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

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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, gray vireos are primarily associated with juniper woodlands of the foothills and mesas, usually with a well-developed grassy understory, and in some areas, a piñon or oak component (New Mexico Department of Game and Fish [NMDGF] 2004). Currently, gray vireo is listed as threatened by the state of New Mexico (NMDGF 2004) and a Species of Conservation Concern by the U.S. Fish and Wildlife Service (USFWS; USFWS 2002). In addition, gray vireo is listed as a Highest Priority Species in piñon-juniper woodlands by New Mexico Partners in Flight (NMPIF; NMPIF 2003). Despite its status in New Mexico, few data are available on distribution and abundance of gray vireo in New Mexico and no data are available on density.

Probably the biggest threat to 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 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 development 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 northwestern New Mexico 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.

While gray vireo populations have disappeared from some historic areas in New Mexico, 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). While Reeves' (1999) study demonstrated that gray vireos may not be as rare on BLM FFO Resource Area lands as previously thought, his study methodology focused on vireo distribution rather than density and abundance. To date, there are no density estimates available for gray vireo in New Mexico; however, there are some recent data available for this species in Colorado (Colorado BLM 1995, Giroir 2001 in Winter and Hargrove 2004), and Arizona and Utah

(Schlossberg 2006). Schlossberg's 2006 study suggests that gray vireo populations may be "relatively safe" for the time being.

The objectives of this study were to establish baseline estimates of gray vireo density in northwestern New Mexico and to identify habitat characteristics that may be important to the species during the breeding season by comparing sites that are occupied by vireos with randomly selected sites. Of particular interest is the percentage of dead trees, the density of natural gas wells, and the distance from occupied habitat to edges and 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 on BLM Farmington 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, 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 (*Pinus edulis*) 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 9.1 (Fig. 1). We randomly selected 29 start points for survey transects within the available 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, 29 transects, each 1.75 km in length, were drawn on USGS 7.5-minute topographic survey maps in ARCMAP. 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

