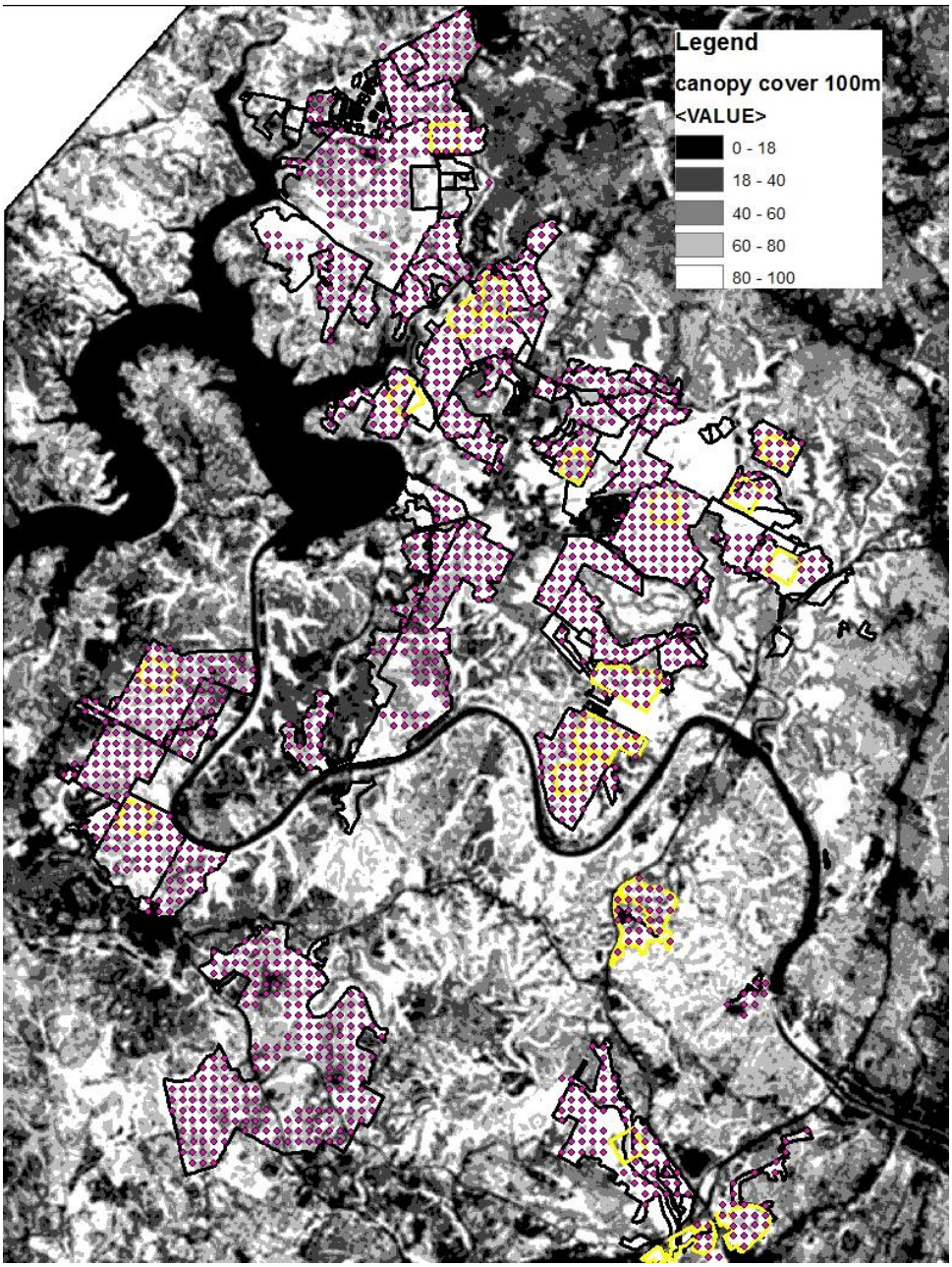

Figure 2. Relationship between predicted (model-based density generated from most supported model in Sesnie et al. 2016) and actual densities of male Golden-cheeked Warblers on the Balcones Canyonlands Preserve, Travis County, Texas, 2011-2014. Pearson correlation coefficient (*r*) indicates high correlation between predicted and actual densities but slope (*m*) indicates the relationship differed across the spectrum of plot densities.

