Population size estimation of breeding Red-faced and Grace's Warblers in pine woodlands of New Mexico: 2017 Report

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Introduction

Effective management of wildlife populations requires accurate estimates of abundance and density to determine population status, monitor spatial and temporal changes in populations, evaluate the impacts of human disturbance, and evaluate the effectiveness of conservation actions and management strategies for sensitive species. The Red-faced Warbler (*Cardellina rubrifrons*) and the Grace's Warbler (*Setophaga graciae*) are New Mexico Department of Game and Fish (NMDGF) Species of Greatest Conservation Need (NMDGF 2016), and they have been identified as current priority nongame bird species. However, despite this conservation concern, much of the information necessary for effective conservation and management is lacking for these understudied species. Population estimates are limited for Grace's Warblers and speculative for Red-faced Warblers. Information about breeding biology for these two species is also limited, and for the Red-faced Warbler, no specific information exists for New Mexico (Martin and Barber 1995, Stacier and Guzy 2002). Nevertheless, both warbler species face high risk as they breed in pine habitats that have experienced loss and degradation over time. Apparent population declines and concerns about their status have fueled the need for information on regional and local abundance of these species. This project was conducted to estimate baseline population sizes of breeding Red-faced and Grace's Warblers in pine woodlands of New Mexico and produce density estimates for New Mexico's mountain ranges. This information will allow for future identification and documentation of status and trends and aid NMDGF with management decisions regarding these species.

The breeding distributions for both the Red-faced and Grace's Warbler are restricted to New Mexico, Arizona, and the Sierra Madre Occidental mountains of Mexico; thus, New Mexico serves an important role and has a high stewardship responsibility for these limited range species. The ranges of these two species overlap in southwest New Mexico in the San Mateo, Magdalena, Sacramento, and Gila mountain ranges. Grace's Warblers are additionally present in mountain ranges of central and northern New Mexico. Both species breed in high elevation (1,800-2,800 m) pine (*Pinus* spp.) and pine-oak (*Quercus* spp.) forests in New Mexico. Red-faced Warblers additionally utilize habitats that include Douglas fir (*Pseudotsuga menziesii*), fir (*Abies* spp.), spruce (*Picea* spp.), or quaking aspen (*Populus tremuloides*) while the Grace's Warbler is considered a pine specialist, most commonly occurring in ponderosa pine (*Pinus ponderosa*) woodlands.

Size of the New Mexico population for both of these species is unknown (NMPIF 2007). Grace's Warblers are more common, with a larger range, and are encountered more frequently on standardized surveys, such as the North American Breeding Bird Survey (BBS), than Red-faced Warblers (Sauer *et al.* 2017). Red-faced Warblers are detected on very few BBS routes, and their low detection rates prevent population size estimates using this method. Both Red-faced and Grace's Warbler are listed as a national and Southwest Region Bird of Conservation Concern by the U.S. Fish and Wildlife Service (USFWS 2008). New Mexico Avian Conservation Partners ranks both species as high conservation priority with high vulnerability as Level 1 Species of Conservation Concern (NMACP 2017). The Grace's Warbler's vulnerability is due to sharp population declines in New Mexico and the Red-faced Warbler's ranking stems from having a small distribution and small population size (NMPIF 2007). It is suggested these species are relatively intolerant of disturbance and habitat degradation (Martin and Barber 1995, Stacier and Guzy 2002). Potential factors influencing Red-faced and Grace's Warbler populations in New Mexico include habitat loss and alteration due to timber harvest and grazing, as well as recent loss from fire and current risk of catastrophic fire (NMDGF 2016). Therefore, it

is important to establish baseline information on breeding density, abundance, distribution, and population sizes in order to understand how these species are affected by potentially harmful activities and stressors.

To address this information need, we conducted surveys in the forested mountains of New Mexico in 2015-2017. In order to document population sizes of these species over the vast state of New Mexico, surveys were spread geographically over three years. Here we report the results from the third and final year of surveys and a comprehensive, state-wide analysis of the results synthesized from 2015 to 2017. Our objectives were to: (1) estimate densities of Grace's and Red-faced Warblers in mountain ranges in northern, central, southeastern, and southwestern New Mexico; (2) improve understanding of target species density distributions in New Mexico; (3) estimate regional and state-wide population sizes of Grace's Warblers and Red-faced Warblers; (4) provide baseline assessments and methodology that can be replicated to monitor species over time and determine population trends; and (5) provide information that can be used to assess species status and inform conservation planning. This information is currently unknown or limited and is necessary for effective management and conservation of these priority nongame bird species.

Methods

Site Selection

To determine population sizes of these species in New Mexico, surveys were designed to encompass their state-wide breeding ranges and significant mountain ranges. Study sites were located in montane pine forest habitat within Bernalillo, Catron, Cibola, Grant, McKinley, Mora, Otero, Rio Arriba, San Miguel, Sandoval, Santa Fe, Sierra, Socorro, Taos, Torrance, and Valencia counties (Map 1). 2015 and 2016 surveys were conducted in northern, central, and southeastern New Mexico in the Carson, Cibola, Lincoln, and Santa Fe National Forests. 2015 surveys were in the Sandia, Manzano, San Mateo, Magdalena, Zuni, and Jemez Mountains and 2016 surveys were in the San Juan, Jemez, Sangre de Cristo, and Sacramento Mountains. To complete state-wide surveys of suitable habitat, 2017 surveys were conducted in the Black Range, Gallo Mountains, Mogollon Mountains, Pinos Altos Range, San Francisco Mountains, and Tularosa Mountains in the Gila region of southwestern New Mexico (Maps 1 – 2). We stratified by U.S. Forest Service Ranger District to estimate warbler densities and population sizes within each district and National Forest; therefore, 2017 surveys were designed to cover each of the six districts in this large mountain region. 2017 project areas included the Black Range, Glenwood, Reserve, Silver City, and Wilderness Ranger Districts of the Gila National Forest, and the Quemado Ranger District of the Apache National Forest (Maps 3 – 8). All surveys were conducted on public lands and required no infrastructure or ground disturbance. Project areas were determined based on identification of suitable habitat for breeding Red-faced and Grace's Warblers using range maps, habitat maps, GIS layers, published literature, BBS sightings, eBird sightings, and general knowledge of the species. Within project areas, survey sites were selected in areas where approximately 2 miles of surveyable habitat was present, where land-ownership was public, and where ponderosa pine habitats were present along part of or the entire survey route. Survey routes were placed along drainages, mesas, ridges, trails, or decommissioned or old roads. Survey routes were conducted at elevations between 2,059 – 2,794 m (6,755 – 9,167 ft). Four survey routes were selected within each project area, and each route

was surveyed two times. Two routes in the Black Range district (2017) and one route in the San Mateo Mountains (2015) could not be accessed for the second round of surveys as they were within wildfire perimeters; therefore, three alternate routes were surveyed one time in their stead. A total of 26 survey routes and 889 survey points were sampled during 48 surveys in 2017, 20 survey routes and 750 survey points were sampled during 40 surveys in 2016, and 25 survey routes and 793 survey points were sampled during 48 surveys in 2015.

Survey Methodology

Point count surveys were conducted between May 1 and June 30 and followed survey guidelines outlined in Ralph et al. (1993, 1995). Two surveys were conducted at each survey route, and the two sampling periods at each route were spaced at least 10 days apart. Surveys were not conducted during inclement weather, including periods with winds > 10 mph or prolonged rain. Surveys began at 6 AM and concluded at 10 AM. Survey routes varied in length according to access, terrain, and habitat, but were approximately 2-2.5 miles long and typically contained 17-20 points. Point count locations were recorded using GPS receivers (UTM zone 12 and 13 in meters, NAD 1983 datum). Points were spaced 200-225 m apart along each transect, and all avian species either seen or heard within a 100 m radius of each point were recorded; detections outside this radius were excluded. Each point was surveyed for 10 minutes, and the 10 minute survey period was divided into three sequential time intervals (3 min, 2 min, and final 5 min) in order to determine detection probability (Farnsworth et al. 2002). Birds were recorded separately during each time interval, along with detection type (auditory, visual, or both). Location information was recorded for the two focal species and all other Species of Greatest Conservation Need detected during surveys. A habitat description was also recorded at each point location.

Analysis

Suitable habitat was estimated within each Ranger District using vegetation, canopy cover, and elevation data. GIS layers were acquired from the U.S. Forest Service for the Carson (https://www.fs.usda.gov/detail/r3/landmanagement/gis/?cid=stelprdb5202766), Cibola (http://www.fs.usda.gov/detail/r3/landmanagement/gis/?cid=stelprdb5212078), Santa Fe (http://www.fs.usda.gov/detail/r3/landmanagement/gis/?cid=stelprdb5203736), Lincoln (https://www.fs.usda.gov/detail/r3/landmanagement/gis/?cid=stelprdb5203236), and the Gila and Apache (https://www.fs.usda.gov/detail/r3/landmanagement/gis/?cid=stelprdb5203027) National Forests. We quantified vegetation and landscape characteristics using mid-scale, extant vegetation dominance type and canopy cover, and 30-m National Elevation Dataset digital elevation models. Because we estimated detection probability separately for each Ranger District, we also estimated total area of suitable habitat separately for each district.