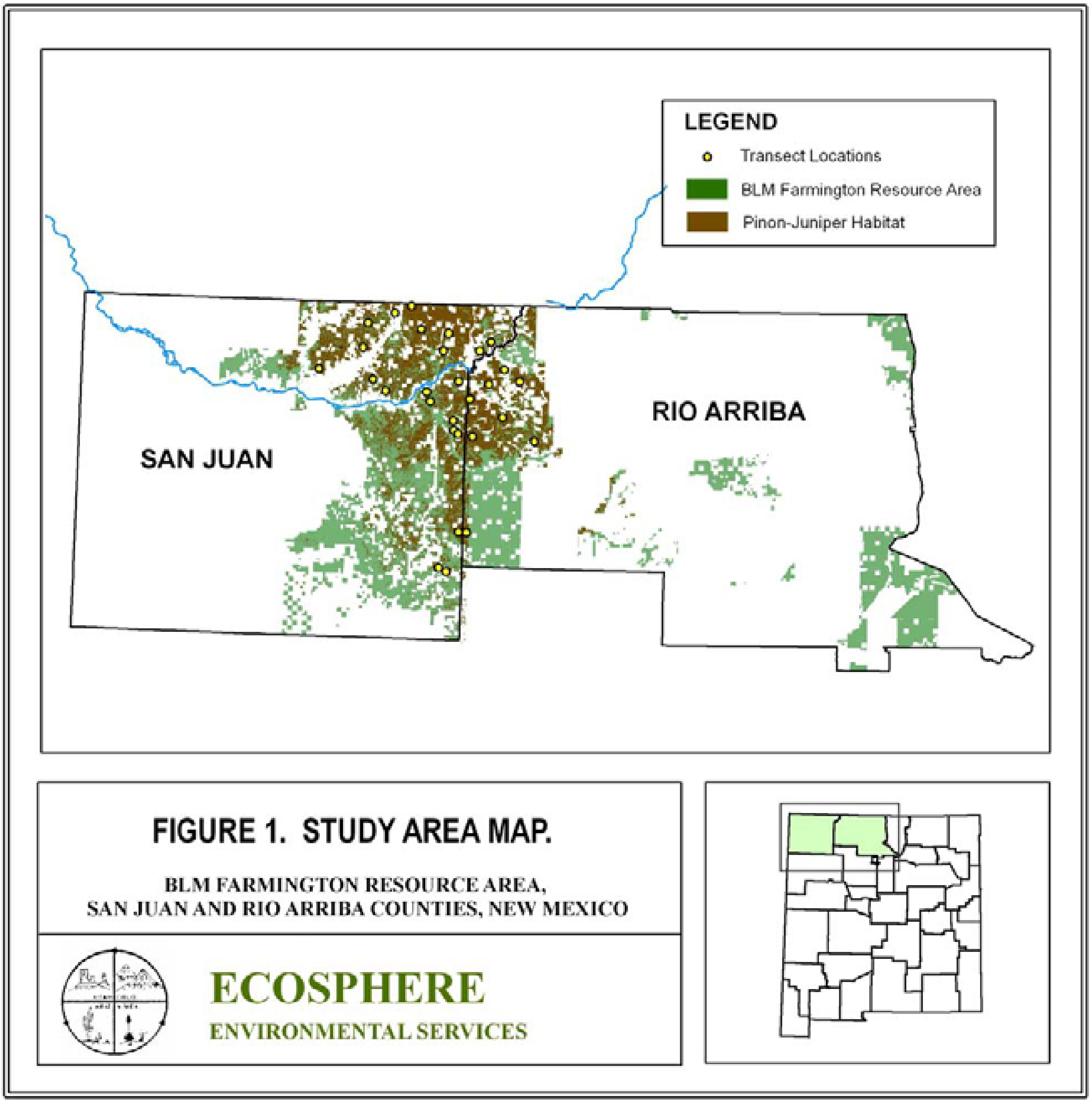

FIGURE 1. STUDY AREA MAP.

BLM FARMINGTON RESOURCE AREA,
SAN JUAN AND RIO ARRIBA COUNTIES, NEW MEXICO

transect data were downloaded into handheld Garmin Global Positioning Systems (GPS) for navigation in the field.

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, May to mid June, with each transect surveyed once during the study. Surveys began within 30 minutes of sunrise and were completed by 10:00

a.m. Observers walked the length of each transects 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 vireos were detected, observers measured the distance from the transect line to the bird to the nearest meter using Bushnell laser range finders. Compasses were used to measure the bearing from the observer to the bird. After measuring the distance and bearing, observers walked to and recorded each bird's exact location using handheld Garmin GPS units. These locations would be used for further analysis using ARCMAP (refer to GIS Analysis). Detection locations were also marked with flagging in the field to serve as the center point for habitat sampling plots.

Habitat Sampling.—Habitat sampling was completed between mid May and late June, 2006. 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 and aspect was measured using a compass. Aspect 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 >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. One densiometer reading was taken at the edge of the circle, facing the center, at each of the four cardinal directions (north, east, south, and west). Additional densiometer readings were taken halfway from the edge to the center of the circle, facing the center, at each of the four cardinal directions. Mean canopy cover was calculated from the eight measurements. 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 in the, 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 Farmington 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 shapefiles from the BLM FFO, depicting the locations of 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) 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 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.

Statistical Analysis.—Line transect survey data was analyzed using program DISTANCE (Thomas et al. 2003). 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 was converted to a perpendicular distance prior to data analysis using trigonometry. To take into account potential outliers, the data were right truncated to remove 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 analysis, 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 the Kolmogorov-Smirnov 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 11 (Systat Software, Inc. ©). For each habitat variable, 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). To identify habitat characteristics that may be important to gray vireos on BLM lands in the Farmington 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 Akaike's Information Criterion modified for small sample size (AIC_c; Anderson et al. 2001), and present all models where $\Delta AIC_c < 2$.

RESULTS

Density.—We observed 28 gray vireos during line transect sampling; vireos were detected on 15 of the 29 (51.7%) transects surveyed (Fig 2). Four vireo detections were too far for observers to get an accurate distance; therefore, these birds were not included in the DISTANCE analysis to avoid biasing the data. Based on the criteria described in the Methodology Section, the best model estimating detection probability and density of gray vireos was the Uniform key function with two cosine series adjustments (Table 1). The estimate of gray vireo density based on this model was 0.056 ± 0.023 (SE) birds/ha. 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. The Kolmogorov-Smirnov goodness of fit test for the uniform key function model indicated that the data are a good fit to the model (D_n = 0.141, P = 0.821).

