DENSITY AND HABITAT USE OF GRAY VIREOS (*VIREO VICINIOR*) IN NORTHWESTERN NEW MEXICO: 2006-07 FINAL REPORT

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EXECUTIVE SUMMARY

Gray vireos breed throughout New Mexico west of the Great Plains, primarily in juniper woodlands of the foothills and mesas. Distribution of the species is patchy throughout its range, and many of the occupied habitats in New Mexico contain only a few territories. Probably the biggest threat to the gray vireo in New Mexico is habitat degradation, primarily due to habitat management activities and natural gas exploration. Natural gas development has fragmented habitats that were once relatively undisturbed by stripping areas of vegetation for the construction of new well pads and associated roads and pipeline right-of-ways (ROWs). Because the rate of natural development in the San Juan Basin has accelerated in recent years and is projected to continue into the foreseeable future, it is important that wildlife managers assess how these activities affect breeding bird communities.

In 2006-07, we randomly selected line transects and conducted distance sampling during the peak breeding period to estimate gray vireo density and identify occupied habitat. We established 29 transects in 2006 and 29 in 2007, each 1.75 km in length, for a total of 50.75 km per year and 101.50 km over the 2-year study. To compare occupied gray vireo habitat to the proportion of available habitat in our study area, we established plots and collected data on habitat characteristics at gray vireo detection and randomly selected sites. The following variables were measured: elevation; slope; aspect; tree height; tree density; snag density; canopy cover; tree diameter at ankle height (DAH); shrub density; percentage of live ground cover, including shrubs, grasses, and forbs; and percentage of non-live ground cover, including rock, litter, woody debris, and bare ground. In addition to these variables, for each detection and random habitat plot we used ARCMAP to measure the distance to the nearest active natural gas well, road, and habitat edge. We also quantified the number of natural gas wells within a 2-km and 5-km radius of each gray vireo detection and random habitat plot.

We observed 28 gray vireos on 52% of survey transects in 2006, and 32 vireos on 70% of transects surveyed in 2007. The best estimate of gray vireo density was 0.044 ± 0.013 (SE; n = 23) in 2006 and 0.066 ± 0.028 (SE; n = 29) in 2007. Our density estimates for gray vireo are similar to that from other recent studies utilizing distance sampling in Colorado, Utah, and California; therefore, our data suggests that current gray vireo density in the San Juan Basin of northwestern New Mexico is similar to that across the species' range. In a comparison of habitat variable means, only elevation differed between gray vireo detection plots and randomly selected plots. Multiple logistic regression analyses indicated that gray vireo use areas were slightly higher in elevation and contained a lower percentage of downed woody debris than randomly selected sites. Our data also suggests that gray vireo use areas have fewer trees >4 m in height and more trees <2 m in height than the proportion of available habitat. The results of our GIS analysis indicate that the density of natural gas wells and the proximity of wells and roads did not appear to influence gray vireo occupancy in the San Juan Basin.

Now that baseline estimates of density for gray vireo have been established in northwestern New Mexico, additional research is needed on population status, specifically nesting success, fledgling survival, and site fidelity. This information will be useful for land managers to assess population status as natural gas exploration continues to expand into the future.

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INTRODUCTION

Gray vireo (*Vireo vicinior*) is a short-distance migrant that breeds only in the hot, arid regions of the southwestern U.S. and northwestern Mexico. Throughout its range, gray vireos generally prefer piñon-juniper, scrubland, or chaparral habitats in arid, mountainous terrain or high plains (Barlow et al. 1999). In New Mexico, the species is primarily associated with juniper (*Juniperus* spp.) woodlands of the foothills and mesas, usually with well-developed grassy understory, and in some areas, a piñon (*Pinus edulis*) or oak (*Quercus* spp.) component (New Mexico Department of Game and Fish [NMDGF] 2004). Gray vireos are found throughout New Mexico west of the Great Plains; however, distribution is patchy and the majority of occupied habitats contain less than 10 territories (DeLong and Williams 2006). Gray vireo populations have disappeared from some historic areas in New Mexico; however, recent investigations have identified new or previously unknown breeding territories throughout the state (NMDGF 2004). Among these are 44 newly discovered breeding territories in piñon-juniper woodlands on Bureau of Land Management (BLM) Farmington Field Office (FFO) Resource Area lands in McKinley, Rio Arriba, and San Juan Counties (Reeves 1999). Currently, the best estimate available of gray vireo population size in New Mexico is 418 territories, and density estimates throughout the state range from 0.005–0.023/ha (DeLong and Williams 2006). These estimates were based on available data for the species up to 2005 including but not limited to "…published records, contractor and agency reports, written and personal communications, Breeding Bird Survey (BBS) data, personal observations, museum records, nest card data, records from *Audubon Field Notes/American Birds* (1948 to present), records from *New Mexico Ornithological Society Field Notes* (1962 to present), and information in the New Mexico Ornithological Society Archives…" (DeLong and Williams 2006). However, to our knowledge, there have been no studies of gray vireo in New Mexico utilizing sampling techniques specifically designed to estimate density.

Probably the biggest threat to the gray vireo in New Mexico is habitat degradation, primarily due to management activities such as burning and grazing, and perhaps more importantly, clearing for development. In the San Juan Basin of northwestern New Mexico, extensive loss and fragmentation of piñon-juniper woodlands has occurred as a result of clearing for industrial development, particularly natural gas exploration. Natural gas exploration has been occurring in the San Juan Basin since the 1940s but has increased significantly since the onset of coal-bed methane production that began in the 1980s (U.S. Department of the Interior [USDI], Bureau of Land Management [BLM] 2003). Currently, San Juan County in northwestern New Mexico is the largest natural gas producing county in the state (USDI BLM 2003). Natural gas development has fragmented habitats that were once relatively undisturbed by stripping areas of vegetation for the construction of new well pads (disturbing 3 acres each, on average), and associated roads and pipeline right-of-ways (ROWs). Because the rate of natural development in the San Juan Basin has accelerated in recent years and is projected to continue into the foreseeable future (USDI BLM 2003), it is important that wildlife managers assess how these activities affect breeding bird communities. In addition to natural gas development, recent drought in the Four Corners region has resulted in extensive piñon pine (*Pinus edulis*) mortality, primarily through outbreaks of Ips beetles (*Ips confusus*) and other insect infestations. To our knowledge, there is no information available on the effects of rapid tree die-offs on gray vireo distribution, abundance, or density.