To estimate total suitable habitat, we included mid-scale vegetation dominance types defined in the Carson and Santa Fe National Forest as: ponderosa pine mix, upper deciduous-evergreen forest tree mix, and spruce-fir; in the Cibola National Forest as: ponderosa pine mix, ponderosa pine-Douglas fir mix, shade intolerant evergreen tree mix, Douglas fir, white fir (*Abies concolor*) mix, and deciduous-evergreen tree mix; in the Lincoln National Forest as: ponderosa pine mix, shade intolerant evergreen tree mix, deciduous-evergreen tree mix, and upper evergreen forest tree mix; and in the Gila and Apache National Forest as: ponderosa pine mix, ponderosa pine-evergreen oak mix, Gambel oak (*Quercus gambelii*)-evergreen tree mix,

Douglas fir mix, white fir mix, deciduous-evergreen tree mix, and upper evergreen forest tree mix. Because the two warbler species occupy mature forest habitat, we only included suitable habitat types with ≥ 30% canopy cover. Finally, because Grace's Warblers breed between 1,800 – 2,700 m (Stacier and Guzy 2002), and Red-faced Warbler breed between 2,000 – 2,800 m (Martin and Barber 1995), we also excluded any habitat above 2,820 m. All mapping analysis was completed using ESRI ArcMap 10.4.

Detection probability ($\hat{p}$) for Grace's and Red-faced Warblers was determined according to time removal model methods described in Farnsworth et al. (2002) and was calculated using Program SURVIV (White 1992) and R (R Core Team 2017). Density was calculated using $\hat{p}$ and total survey area. Detection probabilities and densities were calculated separately for each project area and were calculated from singing birds only. Visual detections were not included in these analyses as the vast majority of detections in forested systems are aural, and the variation in detectability and detection processes for auditory vs. visual detections precludes robust detection probability estimates from time-of-detection methods when combining both types of detection cues (Alldredge et al. 2007b). Differences in detection probabilities between survey bouts were tested using student's two-sample t-tests. Population estimates were extrapolated across each focal project area from the density of the target species, calculated for each project area, and the total estimated area of suitable habitat within that project area. Because density was calculated from singing males only, density was doubled for the population estimate to reflect the assumption that the males were paired.

To examine avian community structure, abundance and diversity of all recorded species were quantified by calculating total number of individuals of all species, total abundance of all species (individuals/area, where area is the survey area with 100 m radius around each survey point), and species richness (S; total number of species detected). Shannon's diversity index (H) was derived using: $H = -\sum [(p_i)(\ln p_i)]$, where p_i is the proportion of individuals of the ith species. A measure of evenness (E) of species distribution was calculated from Shannon's index and species richness using the equation: $E = H/\ln S$. Relative abundance ($p_i = n_i/N$, where n_i is the number of individuals of the ith species and N is total number of individuals of all species) was calculated to describe the proportion of total individuals comprised of any single species, and was used to determine which species were relatively common or rare within the study area. Differences in abundance and diversity among study sites were tested using one-way ANOVA and Tukey HSD post-hoc comparisons. Statistical analyses were conducted in R version 3.4.1 (R Core Team 2017) and were evaluated at an α-level of 0.05.

Results

Suitable Habitat

We estimated that 426,108 ha of suitable habitat are present across the six project areas that we surveyed in 2017 in the Gila region of southwestern New Mexico (Table 1).

Table 1. Total size of 2017 survey areas, and extent and breakdown of suitable habitat within these areas. All sizes are reported in hectares.

Ranger District	Total size	Suitable habitat	Ponderosa pine mix	Douglas fir or white fir mix	Deciduous - evergreen tree mix	Evergreen tree mix	Pine-oak mix
Black Range	225,642	73,111	64,207	4,829	98	120	3,857
Glenwood	212,641	37,590	16,690	15,891	427	1,130	3,452
Reserve	248,120	109,361	97,318	7,697	254	132	3,960
Silver City	164,612	20,512	11,295	4,977	19	57	4,164
Wilderness	277,684	94,314	75,319	10,879	191	525	7,400
Quemado	244,180	91,219	84,025	4,778	34	12	2,370

In total, an estimated 986,117 ha of suitable habitat is located state-wide in the National Forest districts we surveyed 2015-2017 (Appendix A). Including all National Forest districts of New Mexico, an estimated 171,803 ha of additional suitable habitat is located in the remaining Ranger Districts that were not surveyed during 2015 to 2017 in the Carson (Questa, Canijilon, and Jicarilla districts), Santa Fe (Cuba and Coyote districts), Lincoln (Smokey Bear and Guadalupe districts), and Coronado (Douglas district) National Forests (Appendix B). State-wide, there is an estimated 1,157,920 ha of suitable habitat for Grace's Warblers and 533,117 ha of suitable habitat for Red-faced Warblers in New Mexico's National Forests (Table 2, Map 9).

Table 2. State-wide estimates (in ha) of area of suitable habitat for breeding Grace's Warblers (GRWA) and Red-faced Warblers (RFWA) in the National Forests of New Mexico.

National Forest	GRWA suitable habitat	RFWA suitable habitat	Ponderosa pine mix	Ponderosa pine - Douglas fir mix	Douglas fir, white fir, or spruce-fir	Deciduous - evergreen tree mix	Evergreen tree mix	Pine - oak mix
Carson	161,180	--	108,656	*	480	52,044	*	*
Santa Fe	266,285	--	176,201	*	855	89,230	*	*
Cibola	208,377	41,130[+]	144,625	24,751	11,334	27,112	555	*
Lincoln	95,652	65,561[+]	13,385	*	*	5,702	76,565	*
Gila	334,889	334,889	264,828	*	44,273	990	1,964	22,834
Apache	91,219	91,219	84,025	*	4,778	34	12	2,370
Coronado	317	317	*	*	*	*	*	317
Total	1,157,920	533,117	791,720	24,751	61,720	175,112	79,097	25,521

* Each forest uses slightly different habitat designations in their geospatial datasets. Habitat designations marked with an asterisk are not used on the National Forest.
-- Species does not breed regularly in this region and was not detected during surveys.
[+] Due to the species distribution, only the San Mateo and Magdalena Mountains of the Magdalena district, Cibola National Forest and the Sacramento district of the Lincoln National Forest are included in this calculation.

Target Species Density and Population Estimate

In 2017, Grace's Warblers were detected in all of the project areas, along every survey route, and at elevations ranging from 2,059-2,777 m (6,755-9,111 ft). Red-faced Warblers were detected on 22 of the 26 surveyed routes at elevations ranging from 2,067-2,761 m (6,781-9,058

ft). Both warbler species were widely distributed, with Grace's Warblers detected at 37% and Red-faced Warblers detected at 29% of the 889 survey points. Of the 374 Grace's Warbler detections, 351 were auditory, 5 were visual, and 18 were both auditory and visual. 61% of Grace's Warbler detections occurred within the first 3 minute time interval. Of the 320 detections of Red-faced Warblers, 274 were auditory, 5 were visual, and 41 were both auditory and visual. 65% of Red-faced Warbler detections occurred within the first 3 minute time interval.

Detection probabilities were estimated separately for each project area. Detection probabilities were generally high for both warbler species, ranging overall from 0.82-0.96 for Grace's Warbler and 0.86-0.99 for Red-faced Warbler (Table 3). Detection probability ($\hat{p}$) did not vary between survey bouts for Grace's Warblers ($t_{8.7} = 1.247$, $P = 0.245$) or Red-faced Warblers ($t_{5.7} = 1.248$, $P = 0.261$). Therefore, we used the combined detection probability from both survey bouts to estimate density for both species.

Density of target species varied among project areas (Table 3). The highest Grace's Warbler density was recorded in the Reserve district (0.21 ± 0.05 singing birds ha^{-1}) and the lowest density was recorded in the Glenwood district (0.07 ± 0.005 singing birds ha^{-1}). The highest Red-faced Warbler density was recorded in the Glenwood district (0.21 ± 0.007 singing birds ha^{-1}) and the lowest density was recorded in the Quemado district (0.03 ± 0.003 singing birds ha^{-1}). Across all six project areas that we surveyed in 2017, we estimate the population size of Grace's Warblers to be between 94,399 and 182,550 individuals, and Red-faced Warblers to be between 81,159 and 118,316 individuals.

Table 3. Detection probability ($\hat{p}$), density (D), total suitable habitat, and population estimates with upper and lower limits based on 95% confidence intervals for Grace's (GRWA) and Red-faced Warblers (RFWA) in the six project areas surveyed in New Mexico in 2017. Densities were estimated for singing males, therefore population estimates reflect 2(D)*suitable habitat.

Project area	Species	$\hat{p}$ ± SE	D ± SE (singing birds ha^{-1})	Total suitable habitat (ha)	Population estimate	Population estimate (95% CI)
Black Range	GRWA	0.89 ± 0.10	0.20 ± 0.02	73,111	28,900	22,056 – 35,745
Glenwood	GRWA	0.96 ± 0.05	0.07 ± 0.005	37,590	5,283	4,593 – 5,973
Reserve	GRWA	0.82 ± 0.18	0.21 ± 0.05	109,361	46,411	25,475 – 67,347
Silver City	GRWA	0.87 ± 0.17	0.15 ± 0.03	20,512	5,958	3,510 – 8,405
Wilderness	GRWA	0.88 ± 0.07	0.15 ± 0.01	94,314	28,686	24,411 – 32,962
Quemado	GRWA	0.87 ± 0.16	0.13 ± 0.02	91,219	23,236	14,354 – 32,117
Total	**GRWA**				**138,474**	**94,399 – 182,550**
Black Range	RFWA	0.90 ± 0.11	0.16 ± 0.02	73,111	23,653	17,610 – 29,697
Glenwood	RFWA	0.97 ± 0.03	0.21 ± 0.007	37,590	15,645	14,648 – 16,642
Reserve	RFWA	0.99 ± 0.002	0.13 ± 0.001	109,361	28,150	27,881 – 28,419
Silver City	RFWA	0.88 ± 0.21	0.05 ± 0.01	20,512	2,230	1,078 – 3,383
Wilderness	RFWA	0.86 ± 0.16	0.13 ± 0.02	94,314	23,793	14,784 – 32,802
Quemado	RFWA	0.93 ± 0.08	0.03 ± 0.003	91,219	6,266	5,160 – 7,372
Total	**RFWA**				**99,738**	**81,159 – 118,316**