Habitat Modeling.—Habitat sampling plots and GIS analyses were conducted at 20 gray vireo detection sites and 24 random sites. Four of the 24 gray vireo detections used in the DISTANCE analysis were two individuals, presumably pairs, in one location. For these detections, only one habitat plot was established, thus reducing the number of plots from 24 to 20. Summary statistics of habitat variable data collected at occupied gray vireo sites and random sites are presented in Table 2. For all habitat variables except distance to the nearest habitat edge, the 95% confidence interval (CI) around the effect size includes zero, indicating there is no difference between detection plots and random plots. For 70% of the gray vireo detection plots and 75% of the random plots, the closest habitat edge was manmade; that is, either a road, ROW, or well pad. The remaining 30% and 25% of detection and random plots, respectively, were edges created by natural breaks in habitat types. Based on the GIS analysis, it was apparent that the density of natural gas wells in the study area is very high (mean = 257 wells/5-km radius). Furthermore, the study area is highly dissected by roads, as approximately 95% of the line transects surveyed crossed at least one existing road.

Of the habitat variables measured in the field and using GIS, six variables were retained for the multiple logistic regression analysis based on the results of the univariate regression analyses. These variables included: distance to the nearest edge; distance to the nearest natural gas well; distance to the nearest road; number of natural gas wells within a 5-km radius; number of trees greater than 4m in height; and percent bare ground (Table 3). Eleven models had a ΔAIC_c that was less than 2 (Table 4). Five of the six habitat variables were represented in these models; however, one variable, distance to the nearest road, was not included in any of the models where $\Delta AIC_c < 2$ (Table 4). The final model predicting gray vireo occupancy included two variables—