The objectives of this study were to establish baseline estimates of gray vireo density in northwestern New Mexico, where natural gas wells are present at relatively high densities and dominate the landscape, and to identify habitat characteristics that may be important to the species during the breeding season. Of particular interest is the proportion of dead trees, density of natural gas wells, and the distance from occupied habitat to natural habitat edges and man-made disturbances including roads, well pads, and ROWs. This information will be particularly useful to wildlife managers in New Mexico in assessing the impacts of habitat altering projects and/or developments on breeding populations of gray vireos.

STUDY AREA AND METHODOLOGY

Study Area

The study was conducted in 2006 and 2007 on BLM FFO Resource Area lands in San Juan and Rio Arriba Counties, New Mexico (Fig. 1). Topography in this region includes broad mesas intersected by steep, rocky canyons and relatively level valley flats and floodplains. The San Juan River is the largest perennial water source in the study area and extends east to west through San Juan County in the northern portion of the BLM Farmington Resource Area (Fig. 1). The study was conducted on those portions of BLM lands occurring in piñon-juniper woodlands or juniper savanna, the preferred habitat of gray vireos in the region (Fig. 1). Elevation in the study area ranges from approximately 1,675 and 2,285 m (5,500 and 7,500 ft). The study area is dominated by piñon pine and Utah juniper (*Juniperus osteosperma*), with Gambel oak (*Quercus gambelii*) present in some areas. Common understory vegetation in the study area includes big sagebrush (*Artemisia tridentata*), Morman tea (*Ephedra viridis*), mountain mahogany (*Cercocarpus montanus*), antelope bitterbrush (*Purshia tridentata*), cheatgrass (*Bromus tectorum*), Indian ricegrass (*Achnatherum hymenoides*) western wheatgrass (*Pascopyrum smithii*), blue grama (*Bouteloua gracilis*), galleta (*Pleuraphis jamesii*), buckwheat (*Eriogonum* spp.) and groundsel *(Senecio multilobatus)*.

Survey Site Selection.—Prior to initiating fieldwork, all piñon-juniper and juniper savannah habitats were identified on BLM FFO lands using the Provisional Data Set for the Southwest Regional Gap Program (http://earth.gis.usu.edu/swgap/). These habitats were mapped on U.S. Geological Survey (USGS) 7.5-minute topographic survey maps using ESRI ARCMAP © Version 9.2 (ARCMAP; Fig. 1). Prior to fieldwork in 2006 and 2007, we randomly selected 29 start points for survey transects within the available piñon-juniper and juniper savanna habitat using Hawth's Analysis Tools © Version 3.23. A random bearing for each transect was also selected using a random numbers table. Using the random starting points and bearings we established 29 transects each year, each 1.75 km in length, on USGS 7.5-minute topographic survey maps using ARCGIS. Total length of transects per year was 50.75 km; 101.50 km were surveyed over the 2-year study. After transects were established, topography and land ownership along each transect were evaluated to determine accessibility. When transects were determined to be inaccessible due to extreme terrain (e.g. steep mesas with sheer rock faces) or private land ownership, we established new transects using the same random selection process. Spatial transect data were downloaded into handheld Garmin Global Positioning Systems (GPS) for navigation in the field.