Over the three years of this project, a total of 1,508 Grace's Warbler detections and 447 Red-faced Warbler detections were recorded. Grace's Warblers were widely distributed throughout New Mexico, detected at 46% of the 2,432 survey points, while Red-faced Warblers

were widely distributed in mountain ranges where they occurred and were detected at 27% of the 1,312 survey points in southwestern and south-central New Mexico. State-wide, we estimated that there were 422,765 (95% CI: 323,060–522,470) Grace's Warblers and 117,477 (95% CI: 93,390–141,565) Red-faced Warblers in the National Forest districts we surveyed 2015-2017 in New Mexico (Table 4). Grace's Warbler density was highest in the Mountainair (0.39 ± 0.02 singing birds ha^{-1}) and Española (0.38 ± 0.004 singing birds ha^{-1}) districts of the Santa Fe and Cibola National Forests, respectively, and was generally higher in northern forests than in southern forests (Table 4, Fig. 1). Red-faced Warbler density was highest in the Glenwood district (0.21 ± 0.007 singing birds ha^{-1}) of the Gila National Forest. Overall, Red-faced Warbler density was higher in the Gila National Forest and in the Magdalena and San Mateo Mountains of the Cibola National Forest than in the Lincoln or Apache National Forests (Table 4, Fig. 1).

Table 4. Estimated density (singing birds ha^{-1}) and abundance of Grace's and Red-faced Warblers by National Forest and Ranger District sampled 2015-2017.

National Forest	**Surveyed districts**	**Grace's Warbler**			**Red-faced Warbler**		
		D ± SE	Abundance	95% CI	D ± SE	Abundance	95% CI
Carson	Camino Real	0.28 ± 0.01	24,453	22,951-25,956	--	--	--
	El Rito	0.31 ± 0.03	28,596	23,887-33,305	--	--	--
	Tres Piedras	0.31 ± 0.03	12,675	10,588-14,763	--	--	--
Santa Fe	Espanola	0.38 ± 0.004	27,956	27,396-28,517	--	--	--
	Jemez	0.29 ± 0.08	30,730	14,015-47,445	--	--	--
	Pecos-Las Vegas	0.20 ± 0.01	34,756	31,540-37,972	--	--	--
Cibola	Sandia	0.34 ± 0.05	9,032	6,512-11,552	--	--	--
	Mountainair	0.39 ± 0.02	19,849	17,768-21,930	--	--	--
	Mt. Taylor	0.28 ± 0.04	64,231	46,385-82,076	--	--	--
	Magdalena	0.14 ± 0.008	13,851	12,124-15,578	0.14 ± 0.01	12,507	10,493-14,522
Lincoln	Sacramento	0.14 ± 0.01	18,160	15,495-20,826	0.04 ± 0.01	5,232	1,737-8,727
Gila	Black Range	0.20 ± 0.02	28,900	22,056-35,745	0.16 ± 0.02	23,653	17,610-29,697
	Glenwood	0.07 ± 0.005	5,283	4,593-5,973	0.21 ± 0.007	15,645	14,648-16,642
	Reserve	0.21 ± 0.05	46,411	25,475-67,347	0.13 ± 0.001	28,150	27,881-28,419
	Silver City	0.15 ± 0.03	5,958	3,510-8,405	0.05 ± 0.01	2,230	1,078-3,383
	Wilderness	0.15 ± 0.01	28,686	24,411-32,962	0.13 ± 0.02	23,793	14,784-32,802
Apache	Quemado	0.13 ± 0.02	23,236	14,354-32,117	0.03 ± 0.003	6,266	5,160-7,372
Total			**422,765**	**323,060-522,470**		**117,477**	**93,390-141,565**

-- species does not breed regularly in this region and was not detected during surveys

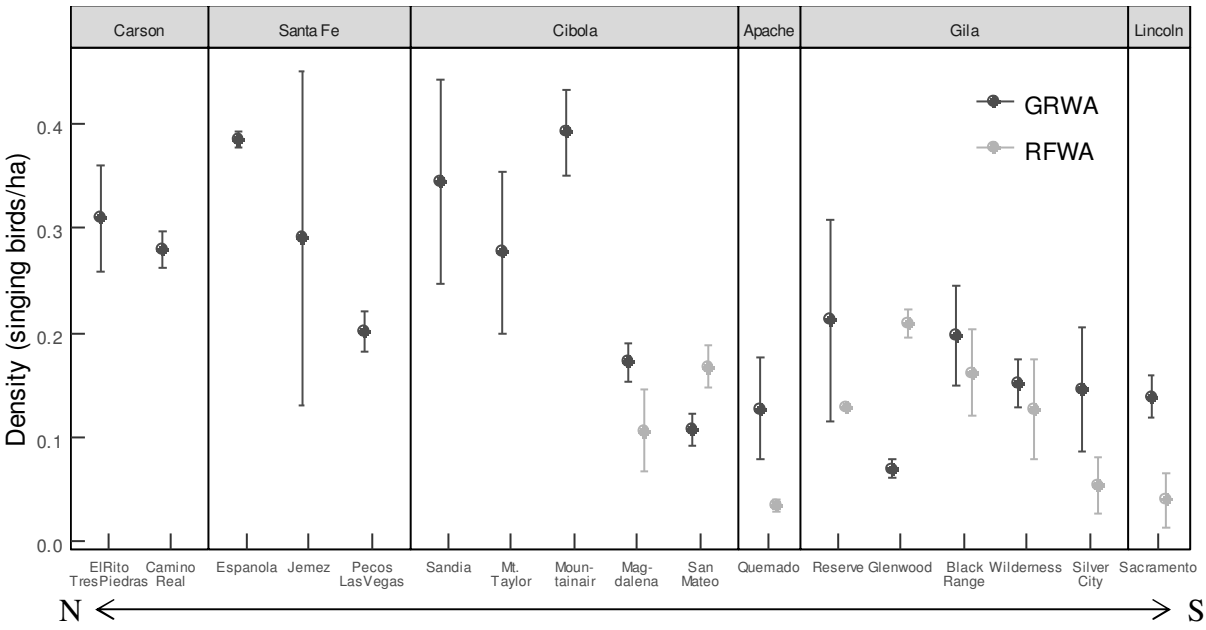

Figure 1. Density estimates (± 95% confidence intervals) for Grace's Warblers (GRWA) and Red-faced Warblers (RFWA) in the Carson, Santa Fe, Cibola, Apache, Gila, and Lincoln National Forests, ordered from northern to southern project area surveyed 2015-2017.

In addition, the hierarchical structure of the study allowed Ranger District strata to be aggregated to make inferences at National Forest levels (Pavlacky et al. 2017). To produce state-wide population estimates, we aggregated estimates of stratum-level (i.e., Ranger District) densities, weighted by the proportion of routes in each stratum, to estimate mean population density per National Forest, and used the resulting forest-specific density estimates to estimate population size for the eight remaining Ranger Districts of New Mexico that were not surveyed from 2015 to 2017. Data from the three surveyed districts of the Santa Fe National Forest were combined to produce population density estimates for the two unsampled districts. Aggregated densities from the three surveyed districts of the Carson National Forest were used for estimates in the three unsampled districts, and density estimates from the surveyed district of the Lincoln National Forest were extrapolated to the two unsampled districts. Densities for the small region of the Coronado National Forest in New Mexico were extrapolated from the closest neighboring district, the Silver City district of the Gila National Forest. We used the same geospatial datasets that were used for the surveyed districts to estimate area of suitable habitat (Appendix B). These analyses estimated an additional 88,892 (95% CI: 68,032-109,753) Grace's Warblers and 35 (95% CI: 17-52) Red-faced Warblers in the National Forests of New Mexico (Appendix B). While there is additional pine forest habitat in private lands of New Mexico (Map 10), our stratification based on National Forest management boundaries and lack of surveys in private land does not permit valid inference to private land regions of New Mexico.

State-wide, we estimated that there were 511,657 (95% CI: 391,092–632,222) Grace's Warblers and 117,512 (95% CI: 93,407–141,617) Red-faced Warblers in the National Forest lands of New Mexico (Table 5). We estimated the greatest abundance of Grace's Warblers in the Santa Fe National Forest. The Santa Fe National Forest supported ~28% of the estimated state-wide population of Grace's Warblers. We estimated the greatest abundance of Red-faced Warblers in the Gila National Forest. The Gila region supported ~85% of the estimated state-

wide population of Red-faced Warblers and ~23% of the estimated state-wide population of Grace's Warblers.

Table 5. Estimated abundance of breeding Grace's Warblers and Red-faced Warblers in the National Forests of New Mexico.

	Abundance (95% CI)	
National Forest	**Grace's Warbler**	**Red-faced Warbler**
Carson	96,069 (83,766-108,372)	--
Santa Fe	143,563 (107,476-179,650)	--
Cibola	106,963 (82,790-131,137)	12,507 (10,493-14,522)
Lincoln	26,496 (22,607-30,384)	5,232 (1,737-8,727)
Gila	115,239 (80,045-150,432)	93,472 (76,000-110,944)
Apache	23,236 (14,354-32,117)	6,266 (5,160-7,372)
Coronado	92 (54-130)	35 (17-52)
Total	511,657 (391,092-632,222)	117,512 (93,407-141,617)

Species Diversity and Abundance

In 2017, 101 species were recorded during surveys in the Gila region of southwestern New Mexico (Appendix C, D). Species richness was highest in the Wilderness district (n = 76 species) and was lowest in the Quemado district (n = 51 species). Examining diversity metrics, there was no significant difference in Shannon's index ($F_{5,20}$ = 0.610, P = 0.693) or evenness ($F_{5,20}$ = 1.495, P = 0.236) among the six project areas, although there was significant variation in species richness ($F_{5,20}$ = 3.199, P = 0.028). Species richness was higher on average on routes in the Wilderness district than in the Quemado district (Tukey adjusted P = 0.040) but did not differ among other districts.