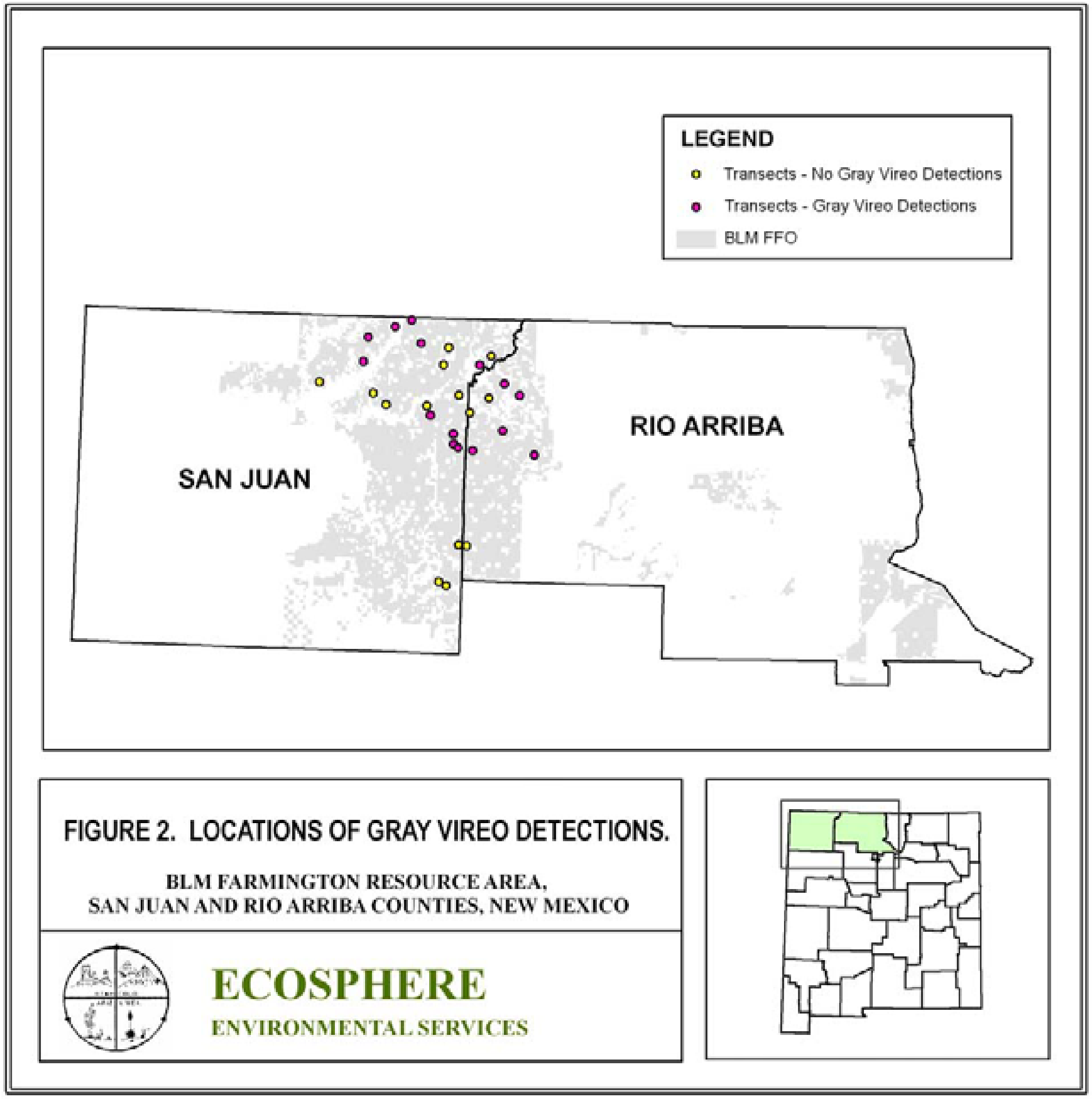

FIGURE 2. LOCATIONS OF GRAY VIREO DETECTIONS.

BLM FARMINGTON RESOURCE AREA, SAN JUAN AND RIO ARRIBA COUNTIES, NEW MEXICO

Table 1. Summary of models generated in Program DISTANCE using the uniform, hazard rate, and half-normal key functions for gray vireo survey data (n = 24) collected in San Juan and Rio Arriba Counties, New Mexico, 2006.

Model	Detection Probability ± SE	Density (Birds/ha ± SE)	95% CI	CV	Effective Strip Width	AIC_c
Uniform	0.428 ± 0.140	0.056 ± 0.023	(0.025, 0.127)	0.424	41.76	174.53
Hazard Rate	0.448 ± 0.117	0.053 ± 0.020	(0.026, 0.111)	0.375	43.71	175.00
Half-normal	0.506 ± 0.065	0.047 ± 0.014	(0.026, 0.085)	0.297	49.37	176.18

Table 2. Mean, standard error (SE), effect size, and 95% CI around effect size for habitat characteristics at gray vireo detection plots (n = 20) and randomly selected plots (n = 24) on BLM FFO Resource Area lands in San Juan and Rio Arriba County, 2006.