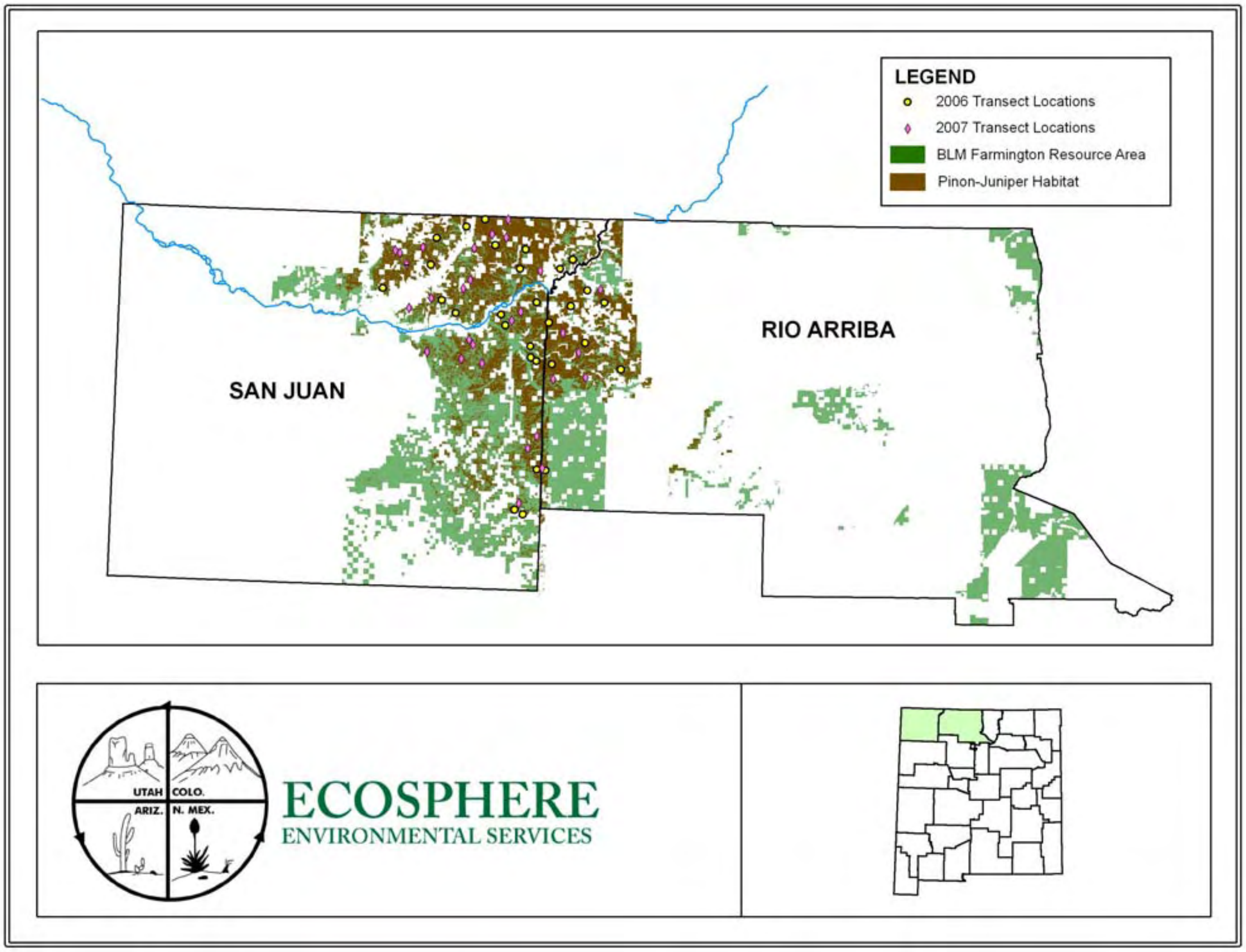

Figure 1. Locations of gray vireo survey transects in San Juan and Rio Arriba Counties, New Mexico, 2006-07.

Methodology

Line Transect Surveys.—To estimate density of gray vireos and identify occupied habitat, we conducted distance sampling using the line-transect survey approach. Surveys were conducted during the peak breeding period for this species, mid May to late June, with each transect surveyed once during the study. Surveys occurred within 30 minutes of sunrise and 1100 hours. Observers walked the length of each transect slowly, listening and watching for gray vireos. Handheld Garmin GPS units and compasses were used to insure observers did not veer from the transect line. When large obstacles such as trees occurred along the transect line, observers would walk around the obstacles, then position themselves back on the transect line. When gray vireos were detected, observers measured: 1) the distance from the transect line to the bird to the nearest meter using Bushnell laser range finders, and 2) the bearing from the observer to the bird using compasses. If vireos were detected aurally but were visually obstructed by trees, observers first marked their location on the transect line using their GPS unit as well as colored flagging, and then walked to and recorded the bird's location using the GPS. If the flagging on the transect line was visible from the detection location, observers measured the distance and reverse bearing back to the transect line using the laser rangefinders and compasses as described above. If the flagging was not visible, the distance and bearing were recorded using the handheld GPS units. For these detections, each distance was recorded in 10 m intervals. For all gray vireo detections, observers recorded the distance and bearing for the location that the bird was first detected; that is, if vireos moved due to an approaching observer, only the initial location of the bird was marked. If observers could not determine the initial location of the bird, it was not recorded. For all detections, after recording distance and bearing, observers walked to the location of each bird, recorded their locations using GPS units, and placed colored flagging at the detection site. The flagged locations served as the center points for habitat sampling plots (refer to *Habitat Sampling*). These locations would be used for further analysis using ARCMAP (refer to *GIS Analysis*).

Habitat Sampling.—Habitat sampling was completed between mid May and late June in each year. After line transect surveys were completed, observers revisited gray vireo detection sites and established 11.3-m radius (0.04 ha) vegetative sampling plots centered at each site (Martin et al. 1997). Habitat characteristics were measured in each sampling plot following a modified BBIRD protocol (Martin et al. 1997). The following variables were measured: elevation; slope; aspect; tree height; tree density; snag density; canopy cover; tree diameter at ankle height (DAH); shrub density; percentage of live ground cover, including shrubs, grasses, and forbs; and percentage of non-live ground cover, including rock, litter, woody debris, and bare ground. Slope was measured using a clinometer. Aspect was measured using a compass and was categorized as north, east, south, or west based on the following groups: north = 0°–45° and 316°–360°; east = 46°–135°; south = 136°–225°; and west = 226°–315°. Height of all trees within the circular sampling plots was measured using a clinometer; each tree was placed into one of three categories (0.5–2.0 m; >2.0 m–4.0 m; and >4.0 m). Tree density was determined by counting the number of trees greater than 0.5 m in height within the circular plot. We identified trees to species, measured the DAH, and placed each tree into one of the following three categories: 8–23 cm; >23–38 cm; and >38 cm (Martin et al. 1997). DAH was measured rather than diameter at breast height (DBH) because juniper trees often contain numerous trunks separated only at the base of the tree. All dead trees (snags) greater than 8 cm DAH were counted to determine snag density. Canopy cover was measured with a concave spherical densiometer at eight different points within the 11.3-m radius circle. Each gray vireo detection plot was centered at a tree; therefore, to reduce bias in canopy cover estimates, we did not record densiometer readings at the plot center. Rather, densiometer readings were taken: 1) at the edge of the circle and 2) halfway from the edge to the center of the plots, facing the center point, at each of the four cardinal directions (north, east, south, and west). Mean canopy cover was then calculated based on the eight densiometer readings. Shrub density was determined by counting the number of shrubs greater than 0.5 m in height within the 11.3-m radius circle. Percentages of live and non-live ground cover were visually estimated within the sampling plots using the following categories: 1 = 0–10%; 2 = 11–20%; 3 = 21–30%; 4 = 31–40%; 5 = 41–50%; 6 = 51–60%; 7 = 61–70%; 8 = 71–80%; 9 = 81–90%; and 10 = 91–100%.