Including all bird species, 9,841 bird records were obtained during the surveys in 2017 (Appendix D). Avian abundance was highest in the Glenwood district (4.2 birds ha^{-1}) and lowest in the Quemado district (2.4 birds ha^{-1}). Examining measures of abundance, there was significant variation in the total number of individuals ($F_{5,20}$ = 4.085, P = 0.010) and total abundance ($F_{5,20}$ = 6.805, P < 0.0001) among the six project areas. The average number of individuals was higher in the Glenwood district than in the Quemado district (Tukey adjusted P = 0.035), although average number of individuals did not differ significantly among other districts. Abundance was higher on average in districts including Black Range (Tukey adjusted P = 0.003), Glenwood (Tukey adjusted P = 0.003), Reserve (Tukey adjusted P = 0.033), and Wilderness (Tukey adjusted P = 0.008) than abundance in the Quemado district, and there was greater average abundance in the Glenwood district than in the Silver City district (Tukey adjusted P = 0.041).

In the Black Range district, the Pygmy Nuthatch, Dark-eyed Junco, and Mountain Chickadee were the most abundant birds. Approximately half (51.5%) of the total individuals were comprised of Pygmy Nuthatch, Dark-eyed Junco, Mountain Chickadee, White-breasted Nuthatch, American Robin, Grace's Warbler, Cordilleran Flycatcher, Steller's Jay, and Northern Flicker (ordered from most to least abundant, here and below).

In the Glenwood district, the Hermit Thrush, Mountain Chickadee, and Western Tanager were the most abundant birds. 48% of the total individuals were comprised of Hermit Thrush,

Mountain Chickadee, Western Tanager, Dark-eyed Junco, Pygmy Nuthatch, House Wren, and American Robin.

In the Reserve district, the Pygmy Nuthatch, Mountain Chickadee, and Dark-eyed Junco were the most abundant birds. 49% of the total individuals were comprised of Pygmy Nuthatch, Mountain Chickadee, Dark-eyed Junco, Steller's Jay, American Robin, Western Tanager, Northern Flicker, and Grace's Warbler.

In the Silver City district, the Dark-eyed Junco, Pygmy Nuthatch, and Western Tanager were the most abundant birds. 51% of the total individuals were comprised of Dark-eyed Junco, Pygmy Nuthatch, Western Tanager, American Robin, Steller's Jay, Northern Flicker, Common Raven, Western Bluebird, and Mountain Chickadee.

In the Wilderness district, the Pygmy Nuthatch, House Wren, and Steller's Jay were the most abundant birds. 49% of the total individuals were comprised of Pygmy Nuthatch, House Wren, Steller's Jay, Northern Flicker, American Robin, Cordilleran Flycatcher, Dark-eyed Junco, and Western Tanager.

In the Quemado district, the Mountain Chickadee, Pygmy Nuthatch, and Western Tanager were the most abundant birds. 52% of the total individuals were comprised of Mountain Chickadee, Pygmy Nuthatch, Western Tanager, Yellow-rumped Warbler, Northern Flicker, Dark-eyed Junco, Steller's Jay, and Grace's Warbler.

State-wide, 125 species were recorded during the three-year project in ponderosa pine, pine-oak, and mixed-conifer forests of New Mexico (Appendix C, D). Examining diversity metrics (Table 6), there was significant variation in Shannon's index ($F_{5,64} = 3.386$, $P = 0.009$) and species richness ($F_{5,64} = 6.606$, $P < 0.001$) among the six National Forests surveyed 2015-2017, although there was no difference in evenness ($F_{5,64} = 0.838$, $P = 0.528$). Shannon's index was higher on average on routes in the Carson than in the Cibola National Forest (Tukey adjusted $P = 0.006$) but did not differ among other forests. Species richness was higher on average on routes in the Carson and Gila than in the Cibola National Forest (Tukey adjusted $P < 0.001$), and higher on average in the Carson than in the Apache National Forest (Tukey adjusted $P = 0.034$).

Table 6. Survey effort (number of points surveyed) and species diversity and abundance across National Forests sampled 2015-2017. Mean and range of species richness, evenness, Shannon's index, total abundance (total individuals/ha), and total number of individuals recorded were calculated per forest using data from each survey route.

National	Effort	Richness		Evenness		Shannon's index		Abundance		Total birds	
Forest	points	$\bar{x}$	range	$\bar{x}$	range	$\bar{x}$	range	$\bar{x}$	range	$\bar{x}$	range
Carson	313	43.0	39-48	0.87	0.85-0.89	3.27	3.13-3.35	4.30	3.49-5.39	528.0	439-660
Santa Fe	420	39.2	34-47	0.87	0.83-0.91	3.18	3.01-3.29	3.62	2.74-4.45	392.0	267-479
Cibola	654	34.2	24-42	0.87	0.80-0.91	3.06	2.71-3.33	3.53	2.80-6.32	370.9	247-576
Lincoln	156	41.5	37-45	0.85	0.82-0.88	3.15	3.12-3.22	4.17	2.87-6.53	512.3	360-820
Gila	740	41.0	30-52	0.86	0.81-0.91	3.17	2.89-3.38	3.75	2.46-5.24	397.2	192-601
Apache	149	33.8	29-37	0.88	0.85-0.92	3.08	2.86-3.33	2.35	2.10-2.64	275.5	236-323

Including all bird species, 28,235 bird records were obtained during the surveys in 2015-2017 (Appendix D). Avian abundance was highest in the Carson National Forest (4.3 birds ha^{-1}) and lowest in the Apache National Forest (2.4 birds ha^{-1}). Examining measures of abundance

(Table 6), there was significant variation in the total number of individuals ($F_{5,64} = 5.092$, $P < 0.001$) and total abundance ($F_{5,64} = 3.822$, $P = 0.004$) among the six National Forests. The average number of individuals was higher in the Carson National Forest than in the Gila (Tukey adjusted $P = 0.028$), Santa Fe (Tukey adjusted $P = 0.045$), Cibola (Tukey adjusted $P = 0.005$), or Apache (Tukey adjusted $P = 0.002$) forests, and higher on average in the Lincoln than in the Apache National Forest (Tukey adjusted $P = 0.017$). Abundance was higher on average in forests including the Carson (Tukey adjusted $P = 0.002$), Lincoln (Tukey adjusted $P = 0.018$), and Gila (Tukey adjusted $P = 0.018$) than abundance in the Apache National Forest.

Species of Greatest Conservation Need

Twenty-one Species of Greatest Conservation Need were recorded during surveys in 2017 (Table 7, Appendix C). The number of species was highest in the Black Range, Reserve, and Wilderness districts ($n = 14$ species) and was lowest in the Quemado district ($n = 9$ species). The federally threatened Mexican Spotted Owl (*Strix occidentalis lucida*) was detected during surveys in the Black Range, Glenwood, Reserve, Silver City, and Wilderness Ranger Districts of the Gila National Forest, the Sacramento Mountains of the Lincoln National Forest, and the San Mateo Mountains of the Cibola National Forest. In total, 24 Species of Greatest Conservation Need were recorded state-wide during the three-year project (Appendix C).

Table 7. Number and location of Species of Greatest Conservation Need recorded during 2017 surveys.

Common Name	Number of individuals					
	Black Range	Glenwood	Reserve	Silver City	Wilderness	Quemado
Common Nighthawk	7	2	4		1	2
Mexican Whip-poor-will	2			2		
Common Black Hawk					1	
Mexican Spotted Owl	4	4	1	2	3	
Lewis's Woodpecker			1		2	
Williamson's Sapsucker		5	4	3		
Peregrine Falcon					1	
Olive-sided Flycatcher	1	5	1		6	
Pinyon Jay	18		25			
Clark's Nutcracker	10	3	2	1	3	1
Juniper Titmouse			1			
Pygmy Nuthatch	213	105	150	86	174	100
Western Bluebird	75	47	70	55	54	51
Mountain Bluebird	2	2		3		1
Evening Grosbeak	1			2		
Yellow-eyed Junco				1		
Virginia's Warbler	7	9	17	5	10	10
Grace's Warbler	89	32	86	53	62	52
Black-throated Gray Warbler	3	6	5		2	1
Red-faced Warbler	73	99	63	20	50	15
Painted Redstart				3	2	
Total individuals of all SGCN	505	319	430	236	371	233
Total abundance of all SGCN (# birds/ha)	1.024	0.672	0.877	0.565	0.826	0.498
SGCN species richness	14	12	14	13	14	9

Breeding Behavior Observations

Breeding behaviors were occasionally observed during point count surveys. While not the primary goal of this study, incidental information was recorded and is summarized in Table 8.

Table 8. Incidental observations of breeding behavior recorded during 2017 point count surveys.