Habitat Variable	Detection Plots Mean ± SE	Random Plots Mean ± SE	Effect Size	95% CI
Elevation (m)	1,949.95 ± 21.16	1,923.58 ± 19.30	-26.37	-84.22, 31.49
Slope (º)	6.95 ± 1.12	7.58 ± 1.20	0.63	-2.68, 3.94
Aspect[a]	2.40 ± 0.23	2.38 ± 0.23	-0.03	-0.69, 0.64
Distance to nearest edge (m)	**77.90 ± 19.60**	**150.63 ± 24.15**	**72.73**	**9.93, 135.52**
Distance to nearest gas well (m)	220.60 ± 18.79	387.88 ± 93.97	167.28	-30.15, 364.70
Distance to nearest road (m)	134.40 ± 22.10	191.08 ± 28.34	56.68	-15.89, 129.25
No. gas wells with 2 km radius	44.35 ± 2.24	40.92 ± 3.00	-3.43	-11.00, 4.13
No. gas wells within 5 km radius	273.10 ± 11.30	240.88 ± 16.39	-32.23	-72.48, 8.03
No. trees 8–23 cm DAH	2.90 ± 0.74	4.63 ± 1.12	1.73	-0.99, 4.44
No. trees >23–38 cm DAH	2.10 ± 0.44	2.75 ± 0.51	0.65	-0.69, 1.99
No. trees > 38 cm DAH	4.55 ± 0.68	4.04 ± 0.72	-0.51	-2.51, 1.49
Total no. trees	9.55 ± 0.85	11.42 ± 1.65	1.87	-1.89, 5.63
No. junipers	7.25 ± 0.93	7.83 ± 1.26	0.58	-2.57, 3.74
No. piñons	2.30 ± 0.72	3.58 ± 0.92	1.28	-1.07, 3.63
No. trees 0.5–2.0 m tall	0.50 ± 0.18	0.96 ± 0.30	0.46	-0.25, 1.17
No. trees 2.0–4.0 m tall	7.50 ± 0.87	7.88 ± 1.28	0.38	-2.74, 3.49
No. trees >4.0 m tall	1.55 ± 0.29	2.58 ± 0.45	1.03	-0.05, 2.11
No. snags	2.80 ± 0.68	3.38 ± 0.83	0.58	-1.58, 2.73
Canopy cover (%)	18.75 ± 2.15	17.96 ± 2.84	-0.79	-7.98, 6.39
No. shrubs	37.35 ± 5.86	29.67 ± 4.68	-7.68	-22.86, 7.49
Ground cover – live[b]	1.46 ± 0.09	1.40 ± 0.10	-0.07	-0.42, 0.29
Ground cover – grass[b]	1.50 ± 0.26	1.29 ± 0.13	-0.21	-0.80, 0.38
Ground cover – forb[b]	1.00 ± 0.00	1.00 ± 0.00	0.00	0.00, 0.00
Ground cover – shrub[b]	1.88 ± 0.19	1.92 ± 0.25	0.04	-0.59, 0.67
Ground cover – bare[b]	5.29 ± 0.26	4.46 ± 0.36	-0.83	-1.73, 0.07
Ground cover – rock[b]	1.63 ± 0.23	0.29 ± 0.36	0.67	-0.21, 1.54
Ground cover – woody[b]	1.20 ± 0.09	1.25 ± 0.09	0.05	-0.21, 0.31
Ground cover – litter[b]	1.95 ± 0.11	2.17 ± 0.21	0.22	-0.28, 0.71

[a] Values for aspect described in Methodology.
[b] Values for ground cover classes described in Methodology.

Table 3. Results of univariate logistic regression analysis for habitat characteristics at gray vireo detection plots (n = 20) and randomly selected plots (n = 24) on BLM FFO Resource Area lands in San Juan and Rio Arriba County, 2006.

Habitat Variable	Estimate ± SE	t	*P*
Elevation (m)	0.003 ± 0.003	0.927	0.354
Slope (º)	-0.022 ± 0.057	-0.388	0.698
Aspect 1[a]	-0.118 ± 0.518	-0.227	0.820
Aspect 2[a]	0.037 ± 0.529	0.069	0.945
Aspect 3[a]	0.373 ± 0.502	0.743	0.457
Aspect 4[a]	[b]	[b]	[b]
Distance to nearest edge (m)	-0.007 ± 0.004	-2.057	**0.040**
Distance to nearest gas well (m)	-0.007 ± 0.003	-2.148	**0.032**
Distance to nearest road (m)	-0.004 ± 0.003	-1.479	**0.139**
No. gas wells with 2 km radius	0.022 ± 0.025	0.888	0.375
No. gas wells within 5 km radius	0.007 ± 0.005	1.506	**0.132**
No. trees 8–23 cm DAH	-0.087 ± 0.072	-1.208	0.227
No. trees >23–38 cm DAH	-0.141 ± 0.148	-0.948	0.343
No. trees > 38 cm DAH	0.048 ± 0.094	0.515	0.606
Total no. trees	-0.047 ± 0.049	-0.954	0.340
No. junipers	-0.022 ± 0.059	-0.368	0.713
No. piñons	-0.090 ± 0.086	-1.053	0.292
No. trees 0.5–2.0 m tall	-0.349 ± 0.289	-1.209	0.227
No. trees 2.0–4.0 m tall	-0.014 ± 0.058	-0.239	0.811
No. trees >4.0 m tall	-0.333 ± 0.191	-1.743	**0.081**
No. snags	-0.046 ± 0.088	-0.531	0.595
Canopy cover (%)	0.006 ± 0.026	0.220	0.826
No. shrubs	0.013 ± 0.013	1.034	0.301
Ground cover – live[b]	0.206 ± 0.533	0.387	0.699
Ground cover – grass[b]	0.278 ± 0.372	0.747	0.455
Ground cover – forb[b]	0.000 ± 0.000	[b]	[b]
Ground cover – shrub[b]	-0.038 ± 0.292	-0.132	0.895
Ground cover – bare[b]	0.371 ± 0.218	1.701	**0.089**
Ground cover – rock[b]	-0.334 ± 0.235	-1.419	0.156
Ground cover – woody[b]	-0.288 ± 0.731	-0.393	0.694
Ground cover – litter[b]	-0.321 ± 0.379	-0.846	0.398