To compare occupied gray vireo habitat with randomly selected sites, or the proportion of available habitat, we randomly selected habitat sampling plots for comparison in ARCMAP using Hawth's Analysis Tools ©. The locations of random plots were downloaded into handheld

Garmin GPS units for ease of navigation in the field. Random plots were centered at the tree closest to the random point in the field. Trees were used as the center points for random plots because 100% of the gray vireo detection locations were located in trees. The center points of each random habitat sampling plot were marked in the field using handheld Garmin GPS units for further analysis (refer to *GIS Analysis*). We performed the same modified BBIRD habitat sampling methodology for randomly selected plots that was used for gray vireo detection sites.

GIS Analysis.—In addition to collecting habitat data in the field, we used ARCMAP to quantify the potential disturbance of natural gas development on gray vireo habitat on BLM lands in the FFO Resource Area. To accomplish this we first created a master map showing the locations of gray vireo detections, center points of randomly-selected habitat sampling plots, and active natural gas wells in San Juan and Rio Arriba Counties. Gray vireo detections and center points of random habitat plots were mapped on USGS 7.5-minute topographic survey maps using the GPS data collected in the field. We obtained the most recent GIS shapefile from the New Mexico Oil Conservation Division (NMOCD) depicting all active natural gas wells in San Juan and Rio Arriba County, and these locations were subsequently overlaid onto the topographic maps. We also overlaid the most recent (2005-06) digital ortho photos for San Juan and Rio Arriba Counties obtained from the New Mexico Resource Geographic Information System (RGIS; available at http://rgis.unm.edu/intro.cfm). In ARCMAP, we measured the distance from each gray vireo detection site and each random habitat plot center point to: 1) the nearest active natural gas well; 2) the nearest road; and 3) the nearest habitat edge (e.g., roads, pipeline ROWs, or natural habitat edges). Roads, pipeline ROWs, and natural habitat edges were visible on the 2005-06 digital ortho photos. In addition to these measurements, we also quantified the number of natural gas wells within a 2-km and 5-km radius of each gray vireo detection site and random habitat plot center point. To insure we counted all wells within these radius classes, we used the multiple ring buffer tool in ARCMAP to create visible 2-km and 5-km circles around each detection location and each random habitat plot center point. We then used the intersect tool in ARCMAP to create individual shapefiles that depicted only the active wells within each 2-km and 5-km radius circle surrounding each gray vireo detection and random point.

Statistical Analysis.—Line transect survey data was analyzed using program DISTANCE, version 4.1 (Thomas et al. 2003). We analyzed the survey data and estimated density separately for 2006 and 2007. For each year, the survey data was pooled for all transects to determine a detection function and estimate density. For each gray vireo detection, the radial distance and bearing collected in the field was converted to a perpendicular distance prior to data analysis using trigonometry. Because some of the distance data (i.e., those recorded using GPS units) were recorded in 10 m intervals, the DISTANCE analysis was grouped into 10 m intervals prior to data analysis. To take into account potential outliers, the data were right truncated to remove approximately 5% of the detections with the greatest distances. In DISTANCE, three key functions were performed on the data to estimate the detection function—uniform, half-normal, and hazard rate. For each of these analyses, the cosine series adjustment was used, if necessary (Buckland et al. 1993). After running these analyses, the best model was selected using Akaike's Information Criterion for small sample size (AIC_c), where the model with the smallest AIC_c indicates the best model. Model fit was evaluated using a Chi-square goodness-of-fit test in program DISTANCE. For this test, higher *P*-values indicate that the data fit the model well.

All habitat sampling data was analyzed using SYSTAT 12 (Systat Software, Inc. ©). For each habitat variable except aspect, we present the means and standard errors (SE) for gray vireo detection plots and randomly selected plots, as well as the effect size (difference between the means) and 95% confidence interval (CI) around the effect size (Anderson et al. 2001, Di Stefano 2004). Because aspect data was categorical and not continuos, we used a Chi-square test of association to determine if aspect differed between gray vireo detection and randomly selected plots. To identify habitat characteristics that may be important to gray vireos on BLM lands in the FFFO Resource Area, we employed a binary logistic regression analysis. Occupied and randomly selected habitat sampling plots were binary independent variables. We reduced the number of candidate independent variables by conducting univariate logistic regression analyses for each habitat variable (Hosmer and Lemeshow 1989), retaining variables that differed between occupied and randomly-selected plots and using an alpha level of ≤0.15. We performed logistic regression using all variables (full model) and on all subsets of the full model. We ranked models using AIC_c (Anderson et al. 2001), and present all models where Δ AIC_c <2.