Date	Location	Waypoint	Species	Observation
5/15	Quemado	Q-Ma11	Red-faced Warbler	Male and female interacting / courtship
5/15	Quemado	Q-Ma13	Yellow-rumped Warbler	Male and female observed together
5/15	Quemado	Q-Ma14	Mountain Chickadee	Cavity nest located in ponderosa pine snag, adult observed bringing food to nest
5/15	Quemado	Q-Sa11	American Robin	Nesting on ponderosa pine
5/16	Quemado	Q-Sa16	Western Bluebird	Nesting on snag
5/17	Silver City	S-Si14	Olive Warbler	Male and female observed together
5/18	Wilderness	W-Ro18	Grace's Warbler	Female observed in ponderosa pine, male singing nearby
5/19	Silver City	S-Sp6	House Wren	Cavity nest located in conifer snag, both adults observed
5/19	Silver City	S-Sp11	Hairy Woodpecker	Cavity nest located in ponderosa pine snag, both adults observed feeding young
5/19	Silver City	S-Sp12	Northern Flicker	Cavity nest located in ponderosa pine snag, both adults observed feeding young
5/19	Silver City	S- Ga2	American Robin	Nesting on fir tree
5/19	Silver City	S- Ga9	Broad-tailed Hummingbird	Nesting on ponderosa pine
5/19	Silver City	S- Ga11	Turkey Vulture	Nesting on hillside
5/27	Black Range	B-Di5	Red-faced Warbler	Nesting on bankside
5/27	Black Range	B-Tu8	Red-tailed Hawk	Juvenile observed
5/30	Reserve	R-Be7	Pygmy Nuthatch	Cavity nest located in ponderosa pine snag, both adults observed
5/31	Reserve	R-Sh10	Pygmy Nuthatch	Cavity nest located in ponderosa pine snag, adult observed bringing food to nest
6/1	Black Range	B-Kl3	Grace's Warbler	Female foraging by peeling off bark of mid-story ponderosa branch, male singing nearby
6/1	Black Range	B-Kl12	Olive Warbler	Male and female observed together
6/1	Black Range	B-Kl14	Grace's Warbler	Male and female observed together
6/1	Black Range	B-Sc6	American Robin	Nesting on deciduous tree
6/2	Wilderness	W-Wi4	Cordilleran Flycatcher	Nesting on bankside
6/2	Wilderness	W-Ir4	Western Bluebird	Male and female observed together
6/2	Wilderness	W-Ir7	Western Bluebird	Male and female observed together
6/2	Wilderness	W-Ir9	Western Tanager	Male and female observed together
6/2	Wilderness	W-Ir9	Grace's Warbler	Male and female observed together
6/2	Wilderness	W-Ir10	Western Bluebird	Male and female observed together
6/3	Glenwood	G-Mi3	Grace's Warbler	Carrying nesting material
6/3	Glenwood	G-Be14	House Wren	Nesting on fallen fir tree
6/13	Quemado	Q-Ma4	Mountain Chickadee	Nesting on oak
6/13	Quemado	Q-Ma5	Grace's Warbler	Pair carrying food
6/13	Quemado	Q-Ma16	Dark-eyed Junco	Nesting on ponderosa pine
6/14	Quemado	Q-Ho20	Olive Warbler	Male and female observed together
6/15	Silver City	S-Sp3	Cordilleran Flycatcher	Nesting on fallen log
6/15	Silver City	S-Sp7	Canyon Wren	Nesting on woodpile
6/15	Silver City	S-Ga13	Hairy Woodpecker	Cavity nest located in ponderosa pine snag, both adults observed feeding young
6/15	Silver City	S-Ga16	Black-headed Grosbeak	Adult feeding fledgling
6/16	Silver City	S-Sh1	Hepatic Tanager	Male and female observed together
6/16	Silver City	S-Sh14	Northern Flicker	Juvenile observed in cavity nest in ponderosa pine snag

Date	Location	Waypoint	Species	Observation
6/16	Silver City	S-Sh16	Western Tanager	Male and female observed together
6/17	Wilderness	W-Bl3	Hairy Woodpecker	Adult feeding fledgling
6/17	Wilderness	W-Bl8	Red-faced Warbler	Male and female observed together
6/17	Wilderness	W-Bl8	Painted Redstart	Juvenile observed
6/17	Wilderness	W-Bl10	House Wren	Cavity nest located in cottonwood tree
6/17	Wilderness	W-Bl10	Violet-green Swallow	Cavity nest located in cottonwood tree
6/17	Wilderness	W-Bl12	Dark-eyed Junco	Male and female copulated
6/17	Wilderness	W-Bl13	Purple Martin	Cavity nest located in cottonwood snag
6/18	Black Range	B-Sc3	Hepatic Tanager	Male and female observed together
6/18	Black Range	B-Kl6	Western Bluebird	Nesting on a dead oak
6/19	Black Range	B-Al18	Northern Flicker	Juvenile observed in cavity nest in ponderosa pine snag, both adults observed
6/19	Black Range	B-Ta4	Hermith Thrush	Carrying nesting material
6/19	Black Range	B-Ta11	White-throated Swift	Nesting in cliff
6/19	Reserve	R-Be camp	Golden Eagle	Pair observed
6/20	Reserve	R-Be18	Cooper's Hawk	Pair in courtship flight
6/21	Glenwood	G-De camp	Sharp-shinned Hawk	Pair observed
6/21	Reserve	R-Sh15	Dark-eyed Junco	Nesting under grass clump
6/21	Reserve	R-Si3	Western Bluebird	Adult male feeding fledgling
6/21	Reserve	R-Si5	Downy Woodpecker	Family group of 2 adults and 2 fledglings
6/21	Reserve	R-Si18	Red-tailed Hawk	Adult observed, juvenile heard calling
6/22	Glenwood	G-De3	Red-faced Warbler	Male and female observed together
6/22	Glenwood	G-De10	Dark-eyed Junco	2 adults feeding 3 fledglings
6/22	Glenwood	G-De15	Western Tanager	Male and female observed together
6/22	Glenwood	G-St20	Red-tailed Hawk	Courtship flight
6/23	Wilderness	W-Ir5	American Three-toed Woodpecker	Nesting on snag
6/23	Wilderness	W-Wi15	Yellow-rumped Warbler	Male and female observed together
6/24	Glenwood	G-Be16	Williamson's Sapsucker	Family group of adult male and 2 male fledglings
6/24	Glenwood	G-Mi11	Cordilleran Flycatcher	Nesting on bankside
6/24	Glenwood	G-Mi11	Yellow-rumped Warbler	Adult feeding juvenile

Discussion

Population Estimates and Trends

We estimate that there were 422,765 (95% CI = 323,060-522,470) Grace's Warblers and 117,477 (95% CI = 93,390-141,565) Red-faced Warblers in pine forests of the National Forest districts that we surveyed in New Mexico from 2015 to 2017. Furthermore, we extrapolate an additional 88,892 (95% CI: 68,032-109,753) Grace's Warblers and 35 (95% CI: 17-52) Red-faced Warblers in the remaining forest districts, resulting in a state-wide estimate of 511,657 (95% CI: 391,092-632,222) Grace's Warblers and 117,512 (95% CI: 93,407-141,617) Red-faced Warblers in the forested mountains of New Mexico. Using North American Breeding Bird Survey (BBS) data, Partners in Flight (PIF) estimate the current U.S. population size for Grace's Warblers is 1,700,000 breeding individuals, and they estimate a global breeding population of 3,200,000 individuals (Rosenberg et al. 2016). Our estimates based on three years of survey data

and removal modeling suggest New Mexico holds 30% (95% CI: 23-37%) of the total U.S. breeding population of Grace's Warblers, and 16% (95% CI: 12-20%) of the global population, as estimated by PIF. PIF estimate the current U.S. population size for Red-faced Warblers is 250,000 breeding individuals, with a global breeding population of 690,000 individuals (Rosenberg et al. 2016). With our estimated population of around 117,500 individuals, New Mexico holds 47% (95% CI: 37-57%) of the U.S. population of breeding Red-faced Warblers, and 17% (95% CI: 14-21%) of the global population, as estimated by PIF.

Breeding Bird Surveys, which were used by PIF to make population estimates, were not designed to estimate population sizes, but rather to provide information on relative abundance and to evaluate trends in species abundance over time (Sauer et al. 2017). Neither of our target species receives "good" data quality ratings, as determined by PIF, for New Mexico (Partners in Flight Science Committee 2013). Average annual BBS counts and survey route detections of Grace's Warblers and Red-faced Warblers show high degrees of variance, and the sample size for Red-faced Warblers on BBS routes is quite small. Indeed, not enough data are collected during BBS routes on Red-faced Warblers to estimate population trends, much less population size. For Grace's Warblers, BBS trend estimates indicate populations in New Mexico have declined 2.05% per year since the 1960s (Sauer et al. 2017). BBS routes are placed along secondary roads and only detect Grace's Warblers on 18 of 66 routes, and Red-faced Warblers on 4 of 66 routes. Because these species inhabit mature forests, and prefer moderate degrees of disturbance at most, roadside habitats are unlikely to be highly representative of habitats most often used by these species. Grace's Warblers were one of the most commonly detected species during our surveys in each mountain range, and Red-faced Warblers were fairly common where they occurred. Thus, due to the nature of BBS routes, populations of these forest-dwelling birds are unlikely to be accurately described via the BBS method. As the BBS routes are restricted to roadsides, inference from these data about bird populations is also limited to roaded areas (Olsen et al. 1999, Pavlacky et al. 2017).

Our study provides a targeted approach to estimating the population sizes of these two warbler species in New Mexico. In this study, point count surveys and removal modeling were used to estimate density of breeding warblers, from which population estimates were generated based on availability of suitable habitat. These methods can be easily applied in the future to evaluate additional study sites and to resurvey the 2015-2017 survey areas in order to determine changes in population size and trends. This information will be useful in making management decisions regarding these species and their preferred habitats.