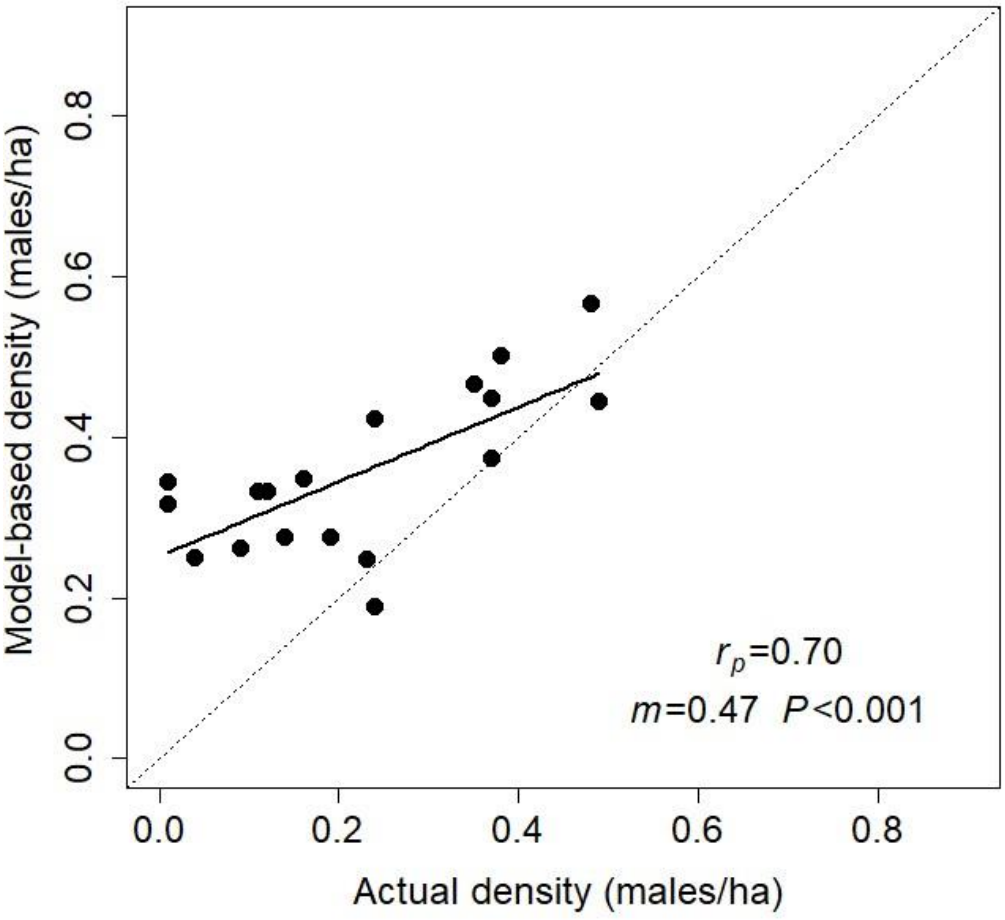

Figure 3. Relationship between the error (difference) of predicted (model-based density generated from most supported model in Sesnie et al. 2016) and actual densities of male Golden-cheeked Warblers on the Balcones Canyonlands Preserve, Travis County, Texas, 2011-2014. Pearson correlation coefficient (r) indicates a strong negative correlation between predicted and actual densities and the slope (m) indicates the relationship between errors differed across the spectrum of plot densities, declining at higher densities.