RESULTS

Density.—In 2006, we observed 28 gray vireos on 15 of the 29 (52%) transects surveyed (Fig 2). Four of these detections were too far for observers to get an accurate distance; therefore, these birds were not included in the DISTANCE analysis. In 2007, we observed 32 gray vireos on 20 of the 29 (70%) transects surveyed (Fig 2). Two of these detections were not included in the DISTANCE analysis because they were too far for observers to get an accurate distance. Density was estimated separately for each year. We did not attempt to estimate the density of breeding pairs because females as well as males may sing during the breeding season (Barlow et al. 1999), and we did not take the time to follow birds and explore their territories to determine if they were male or female. In 2006, the best model estimating detection probability and density of gray vireos was the uniform key function with one cosine series adjustments (Table 1). The estimate of gray vireo density of this model is 0.044 ± 0.013 (SE). The Chi-square goodness-of-fit test for the uniform key function model indicated that the data were a good fit to the model (χ^2 = 1.916, df = 4, *P* = 0.751). Estimates of gray vireo density in 2006 for the two alternate models ranged from 0.040 to 0.045, with each model having a Δ AIC_c of <2 (Table 1). In 2007, the best model estimating detection probability and density of gray vireos was the hazard rate function with no cosine series adjustments (Table 1). The estimate of gray vireo density of this model is 0.066 ± 0.028 (SE). The Chi-square goodness-of-fit test for the uniform key function model indicated that the data are a good fit to the model (χ^2 = 0.531, df = 2, *P* = 0.767). The estimate of gray vireo density in 2007 for the two alternate models were each 0.057, with each model having a Δ AIC_c of <2 (Table 1).

During line transect sampling in 2007, we located one active gray vireo nest (Fig. 3). The nest was located on Encinada Mesa in Rio Arriba County. At the time the nest was found, it was in the incubation stage. Due to time constraints and the location of the nest (i.e., it was isolated from locations of additional fieldwork efforts), we did not re-visit the nest to determine nest fate.

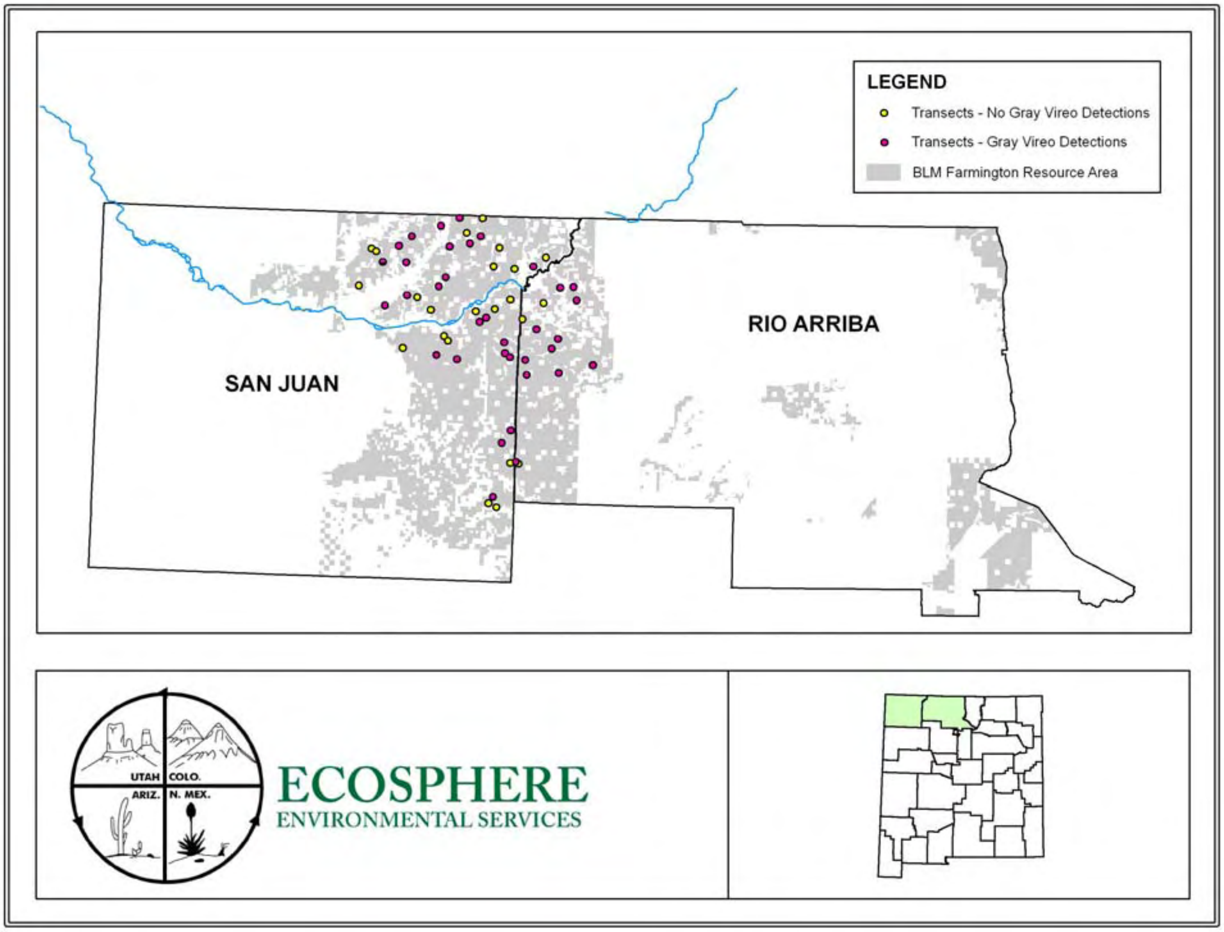

Figure 2. Locations of gray vireo detections in San Juan and Rio Arriba Counties, New Mexico, 2006-07.

Table 1. Summary of models generated in Program DISTANCE using the uniform, hazard rate, and half-normal key functions for gray vireo survey data collected in San Juan and Rio Arriba Counties, New Mexico in 2006 (n = 23[a]) and 2007 (n = 29[a]).