The Grace's Warbler is listed on the PIF Watch List as a species of highest conservation concern at the continental, range-wide scale due to a 52% loss of the global population from 1970-2014 and major threats including changing forest conditions, tropical deforestation, and climate change (Rosenberg et al. 2016). Breeding regions of highest importance identified by PIF include areas surveyed in this project: the Southern Rockies/Colorado Plateau Bird Conservation Region (BCR), which includes the Carson, Santa Fe, and Cibola National Forests, and the Sierra Madre Occidental BCR, which includes the Gila, Apache, and Coronado National Forests and the Magdalena Mountains. While Red-faced Warblers are not on the national PIF Watch List, PIF attribute high vulnerability for both Grace's Warblers and Red-faced Warblers to their small populations and restricted distributions, the magnitude of long-term population declines, and threats to breeding and non-breeding areas (Rosenberg et al. 2016).

Avian species of pine forest habitats face large threats of habitat loss and degradation. Ponderosa pine and mixed-conifer forests of the southwest are commercially valuable forest types that are also threatened by the risk of large-scale, severe wildfire, insect and disease

epidemics, overgrazing, and climate change (Reynolds et al. 2013). These threats may be amplified for bird species of conservation need that rely heavily on southwestern pine forests for breeding habitat and are already experiencing population declines or small population sizes and have small geographic ranges. Southwestern pine forests historically experienced frequent, low-intensity, surface-burning wildfires, which cleared ground fuel, sapling, and shrub layers while leaving mature trees intact and maintained an open forest structure of park-like stands with scattered groups of large trees and grassy openings. However, decades of human-induced reduction in fire frequency, due to livestock grazing, logging, and fire suppression, has altered the characteristic structure and species composition of southwestern pine forests, and has resulted in forests with increased tree densities, more closed canopies, higher proportions of young trees and a loss of old trees, larger amounts of downed branches, and higher levels of disease and insect outbreaks (Reynolds et al. 2013). This altered structure undoubtedly impacts the Grace's Warbler, as a species that prefers habitats of park-like stands of mature pine forest that now occur less frequently, largely due to forestry practices of logging and fire suppression (Stacier and Guzy 2002). The increase in forest density and understory fuel accumulation has also caused southwestern pine forests to become increasingly susceptible to severe, stand-replacing fire. For Red-faced Warblers, habitat loss and degradation from severe wildfire has been identified as the greatest conservation concern for breeding populations (Corman and Wise-Gervais 2005). The threat of catastrophic fire was clearly demonstrated during each year of our three-year project. Lightning-ignited and human-caused fires occurred during the survey period and certainly caused reproductive failure for many Grace's and Red-faced Warblers within our survey areas in the San Mateo Mountains (Red Canyon fire: 18,000 acres, both Grace's and Red-faced Warbler had been recorded within fire perimeter), Manzano Mountains (Dog Head fire: 18,000 acres, Grace's Warbler had been recorded 1.5 km from fire perimeter), and Black Range (Round fire: 7,500 acres, both Grace's and Red-faced Warbler had been recorded within fire perimeter). In addition, drought conditions and high temperatures have been linked to increases in wildfire burn area, fire occurrences, and bark-beetle outbreaks in southwestern forests (Westerling et al. 2006, Williams et al. 2010). With habitat loss and habitat alteration already documented factors influencing declining populations of Grace's and Red-faced Warblers (Martin and Barber 1995, Stacier and Guzy 2002), and projections for the southwest U.S. under future climate change scenarios including decreased winter precipitation and increased drought frequency and severity, along with increased temperatures and more frequent, extreme heat events (Meehl and Tebaldi 2004, Seager et al. 2007, Sheffield and Wood 2008, Cayan et al. 2010), current forest conditions in many parts of the National Forest and wildfire are large causes for concern that may contribute to current and future declining populations.

Target Species Detection and Density

Grace's Warbler distribution extends throughout New Mexico although our results show they occur in higher densities in the north than in the south. Red-faced Warblers are restricted to southwestern and south-central New Mexico. Grace's Warblers were detected on every survey route across all project areas that we surveyed 2015-2017, although they occurred in varying densities. Density ranged from 0.07 ± 0.005 singing birds ha^{-1} in the Mogollon Mountains of the Gila National Forest, Glenwood district to 0.39 ± 0.02 singing birds ha^{-1} in the Manzano Mountains of the Cibola National Forest, Mountainair district (Table 4). Red-faced Warblers were detected in all project areas in the mountain ranges where they occur, and on 33 of 39 survey routes in these project areas, at densities ranging from 0.03 ± 0.003 singing birds ha^{-1} in

the San Francisco and Gallo Mountains of the Gila National Forest, Quemado district to 0.21 ± 0.007 singing birds ha^{-1} in the Mogollon Mountains of the Gila National Forest, Glenwood district. Detected at 29% of all points surveyed, Red-faced Warblers were more broadly distributed in the Gila region in New Mexico than in a study in the Sky Island mountain ranges of southeastern Arizona, where they were detected at 24% of survey points in pine-oak, ponderosa pine, and mixed-conifer forests (Kirkpatrick et al. 2006). Grace's Warbler density was considerably lower in southern New Mexico than in northern New Mexico, ranging between 0.07-0.20 singing birds ha^{-1} in the south to between 0.20-0.39 singing birds ha^{-1} in the north (Fig. 1). Interestingly, these southern project areas were also the only ones where Red-faced Warblers were detected. The combined density of Grace's and Red-faced Warblers in project areas where they co-occur ranged from 0.16-0.36 singing birds ha^{-1}; densities much more similar to those recorded for Grace's Warblers alone in the northern project areas.

The variation in density of Grace's and Red-faced Warblers among the mountain ranges we surveyed may reflect the distributional limits of these two species, the availability of suitable microhabitat, the quality of habitat, and species-specific habitat preferences. Though these species co-occur in pine-oak woodlands, they differ in microhabitat preferences, nesting strategies, and foraging behaviors. These differences are likely to alleviate direct competition for resources. However, the similarities in habitat use for these two species could potentially be a limiting factor in ranges where both species occur and could in part explain lower Grace's Warbler densities in areas where Grace's and Red-faced Warblers co-occur. Alternatively, the southern mountains are on average drier and hotter than the other, northern ranges we surveyed. The drier nature of these mountain ranges could also limit total bird density, although we found high levels of total avian abundance and diversity in the Gila National Forest relative to the northern forests that we surveyed. While our data could suggest Grace's Warbler density exhibits trends in relation to latitude or temperature, their breeding distribution does extend further south than the Red-faced Warbler, and goes throughout the Sierra Madre Occidental of Mexico. Grace's Warblers are also distributed as far north as southern Colorado and Utah, where lower densities are expected as species abundance typically declines towards range boundaries (Brown et al. 1995). However, BBS trend estimates show a general downward trend in Grace's Warbler populations, except in Colorado and Utah, where trend estimates indicate increasing populations (Sauer et al. 2017). Northern shifts in distributions in response to climate warming have been widely reported for many avian species in North America (Parmesan and Yohe 2003, Root et al. 2003). The BBS trend estimates could be evidence of a northward range expansion or shift, and count data from the BBS could be investigated for changes in the northern distributional limits of this species (Macias-Duarte and Conway 2015). Our baseline data cannot, by definition, provide evidence of trends or evaluate changes, although it is clear our results show Grace's Warbler density distributions increasing from southern to northern New Mexico.

We detected Red-faced Warblers in areas where they were previously known to breed, but did not detect this species outside of expected areas. Red-faced Warblers were recorded at low densities of 0.04 singing birds ha^{-1} in the Sacramento Mountains and 0.03 singing birds ha^{-1} in the San Francisco and Gallo Mountains. These lower densities may be due to the location of the mountains relative to the warbler's entire distribution; the Sacramento Mountains are at the eastern edge and the San Francisco and Gallo Mountains at the northern edge of this species' breeding range (NMPIF 2007). While the northern limit of the Red-faced Warbler's breeding range extends into west-central New Mexico, and less regularly north into the Zuni Mountains (NMPIF 2007), we did not detect this species in our central mountain surveys. Only one eBird sighting in the Zuni Mountains is documented (eBird 2017), but birders have reported occasional

sightings of this species in this mountain range. It is possible that we failed to detect this species in the Zuni Mountains due to a small sampling area; however, this species was easily detected in the ranges where it occurs. While the Zuni Mountains may be a region of occasional sightings or even breeding, we do not expect that this range is the site of a significant breeding population. If present, they may be highly localized within suitable microhabitat.

According to eBird, Red-faced Warblers have also been sighted as far north as locations in the Sandia Mountains, at the Rio Grande Nature Center (RGNC) in Albuquerque, and in Galisteo, NM (eBird 2017). However, these detections occurred in April and May and are likely representative of migrant or vagrant individuals. Further, the RGNC and Galisteo do not offer suitable breeding habitat for this species. While the Sandia Mountains do have suitable breeding habitat, we did not detect Red-faced Warblers during our surveys, and we do not expect that sizable breeding populations occur in the Sandia Mountains.