[a] Values for aspect described in Methodology.
[b] Values not generated in SYSTAT.
[c] Values for ground cover classes described in Methodology.

Table 4. Logistic regression models predicting occupied gray vireo habitat compared with randomly selected habitat on BLM FFO land in Rio Arriba and San Juan County, New Mexico, 2006.

Model	AIC_c	ΔAIC_c	-2loge(L)	w^b	P^c
2.585 + (−0.008 W) + (−0.389 T)	56.62	0.00	50.02	0.10	0.005
0.716 + (−0.007 W) + (−0.403 T) + (0.342 B)	56.77	0.15	47.75	0.09	0.005
−0.251 + (−0.008 E) + (−0.418 T) + (0.366 B)	57.13	0.51	48.11	0.08	0.006
1.539 + (−0.008 E) + (−0.405 T)	57.31	0.69	50.71	0.07	0.007
2.413 + (−0.004 E) + (−0.005 W) + (−0.004 T)	58.08	1.45	49.05	0.05	0.009
1.681 + (−0.007 W)	58.24	1.61	53.94	0.04	0.010
−0.061+ (−0.007 W) + (0.330 B)	58.30	1.68	51.70	0.04	0.011
0.576 + (−0.004 W) + (−0.004 E) + (0.343 B) + (−0.407 T)	58.39	1.76	46.81	0.04	0.008
−1.950 + (−0.008 E) + (0.367 B) + (−0.386 T) + (0.006 N)	58.48	1.86	46.90	0.04	0.008
−0.101 + (−0.008 E) + (0.006 N) + (−0.381 T)	58.55	1.92	49.52	0.04	0.011
1.472 + (−0.007 W) + (0.004 N) + (−0.374 T)	58.55	1.93	49.52	0.04	0.011

[a] B = Bare ground; E = Distance to nearest edge; N = Number of gas wells within 5 km; T = Number of trees > 4m; and W = Distance to nearest gas well
[b] Akaike weight
[c] Probability values from χ^2 test indicating overall model significance

distance to the nearest natural gas well and the number of trees greater than 4 m in height (Table 4). This model predicted that gray vireos are more likely to be found in areas slightly closer to a natural gas well with fewer trees greater than 4 m than the proportion of available habitat.

Nine of the models where $\Delta AIC_c < 2$ indicated that vireos prefer habitat with fewer trees greater than 4 m in height; seven models indicated that vireos may use habitat slightly closer to a natural gas well (Table 4). Of the other three habitat variables, six of the models indicated that gray vireos may be found in areas that are closer to habitat edges; five models suggested that vireos may use habitat with a higher percentage of bare ground; and three models indicated that vireos may prefer habitat with a slightly higher density of natural gas wells (Table 4).

DISCUSSION

Density.—Our density estimate for gray vireo (0.056 birds/ha) is similar to that from other recent and historical studies. Most recently, Schlossberg (2006) reported gray vireo density from 31 sites in Arizona and southern Utah at 0.064 birds/ha and Hutton et al. (2006) reported density in western Colorado and southern Utah at 6.85 birds/km^2 (0.069 birds/ha). Gray vireo density from other recent studies in Colorado included 6 birds/100 ha (0.060 birds/ha) on BLM lands throughout the state (Colorado BLM 1995) and 0.055 birds/ha at Colorado National Monument (Giroir 2001 in Winter and Hargrove 2004). In California, Weathers (1983) reported 1.6