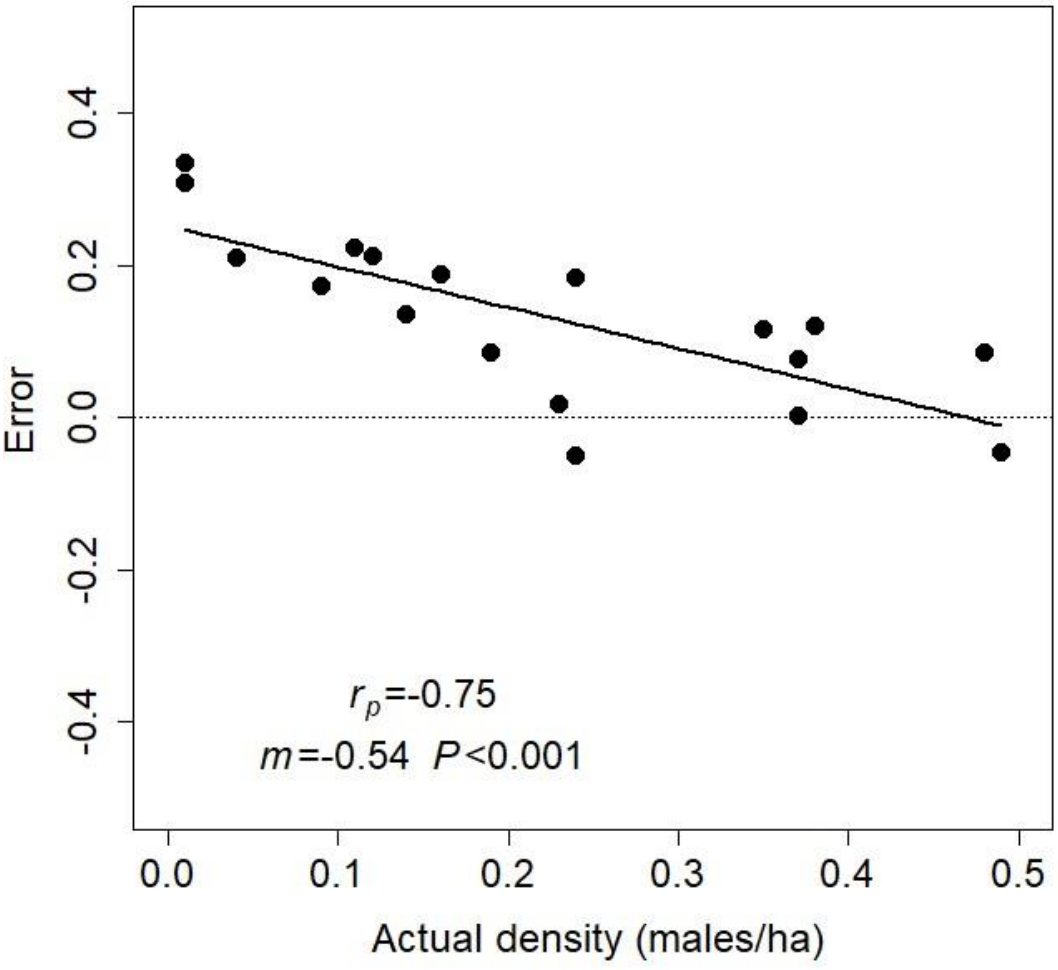

Figure 4. Relationship between the magnitude of error (predicted density generated from most supported model in Sesnie et al. 2016/actual density) and actual densities of male Golden-cheeked Warblers on the Balcones Canyonlands Preserve, Travis County, Texas, 2011-2014.