As both of our target species are understudied, there are not many density estimates available to compare with our results. Densities that have been reported in the literature were obtained utilizing differing methods, which precludes rigorous comparisons. Nevertheless, as a generalization, our results are within the range of breeding densities from other studies in similar habitats in Arizona. Differences may be due to how studies were conducted and densities estimated; no other density estimates for our target species are available from New Mexico. In general, the range of densities reported in this project suggests moderate to low breeding density in New Mexico as compared to other published studies. For Grace's Warblers, breeding density estimates from spot-mapping ranged from 0.15-0.49 pairs ha^{-1} (Szaro and Balda 1979) and from 0.25-0.75 pairs ha^{-1} (Brawn et al. 1987) in northern Arizona ponderosa pine forests and from 0-0.18 pairs ha^{-1} in burned and unburned ponderosa pine habitats (Overturf 1979, *in* Block and Finch 1997). However, territory mapping in the most productive of these areas and in dense populations gave estimates of 0.28-0.33 pairs ha^{-1} (Stacier and Guzy 2002). Breeding density estimates were 0.49 pairs ha^{-1} in ponderosa pine forests and 0.07 pairs ha^{-1} in pine-oak-juniper woodlands of southeast Arizona (Balda 1969). Using total counts, without correcting for detectability, as an index of avian abundance, Grace's Warbler abundance averaged 0.37 birds ha^{-1} and ranged 0.07-0.91 pairs ha^{-1} while Red-faced Warbler abundance averaged 0.20 birds ha^{-1} and ranged 0.07-0.57 pairs ha^{-1} in northern Arizona ponderosa pine and pine-oak habitats (Rosenstock 1996). Estimates of Red-faced Warbler breeding densities from spot-mapping ranged from 0.04-0.11 pairs ha^{-1} in northern Arizona ponderosa pine forests (Szaro and Balda 1979). In a study in montane riparian forest in which study sites were located non-randomly in preferred breeding habitat, but density estimates were adjusted for detection probability, Red-faced Warbler breeding density averaged 2.4 singing males ha^{-1} along forested drainage bottoms of the Santa Catalina Mountains, Arizona; authors suggest this density estimate was "noticeably higher than in other high-elevation forests" of southern Arizona, although these densities are not reported (Kirkpatrick and Conway 2010). In the Sky Islands and Sierra Madre Occidental of Mexico, detectability-corrected estimates of density were 0.25 birds ha^{-1} for Red-faced Warbler and 0.11 birds ha^{-1} for Grace's Warbler (Flesch 2014).

Habitat and Microhabitat

Grace's Warblers and Red-faced Warblers use largely similar habitats, occupying montane pine forests in New Mexico. However, they specialize in ponderosa pine habitats to different degrees and vary in their specific habitat preferences. These differences should be considered when examining the results of this study. Grace's Warblers are characteristic of

ponderosa pine habitats, and are 2-3 times more abundant in ponderosa pine habitats than in comparison areas (Carothers et al. 1973, *in* Block and Finch 1997). They rely heavily on pines for foraging activities and nesting, as they forage for arthropods in the outer foliage at the tips of upper branches of mature pines (Szaro and Balda 1979) and nest in the crowns or upper limbs of large pines (Stacier and Guzy 2002). Grace's Warblers are found in forests with relatively high canopy closure (the average canopy closure was 46% in an Arizona study), and they are more strongly associated with ponderosa pine woodlands with Gambel oak (*Quercus gambelii*) understories (Stacier and Guzy 2002). Grace's Warblers are often found in dry, park-like habitats and may occupy mesa tops and lower canyon bottoms (Stacier and Guzy 2002).

Red-faced Warblers also utilize ponderosa pine habitats, but do not use these habitats as exclusively as Grace's Warblers. Mixed conifer and ponderosa pine forests, typically with Gambel oak or another deciduous tree component, are main habitat types of Red-faced Warblers in New Mexico (NMPIF 2007), and they are associated with fir, spruce, Douglas fir, aspen, and maple (*Acer* spp.) in addition to ponderosa pine. A ground-nesting species, Red-faced Warblers most frequently place nests at the bases of fir or maple trees and only rarely at the base of ponderosa pine (Martin and Barber 1995), and they forage for arthropods on small branches and twigs in the lower regions of medium and tall firs and pines (Franzreb and Franzreb 1983). They often occur in montane riparian vegetation along mesic drainages and canyon bottoms and along the base of steep, forested slopes (Martin and Barber 1995).

The two warbler species also show differences in their tolerance of disturbance and in their elevational range. Although both species are relatively intolerant of disturbance and habitat degradation (Martin and Barber 1995, Stacier and Guzy 2002), Red-faced Warblers use mature ponderosa pine forests in undisturbed or lightly disturbed areas, while Grace's Warblers use lightly to moderately disturbed ponderosa pine habitats (Szaro and Balda 1982). There is a large degree of overlap in the elevational ranges that these two species occupy, though Red-faced Warblers typically occupy a slightly higher and narrower range of elevations (Grace's Warbler: 1,800 – 2,700 m [Stacier and Guzy 2002], Red-faced Warbler: 2,000 – 2,800 m [Martin and Barber 1995]). In this study, both species were detected across the range of elevations that we surveyed (Grace's Warbler: 2,059 – 2,791 m, Red-faced Warbler: 2,067– 2,761 m), suggesting their presence is not defined solely by elevation.

Evaluation of Suitable Habitat

We estimated the extent of mature ponderosa pine, mixed-conifer, and pine-oak habitat types within elevational limits for these two species using GIS layers of the dominant vegetation type and the canopy cover. However, the different microhabitats utilized by these species cannot be differentiated using large-scale GIS layers available for the study areas. The basic habitat types used by these two species (ponderosa pine, Douglas fir, fir, spruce, and deciduous tree species), as shown in these datasets, are similar, and each species shows a preference for one habitat, but not to the exclusion of the other habitat (i.e., Grace's Warblers in ponderosa, Red-faced Warbler association with fir and maple). For this reason, and the lack of quantifiable information on each species' level of preference for these different habitat types, estimates of suitable habitat based on broad dominant vegetation categories will likely overestimate actual suitable habitat for both species. In order to more specifically determine total suitable habitat, a large-scale vegetation survey or large-scale interpretation of high resolution aerial photography would need to occur. To ground-truth GIS layers and differentiate smaller scale habitat features would be a very large undertaking and was beyond the scope of this project.

In this study, we limited our survey areas to public lands, and as these warbler species occupy high-elevation montane forests, the majority of this public land is managed by the U.S. Forest Service. Though a large proportion of the forested land in New Mexico is operated by the Forest Service, there is suitable pine forest habitat that occurs on private land (Map 10). However, the habitat data that we used in this project to quantify vegetation and landscape characteristics and identify project survey sites and availability of suitable habitat are not available for private lands, which prevents use of a consistent method of survey site selection and suitable habitat estimation across private lands. In addition, we stratified by National Forest management boundaries and conducted no surveys within private land. This precludes inference to populations occurring on private lands, though our target species certainly occur in private land regions of New Mexico.

This study did not take into account certain habitat features that could impact habitat suitability, such as location on a slope, steepness of a slope, recent wildfire activity, or tree density. Survey routes often followed along, or crossed through, canyons, with drainages varying in steepness from broad, park-like forests with shallow slopes to more incised, narrow drainages with steep slopes, and with point locations at the bottom, mid-slope, and along ridges or mesa tops. It is not known whether density of our target species varied according to location on a slope or steepness, and these two factors could be confounding. Location on a slope may play a role in determining presence for Red-faced Warblers, who may preferentially use steeper-walled canyon bottoms, where mesic tree species, such as maple or fir, are more likely to occur (Martin and Barber 1995). Grace's Warblers may use more park-like habitats or mesa tops, both of which are relatively flat habitats, and these habitats occur both in drainage bottoms and on the uppermost slopes. There is no quantitative information that defines habitat use by steepness or by location on a slope for Grace's Warblers, and there is only limited data for Red-faced Warblers. For Red-faced Warblers studied in Arizona, most nest sites were ≤ 30 m from drainage bottoms, although nest sites were located across the gradient from mesic drainage bottoms to xeric slopes and ridgetops, and this targeted study surveyed only along forested drainage bottoms and not in adjacent mixed-conifer or ponderosa pine forest (Kirkpatrick and Conway 2010). In another Arizona study, slope at Red-faced Warbler nests averaged 34.1° (95% CI = 15.4-52.9°), although the sample size was only 17 nests, high and low values of nest-site slopes were not discussed, and warblers nested primarily in pine-oak and mixed-conifer forest (Ganey et al. 2015). The presence or density of Grace's and Red-faced Warblers may be defined more by the microhabitat conditions that are created by steepness or location on a slope than by these factors intrinsically. Future studies may aim to determine whether density of Grace's and Red-faced Warblers are similar along drainage bottoms, mid-slope, and upper slopes, and whether steepness plays a differential role in defining occurrence or density.

Recent wildfires could also affect the availability of suitable habitat. The impact of fires on these two warbler species is not clear and should vary based on fire intensity. Reviewing the available literature, Arizona studies have shown conflicting results: in one study, Grace's Warblers were more abundant in unburned areas (Overturf 1979, *in* Block and Finch 1997); in another study, they were more abundant in burned areas (Blake 1982, *in* Block and Finch 1997); fire intensity was not discussed. Grace's Warbler presence has been positively associated with recent low, moderate, and severe surface fire, which study authors attributed to their preference for open pine forests (Kirkpatrick et al. 2006). Conflictingly, higher abundance has also been recorded in untreated forest than in adjacent forest that had undergone restoration treatments of thinning and prescribed fire to return ponderosa pine forests to historical, open conditions (Battin and Sisk 2011). Further, population declines have been observed in response to severe fire (Bock

and Block 2005). While neither positive or negative associations with fire were detected for Red-faced Warblers in one study (Kirkpatrick et al. 2006), in another study, Red-faced Warblers avoided nesting in areas burned by recent fire (Kirkpatrick and Conway 2010). In addition, fire may have indirectly reduced nesting success by increasing nest predation (Kirkpatrick and Conway 2010). In the Gila region of New Mexico, Grace's Warbler density increased after low- to moderate-intensity prescribed fire, although the same study showed decreased density after fire in nearby Arizona study sites (Dickson et al. 2009). Clearly more research is needed investigating impacts of fire and bird response with the present-day increase in frequency of large-scale, severe wildfires in the southwest.