Model	Density (birds/ha ± SE)	95% CI	% CV	AIC_c	Δ AIC_c	Detection Probability	Encounter Rate
2006							
Uniform	0.044 ± 0.013	0.025−0.080	29.80	70.31	0.00	19.7	76.4
Half-normal	0.045 ± 0.015	0.024−0.086	32.73	70.34	0.03	33.4	63.3
Hazard Rate	0.040 ± 0.014	0.020−0.077	34.48	72.26	1.95	40.0	57.1
2007							
Hazard Rate	0.066 ± 0.028	0.029−0.151	42.40	84.20	0.00	82.2	16.1
Half-normal	0.057 ± 0.016	0.033−0.098	27.89	84.30	0.10	59.1	37.2
Uniform	0.057 ± 0.022	0.027−0.122	38.89	86.15	1.95	78.9	19.1

[a] Sample sizes reflect the number of birds included in the DISTANCE analysis after right truncating the data..

Figure 3. Gray vireo nest located on Encinda Mesa, San Juan County, New Mexico, 2007.

Habitat Modeling.—Habitat sampling plots and GIS analyses were conducted at 46 gray vireo detection sites and 50 random sites. For all continuous habitat variables except elevation, the 95% confidence interval (CI) around the effect size included 0, indicating there was no difference between detection and random plots (Table 2). Aspect also did not differ between gray vireo detection and randomly selected plots (χ^2 = 4.993, df = 3, P = 0.172; Table 3).

Of the habitat variables measured in the field and using GIS, four were retained for the multiple logistic regression analysis based on the results of the univariate regression analyses. These variables included elevation, number of trees 0.5−2.0 m, number of trees >4.0 m, and woody debris ground cover index (Table 4). Four models had a Δ AIC_c that was less than 2 (Table 5). Of these models, elevation was included in four, ground cover of woody debris in three, number of trees >4 m in two, and number of trees 0.5−2.0 m in one. All models where Δ AIC_c was less than 2 indicated that gray vireo use sites were likely to be slightly higher in elevation than the proportion of available habitat. Three of the four models with Δ AIC_c less than 2 indicated that gray vireo use areas were likely to contain less downed woody debris than the proportion of available habitat. Two models indicated that vireo use sites were likely to have fewer trees greater than 4.0 m tall than the proportion of available habitat. Finally, in one model with Δ AIC_c of less than 2, gray vireo use areas were likely to contain more trees between 0.5 and 2.0 m than randomly selected sites. The best model predicting gray vireo habitat use included elevation and ground cover of woody debris (Table 5).

Table 2. Mean, standard error (SE), effect size, and 95% CI around effect size for habitat characteristics at gray vireo detection plots (*n* = 46) and randomly selected plots (*n* = 50) in San Juan and Rio Arriba County, 2006−07.

Habitat Variable	Detection Plots Mean ± SE	Random Plots Mean ± SE	Effect Size	95% CI
Elevation (m)	1,964.04 ± 16.23	1,917.70 ± 14.24	46.34	**3.46−89.23**
Slope (º)	6.67 ± 0.65	7.32 ± 0.82	-0.65	-2.72−1.43
Distance to nearest edge (m)	114.78 ± 15.90	122.98 ± 16.02	-8.20	-53.01−36.62
Distance to nearest gas well (m)	306.76 ± 34.50	384.48 ± 51.62	-77.72	-201.19−45.75
Distance to nearest road (m)	173.80 ± 17.24	194.70 ± 21.24	-20.90	-75.23−33.44
No. gas wells within 2 km radius	39.96 ± 2.10	38.70 ± 1.98	1.26	-4.47−6.99
No. gas wells within 5 km radius	252.07 ± 11.62	235.88 ± 10.16	16.19	-14.48−46.86
No. trees 8–23 cm DAH	3.72 ± 0.51	4.22 ± 0.71	-0.50	-2.24−1.23
No. trees >23–38 cm DAH	2.72 ± 0.36	2.54 ± 0.34	0.18	-0.80−1.16
No. trees > 38 cm DAH	4.15 ± 0.49	3.70 ± 0.44	0.45	-0.85−1.75
Total no. trees	10.59 ± 0.87	10.46 ± 1.12	0.13	-2.69−2.94
No. junipers	7.74 ± 0.76	7.50 ± 0.87	0.24	-2.04−2.52
No. piñons	2.85 ± 0.56	2.96 ± 0.53	-0.11	-1.64−1.42
No. trees 0.5–2.0 m tall	1.74 ± 0.39	1.06 ± 0.22	0.68	-0.22−1.58
No. trees 2.0–4.0 m tall	7.15 ± 0.69	6.80 ± 0.82	0.35	-1.77−2.48
No. trees >4.0 m tall	1.70 ± 0.32	2.60 ± 0.41	-0.90	-1.92−0.12
No. snags	2.35 ± 0.40	2.12 ± 0.46	0.23	-0.94−1.40
Percent canopy cover	20.04 ± 2.04	16.38 ± 1.79	3.66	-1.73−9.05
No. shrubs	34.63 ± 3.95	32.94 ± 3.46	1.69	-8.74−12.12
Ground cover index – live[a]	1.53 ± 0.08	1.55 ± 0.07	-0.02	-0.23−0.20
Ground cover index – non-live[a]	2.62 ± 0.07	2.71 ± 0.09	-0.10	-0.32−0.13
Ground cover index – grass[a]	1.44 ± 0.17	1.32 ± 0.09	0.12	-0.28−0.50
Ground cover index – forb[a]	1.07 ± 0.04	1.06 ± 0.04	0.01	-0.11−0.12
Ground cover index – shrub[a]	2.11 ± 0.16	2.28 ± 0.16	-0.17	-0.62−0.28
Ground cover index – bare[a]	5.13 ± 0.29	5.06 ± 0.28	0.07	-0.73−0.87
Ground cover index – rock[a]	2.11 ± 0.27	2.12 ± 0.24	-0.01	-0.73−0.70
Ground cover index – woody[a]	1.20 ± 0.06	1.39 ± 0.09	-0.18	-0.39−0.02
Ground cover index – litter[a]	2.04 ± 0.10	2.28 ± 0.18	-0.24	-0.66−0.18

[a] Values for ground cover indices described in Methodology.