birds/40 ha (0.040 birds/ha) and Grinnell and Swarth (1913) estimated 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 the other recent studies, their estimate was not based on systematic sampling efforts but rather observations studies. Because our density estimate is similar to other recent density estimates in Colorado, Utah, and California, our preliminary data suggests that gray vireo distribution and abundance is similar across the species' range and that the high level of natural gas development activities have had little affect on the density or abundance of gray vireos on BLM lands in San Juan and Rio Arriba Counties. However, because we have no density data from San Juan and Rio Arriba Counties prior to the natural gas exploration boom in the 1940s, we cannot make conclusions on the impact of natural gas development on vireo abundance or density. That is, it is possible that gray vireos were more abundant prior to natural gas development in San Juan Basin than they are presently.

Habitat Modeling.—Results of the habitat analyses were variable. The best logistic regression model indicated that gray vireos may prefer habitat that is slightly closer to natural gas wells and absent of mature trees; however, comparison of habitat variable means between gray vireo detection plots and randomly selected plots indicated that there were no differences between all but one habitat variable. The inconsistency in these analyses may be a result of the relatively small sample size (n = 20 detection plots and n = 24 random plots); thus additional data are needed to more accurately assess potential preferences in habitat for this species. Our preliminary habitat data analysis does indicate, however, that gray vireos may not be deterred from occupying habitat close to natural gas well and roads in the San Juan Basin. While the best logistic regression model suggests that gray vireos may prefer habitat that is slightly closer to at least one well pad, several other models where $\Delta AIC_c < 2$ also indicate that gray vireos may prefer habitat with slightly higher density of gas wells compared with the proportion of available habitat. Furthermore, several of the regression models suggest that vireos prefer habitat that is closer to edges, and approximately 70–75% of the "closest habitat edges" measured in this study were related to natural gas development (i.e., roads, ROWs, well pads). Alternatively, these counterintuitive results may be related to the relatively high level of natural gas development in the study area. Because potential gray vireo habitat is so highly dissected with wells, roads, and ROWs, there may be few places to establish a territory without being close to a disturbance. If this is indeed the case, the argument that vireos are not avoiding areas developed by natural gas wells would be stronger, at least at the current density of wells in the study area. Additional studies would then be needed to determine at what level of disturbance (i.e., well and road density) gray vireos avoid areas in search of more contiguous habitat.

Other than tree height and percentage of bare ground, no other vegetative variables appeared to be important in predicting gray vireo habitat. In a recent study, Schlossberg (2006) found that gray vireos in Arizona and Utah prefer juniper-dominated woodlands with a high proportion of sagebrush cover. In our study, the proportion of junipers and overall shrub density and shrub cover were not included in the multiple logistic regression analysis because the corresponding univariate analyses did not reveal these variables to be potentially important. Additional data collected in 2007 will help determine if the trends form 2006 hold, or if other trends, such as shrub density and proportion of junipers, become apparent.

MANAGEMENT IMPLICATIONS

Based on the relatively small sample of data collected in 2006, it would be pre-mature to recommend specific management objectives for gray vireo in northwestern New Mexico. At this time, it does not appear that natural gas development has deterred gray vireos from habitat in northwestern New Mexico; although, we have no data on vireo density or abundance prior to the natural gas exploration boom in the San Juan Basin. Few trends in vegetative structure were found for occupied gray vireo habitat compared with randomly selected sites; however, our data suggests that vireos may prefer areas with shorter, less mature trees than the proportion of available habitat. The BLM Farmington Resource Area includes stands of piñon-juniper woodlands that are both relatively open and that form a dense canopy (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 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.

Surveys for gray vireo and habitat sampling will be conducted in 2007 as a continuation of our Share With Wildlife grant from NMDGF and these data will be combined with the 2006 data. We will analyze all the data in 2007 to determine if the trends from 2006 hold, or if other trends become apparent. The 2007 results will likely coincide with the final recovery plan for gray vireo, which is currently being developed through coordination of biologists throughout New Mexico. After the completion of this study and the implementation of the New Mexico recovery plan, management considerations and recommendations will be presented that address the specific concerns of the BLM and other land managers in the northwestern portion of the state.

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