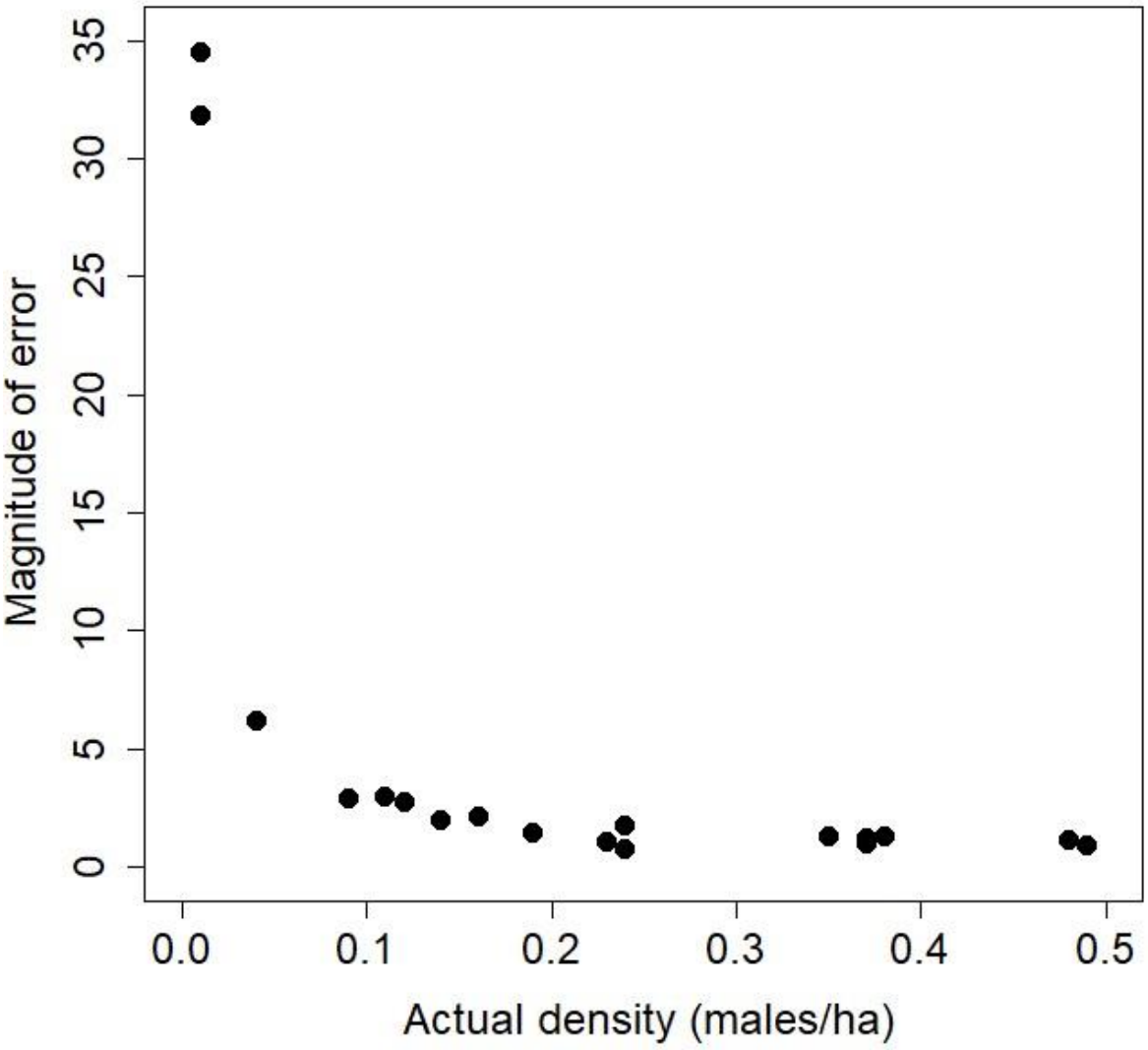

Table 1. Descriptive statistics of variables used to predict density of male Golden-cheeked Warblers for 1507 points and for the entire Balcones Canyonlands Preserve, Travis County, Texas, 2011-2014.

	Points (n=1507)				Raster (n=1,232,377 pixels)			
Variable	Mean	SD	Min	Max	Mean	SD	Min	Max
Canopy cover	82.5	16.2	2.9	100.0	82.0	16.4	0.5	100.0
Juniper composition	76.4	16.4	0.0	100.0	75.7	17.1	1.4	100.0
Solar radiation	1445052.5	66214.1	912338.6	156563 5.0	1441910.4	68887.0	880977.0	1572070.0

Table 2. Beta estimates (β), standard deviations (SD), and 95% confidence intervals (LCL, UCL) for covariates used to predict density of Golden-cheeked Warbler males (generated from most supported model in Sesnie et al. 2016) on Balcones Canyonlands Preserve, Travis County, Texas, during 2011-2014.

Variable	β	SD	LCL	UCL
Intercept	-1.55	0.10	-1.74	-1.36
Canopy cover	0.80	0.13	0.54	1.04
Juniper composition	0.76	0.41	-0.03	1.55
Juniper composition^2	-0.89	0.40	-1.68	-0.09
Solar radiation	-1.38	0.60	-2.54	-0.21
Solar radiation^2	1.48	0.61	0.29	2.67

Table 3. Mean predicted (and 95% confidence intervals) and actual densities of Golden-cheeked Warblers for 18 intensive monitoring plots in Balcones Canyonlands Preserve, Travis County, Texas, surveyed during spring 2011-2014.

		Density	
Study area	Plot area (ha)	Predicted	Actual
Barton Creek Wilderness Area	40.5	0.348 (0.342, 0.353)	0.16
Emma Long	40.5	0.466 (0.462, 0.470)	0.35
Double J&T	40.5	0.263 (0.260, 0.267)	0.09
Forest Ridge	40.5	0.448 (0.442, 0.453)	0.37
Kent Butler	40.5	0.567 (0.563, 0.571)	0.48
3M	40.5	0.445 (0.441, 0.449)	0.49
Vista Point	40.5	0.374 (0.371, 0.379)	0.37
Baker	40.5	0.424 (0.420, 0.427)	0.24
Vireo Ridge	~45	0.248 (0.244, 0.252)	0.23
Lake Perspectives	40.5	0.276 (0.273, 0.279)	0.19
Wild Basin	180	0.250 (0.248, 0.253)	0.04
Coldwater	107	0.333 (0.331, 0.336)	0.11
Emma Long Bike Park	96	0.276 (0.274, 0.278)	0.14
Reicher Ranch	40.5	0.333 (0.330, 0.336)	0.12
Gus Fruh	85	0.318 (0.315, 0.321)	0.01
Sunset Valley	27	0.345 (0.341, 0.350)	0.01
Canyon Vista	40.5	0.501 (0.497, 0.504)	0.38

Hamilton	40.5	0.190 (0.188, 0.192)	0.24