Table 3. Frequency table comparing aspect between gray vireo detection (*n* = 46) and randomly selected (*n* = 50) habitat plots in San Juan and Rio Arriba County, 2006-07.

	Detection Plots		**Random Plots**		**Total**	
Aspect	**Frequency**	**Percent**	**Frequency**	**Percent**	**Frequency**	**Percent**
North	12	12.5	14	14.6	26	27.1
East	9	9.4	17	17.7	26	27.1
South	18	18.8	10	10.4	28	29.2
West	7	7.3	9	9.4	16	16.7
Total	**46**	**47.9**	**50**	**52.1**	**96**	100

Table 4. Results of univariate logistic regression analysis for habitat characteristics at gray vireo detection plots (*n* = 46) and randomly selected plots (*n* = 50) in San Juan and Rio Arriba County, 2006-07.

Habitat Variable	Estimate ± SE	Z	*P*
Elevation (m)	0.004 ± 0.002	2.082	**0.037**
Slope (º)	-0.025 ± 0.040	-0.615	0.539
Aspect – North	0.097 ± 0.639	0.152	0.879
Aspect – East	-0.385 ± 0.651	-0.591	0.555
Aspect – South	0.839 ± 0.640	1.311	0.190
Aspect – West [a]	[a]	[a]	[a]
Distance to nearest edge (m)	-0.001 ± 0.002	-0.366	0.715
Distance to nearest gas well (m)	-0.001 ± 0.001	-1.158	0.247
Distance to nearest road (m)	-0.001 ± 0.002	-0.759	0.448
No. gas wells with 2 km radius	0.006 ± 0.015	0.440	0.660
No. gas wells within 5 km radius	0.003 ± 0.003	1.048	0.294
No. trees 8–23 cm DAH	-0.027 ± 0.048	-0.571	0.568
No. trees >23–38 cm DAH	0.031 ± 0.086	0.363	0.717
No. trees > 38 cm DAH	0.045 ± 0.065	0.697	0.486
Total no. trees	0.003 ± 0.029	0.089	0.929
No. junipers	0.008 ± 0.036	0.209	0.835
No. piñons	-0.008 ± 0.055	-0.147	0.883
No. trees 0.5–2.0 m tall	0.153 ± 0.103	1.485	**0.138**
No. trees 2.0–4.0 m tall	0.013 ± 0.039	0.329	0.742
No. trees >4.0 m tall	-0.151 ± 0.090	-1.674	**0.094**
No. snags	0.027 ± 0.071	0.386	0.699
Percent canopy cover	0.022 ± 0.016	1.334	0.182
No. shrubs	0.003 ± 0.008	0.326	0.744
Ground cover index – live[b]	-0.065 ± 0.391	-0.166	0.868
Ground cover index – non-live[b]	-0.310 ± 0.373	-0.831	0.406
Ground cover index – grass[b]	0.136 ± 0.227	0.598	0.550
Ground cover index – forb[b]	0.066 ± 0.724	0.091	0.928
Ground cover index – shrub[b]	-0.141 ± 0.187	-0.757	0.449
Ground cover index – bare[b]	0.019 ± 0.105	0.177	0.860
Ground cover index – rock[b]	-0.004 ± 0.118	-0.032	0.975
Ground cover index – woody[b]	-0.728 ± 0.429	-1.699	**0.089**
Ground cover index – litter[b]	-0.221 ± 0.202	-1.095	0.273

[a] Values not generated in SYSTAT.
[b] Values for ground cover indices described in Methodology.

Table 5. Logistic regression models predicting gray vireo use areas (n = 46) compared with randomly selected habitat (n = 50) in Rio Arriba and San Juan County, New Mexico, 2006-07.

Model	AIC_c	ΔAIC_c	-2loge(L)	w^b	P^c
-10.099 + (0.006 E) + (-1.113 W)	128.758	0.00	122.158	0.098	0.005
-10.545 + (0.006 E) + (-0.130 T4) + (-0.878 W)	129.342	0.584	120.316	0.073	0.006
-9.809 + (0.006 E) + (0.116 T2) + (-1.101 W)	129.942	1.184	120.916	0.054	0.007
-9.433 + (0.005 E) + (-0.187 T4)	130.328	1.570	123.728	0.045	0.010

[a] E = Elevation; T2 = No. trees 0.5–2.0 m; T4 = No. trees > 4 m; and W = Ground cover index – woody debris
[b] Akaike weight
[c] Probability values from χ^2 test of overall model significance

DISCUSSION

Density.—Our density estimates for gray vireo in 2006 and 2007 (0.044 and 0.066 birds/ha, respectively) are similar to that from other recent and historical studies utilizing distance sampling. Recent estimates of gray vireo density include 0.064 birds/ha in Arizona and southern Utah (Schlossberg 2006), 6.85 birds/km^2 (0.069 birds/ha) in western Colorado and southern Utah (Hutton et al. 2006), 0.055 birds/ha in the Colorado National Monument (Giroir 2001 in Winter and Hargrove 2004), and 6 birds/100 ha (0.060 birds/ha) on BLM lands throughout Colorado (Colorado BLM 1995). In two earlier studies not utilizing distance sampling, Weathers (1983) reported 1.6 gray vireos/40 ha (0.040 birds/ha) in California and Grinnell and Swarth (1913) estimated gray vireo density at one pair per 40 acres (0.124 birds/ha). While Grinnell and Swarth's estimate would indicate gray vireos are twice as dense as in our study and other recent studies, their estimate was not based on systematic sampling efforts but rather observational studies. Our and other recent density estimates are higher than that reported by DeLong and Williams (2006); however, their methods also did not include distance sampling. Because our density estimate is similar to other recent density estimates in Colorado, Utah, and California, our data suggests that current gray vireo density in the San Juan Basin of northwestern New Mexico is similar to that across the species' range.

Habitat Modeling.—Results of habitat modeling indicated that gray vireos may prefer habitat that is higher in elevation than the proportion of available habitat in our study area. The logistic regression analyses suggested that vireos may prefer habitat that is only slightly higher in elevation; but, a comparison of mean elevation of gray vireo use areas and randomly selected sites also showed clear differences between the two samples. Schlossberg (2006) also reported a relationship between elevation and gray vireos; however, in his study area, vireo density was higher in lower-elevation (1,500−1,900 m) compared with higher elevation (>1,900 m) sites. Schlossberg's (2006) data suggests that habitats between 1,500 and 1,900 m are most important to gray vireos on the Colorado Plateau and should be given priority for conservation of the species. In our study, however, 34 of 46 (74%) gray vireo detections occurred above 1,900 m. In Nevada, Johnson (1972) also reported a higher overall elevation range (1,830−2,100 m) for gray vireo. These somewhat contradictory results may be a function of the difference in elevation range between study areas as well as vegetative characteristics. Elevation included in the Schlossberg (2006) habitat analyses ranged from approximately 1,550−2,100 ft, whereas elevation in our analyses ranged between 1,725−2,228 ft. Schlossberg (2006) also reported that some vegetative characteristics influenced gray vireo density, specifically the proportion of junipers and cover of big sagebrush (*Artemisia tridentata*). His analyses indicated that the influence of elevation on gray vireo density was largely independent of vegetation; however, some vegetative characteristics, such as proportion of junipers, were associated with lower elevation habitats. In our study, proportion of junipers did not influence gray vireo presence/absence nor did we observe other trends in vegetative data that would be associated with elevation.

Other habitat characteristics that appeared to influence gray vireo occupancy in this study include tree height and percentage of downed woody debris. Some of the best logistic regression models indicated that vireos may prefer sites with fewer tall, presumably mature, trees. One of these models also suggested that vireos may select sites with a higher proportion of shorter, presumably younger, trees. Of all habitat characteristics included in the logistic regression analyses, however, the strongest relationship appeared to be with downed woody debris. Specifically, gray vireo detection sites had less woody debris than the proportion of available habitat. None of these trends in habitat characteristics were observed in the recent Schlossberg (2006) study of gray vireos on the Colorado Plateau.

The results of our GIS analysis indicate that the density of natural gas wells and the proximity of wells and roads do not appear to influence gray vireo distribution in the San Juan Basin. Overall, density of natural gas wells in our study area was relatively high (Table 2) and we were unable to delineate areas of contiguous habitat in our study area. Because potential gray vireo habitat is so highly dissected with wells, roads, and pipeline ROWs, there may be few places to establish a territory without being close to a disturbed area. Because we have no data on distribution, density, or abundance prior to the natural gas exploration boom in the San Juan Basin, additional studies comparing relatively contiguous potential gray vireo habitat with that of the San Juan Basin would be helpful in determining if natural gas exploration has any measurable impacts on gray vireo distribution and density.

MANAGEMENT IMPLICATIONS

We recommend continued monitoring and additional studies of gray vireo density and distribution, breeding season productivity, and survival into the future as natural gas exploration continues and expands. While we did not discover any relationship between occupancy and well density or proximity to roads/wells, occupancy is just one aspect of gray vireo biology. With a baseline density estimate established, further study is crucial to evaluate the impacts of increased natural gas development on the San Juan Basin population of gray vireos. In addition to monitoring bird density, research is needed on productivity and recruitment of future generations. Specifically, studies are needed to evaluate gray vireo nesting success, fledgling survival, and site fidelity. Of particular interest is: 1) the level of nest predation and brood parasitism by brown-headed cowbirds (*Molothrus ater*); 2) the influence of noise (from pumpjacks and compressors) on nesting success; 3) the influence of habitat patch size and proximity of gas wells and roads on fledgling movements and survival; and 4) the level of site fidelity of first year birds.

Few trends in habitat characteristics were found for occupied gray vireo habitat compared with randomly selected sites; however, our data suggests that vireos may prefer areas at slightly higher elevation, with fewer mature trees, and less downed woody debris than the proportion of available habitat. Based on the range of elevation at which we detected gray vireos and the known range of elevation in the BLM FFO Resources Area, elevation does not appear to be a crucial factor for gray vireo conservation in northwestern New Mexico. Of more importance may be maintaining enough stands of piñon-juniper woodlands of appropriate age and size. The BLM FFO Resource Area contains stands of piñon-juniper woodlands of a variety of age and size classes (USDI BLM 2003). If vireos prefer stands with shorter, presumably younger trees, the BLM FFO may consider land management prescriptions (e.g., fire, logging/chaining) that would facilitate maintaining a mosaic of piñon-juniper stands in varying ages throughout the district, to insure that potential habitat for gray vireos is available into the future.

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APPENDIX A

REPRESENTATIVE PHOTOS OF GRAY VIREO DETECTION SITES

Photo 1. Gray vireo detection site on Devil Mesa, Rio Arriba County.

Photo 2. Gray vireo detection site on Devil Mesa, Rio Arriba County.

Photo 3. Gray vireo detection site on Crow Mesa, San Juan County.

Photo 4. Gray vireo detection site on Crow Mesa, San Juan County.

Photo 5. Gray vireo detection site in the vicinity of Farmington, San Juan County.

Photo 6. Gray vireo detection site in Miller Canyon, San Juan County.

Photo 7. Gray vireo detection site near Armenta Canyon, San Juan County.

Photo 8. Gray vireo detection site on Encinada Mesa, Rio Arriba County.