The occurrence of wildfire in ponderosa pine forests in New Mexico does not necessarily result in loss of suitable habitat for the two warblers, but severe fires that destroy ground cover and understory vegetation, as well as mature trees, will result in habitat loss. In calculating total suitable habitat for this study, we attempted to eliminate some habitat that had recently burned, but found the available GIS layers inadequate for determining whether suitable habitat had actually been lost. For example, in 2014, the Pino fire on the Jemez Ranger District burned approximately 4,300 acres. The boundary of this fire lies along one of our 2015 survey routes in Paliza Canyon, which was a route where we observed mature ponderosa pine and detected Grace's Warbler at nearly every point. However, the 2004 Trigo fire, which burned 14,000 acres in the Manzano Mountains, was a severe, stand-replacing fire within much of the burn area. This burn scar is mostly devoid of mature live trees and does not provide suitable ponderosa pine habitat for these species. However, in available GIS layers, only the fire boundaries, not an assessment of burn severity or changes in forest structure, are displayed. These data do not accurately describe whether the habitat within fire boundaries is still suitable for these species. Therefore, we did not attempt to exclude areas recently impacted by wildfire from our estimation of suitable habitat availability, though severe, stand-replacing fire will certainly limit available habitat for these species.

Specific habitat features may also impact the availability of suitable habitat and influence the abundance of Grace's and Red-faced Warblers. Key habitat features of importance for the target species are generally unknown, and structural components of vegetation cannot be identified by available GIS layers. LANDFIRE products have been used to evaluate landscape-scale wildlife habitat from 30-m grid spatial resolution datasets on vegetation type, cover, and height; however, microhabitat features cannot be differentiated and fine-scale habitat structure may be important for our target species. LiDAR-derived data combined with imagery have been used to map average canopy height over large forest patches (Lefsky 2010), although state-wide coverage of LiDAR data, or even coverage for the majority of our study sites, is not yet available. While coarse-resolution descriptors from available GIS layers may provide insight into habitat associations over large spatial extents, vegetation surveys and field-based measurements may be necessary to detect specific habitat requirements at the finest scales. For example, tree density, tree height and diameter, dominant tree species and species composition, forest structural stage, and canopy closure may be important for habitat suitability. The presence and percent cover of riparian vegetation, deciduous trees, and understory vegetation may be important components of preferred habitat for Red-faced Warblers. Presence of Gambel oak may also be important for both target species (Rosenstock 1998), although it may be more than simply presence but oak of certain size classes (Jentsch et al. 2007). Previous occurrence or levels of timber harvest and thinning activities were also not considered. Red-faced Warblers may show a negative response to small-diameter thinning, as these treatments may remove cover for foraging and nesting, while Grace's Warblers may respond positively as they may benefit

from a more open forest structure (Kalies et al. 2010). However, both species may be negatively impacted by overstory removal and selective harvest treatments that often remove large-diameter trees (Kalies et al. 2010). Although habitat-specific abundance estimates were beyond the scope of this study, future studies may aim to determine whether density of Grace's and Red-faced Warblers varies in relation to landscape characteristics and habitat features such as elevation, species composition, and habitat structure, or logging, fire, or infrastructure disturbance.

Study Limitations

This study estimated the population sizes of two forest-dwelling warblers based on estimation of suitable habitat area and density determined through survey data corrected for incomplete detection. There are, of course, limitations associated with a study of this nature. First, there are assumptions inherent in establishing detection probabilities and therefore densities. These assumptions are fully discussed in Farnsworth et al. (2002), but in summary are: the population of birds within the detection radius does not change during the point count (i.e., closed population), individuals are not double-counted, detection probability is constant throughout the point count, and birds are correctly assigned to a distance category. Though these assumptions are likely to be violated to some degree, time-removal modeling is still one of the most robust methods available (Farnsworth et al. 2002, McCallum 2005). This method is appropriate for closed forest habitats, for surveys where most of the detections are by sound, and for focal species that have high singing frequencies (Farnsworth et al. 2002, Alldredge et al. 2007b, Reidy et al. 2011, Golding et al. 2016). This method can produce robust estimates of population size and density when detection probabilities are high, when using fixed-radius counts, and when models incorporate heterogeneity (Farnsworth et al. 2005, Alldredge et al. 2007b, Efford and Dawson 2009). In this study, focal species detections were almost exclusively auditory, focal species sang frequently, detection probabilities were high overall, fixed-radius counts were utilized, and models accounted for heterogeneity. While distance sampling is also commonly used in population size estimation, there can be substantial error in distance estimates to auditory detections in closed-canopy forests, resulting in high levels of uncertainty in estimates of abundance that are obtained by estimating distances to birds detected aurally in forested habitats (Alldredge et al. 2007a, Alldredge et al. 2008).

We estimated detection probability and density for Grace's and Red-faced Warblers within the areas that we surveyed. In extrapolating these estimates to larger areas that were not all surveyed, we make the following assumptions: our survey areas are representative of habitat as a whole within each project area; and the true density of these species is constant over the entire range of suitable habitat. We selected survey routes randomly, as long as they met certain criteria for general habitat type and overall length; therefore, routes should be fairly representative of habitat within a project area. However, having only four sampling sites per project area is unlikely to capture all of the habitat characteristics or variability present within each mountain range.

We have attempted to conservatively estimate suitable habitat for these species using available GIS layers. However, limitations are also inherent in estimating total suitable habitat for a large area. As discussed above, large-scale GIS mapping is incapable of differentiating microhabitat features that may affect the presence or density of these two species. Thus, our methods may overestimate the suitable habitat, and therefore population sizes, for these species. Our methods likely also underestimate available suitable habitat as we did not attempt to include habitat located on private lands of New Mexico or estimate private land warbler populations. In

addition, for Red-faced Warblers we conservatively removed habitat of the Gallinas Mountains in the Magdalena district, Cibola National Forest because New Mexico Avian Conservation Partners suggests the species breeds less regularly in this region (NMPIF 2007), although eBird sightings have documented the species in these mountains (eBird 2017). Incidentally, if the Gallinas Mountains were included, this would add an additional 12,999 ha of suitable habitat. We also removed habitat of the Smokey Bear and Guadalupe districts of the Lincoln National Forest for Red-faced Warblers as these regions are likely outside of their regular breeding distribution.

Though there are limitations to making population estimates as described here, this study provides baseline assessments of density and population size of Grace's and Red-faced Warblers in New Mexico. We used statistically rigorous methods to cost-effectively conduct state-wide surveys and cover large portions of suitable habitat across the geographically disparate mountain ranges of New Mexico within single breeding seasons. As discussed previously, there is currently only limited information about the population sizes of these two species in New Mexico, and this extant information is based on methods not specifically designed to estimate population size. Here, we implemented methodology targeted at producing robust density estimates for forest-dwelling species to provide more reliable population size estimates to inform effective management.

Future Work

During this three year study, 125 species and 28,235 individuals were recorded. Because time of detection was recorded for all species detected, the statistical methods applied in this study for the two focal warbler species could potentially be used to calculate regional density estimates for other bird species detected from 2015-2017, provided the sample sizes of detections are large enough and estimates for ponderosa pine, pine-oak, or mixed-conifer forest habitats that we sampled are of biological interest. Bird species of interest for which potential analyses could be conducted include: (1) other priority Species of Greatest Conservation Need such as Virginia's Warbler (n = 125), Pygmy Nuthatch (n = 1,186), Western Bluebird (n = 567), and Pinyon Jay (n = 118); (2) common species showing significant declines in New Mexico (NMACP 2017) such as Mountain Chickadee (n = 1,805), Violet-green Swallow (n = 174), and Steller's Jay (n = 1,341); (3) species with high threats in New Mexico (NMACP 2017) such as Brown Creeper (n = 149), House Wren (n = 397), and Chipping Sparrow (n = 462); (4) other species of concern for which New Mexico has a high stewardship responsibility (NMACP 2017) such as Broad-tailed Hummingbird (n = 587), Townsend's Solitaire (n = 167), Olive Warbler (n = 63), and Band-tailed Pigeon (n = 82); or (5) any other species of research or management interest.

This study produced comprehensive results on the state-wide distribution, density, and population sizes of breeding Red-faced and Grace's Warblers in New Mexico; information that previously was unknown and will improve management. Nevertheless, further information is still lacking on aspects of breeding biology necessary for conservation. Identifying habitat relationships and habitat requirements is essential for effective conservation efforts, and key habitat variables influencing the abundance of the two focal species of warblers, as well as many other species detected in this study, are generally unknown. Large detection databases are a valuable resource for many different natural resource questions, such as wildlife habitat modeling. More work could be done using the large detection database compiled over the three

years of this study to investigate habitat associations and gain insight into habitat requirements of priority species to guide habitat management and conservation efforts in New Mexico.

To investigate species-habitat relationships, the 2015-2017 point count survey and removal sampling data could be analyzed in conjunction with environmental descriptors at survey locations. Specifically, models of variation in species abundance and occurrence as a function of site-specific habitat variables could be generated in order to identify important habitat features for each species and determine if species occurrence varies with landscape characteristics such as elevation, slope, or disturbance levels. In this three year study, we have likely obtained appropriate sample sizes and spatial coverage to allow for robust inferences regarding species-habitat relationships for the target species, including sampling variation in habitat features and expected species densities in New Mexico. While detection probability and density were calculated at the project area scale for population size estimation in this current study, point- and route-specific estimates of density and presence/absence can also be calculated from detection data at individual survey points to model variation in abundance and occupancy in relation to habitat features. Local and landscape-scale factors potentially influencing habitat use and abundance of the target species can be obtained using extant GIS datasets, including timber harvest and thinning activities, road density, vegetation type, distance to water feature or drainage, terrain ruggedness, slope, aspect, elevation, fire boundaries and management, and other variables of potential biological importance. Species distribution modeling, based on analyses of associations with these types of broad-scale habitat features, can map predicted species breeding distribution and density throughout New Mexico. Species-habitat association results could be further improved, and even more informative, with the use of vegetation measurements collected at the survey point locations, in order to quantify microhabitat features and structural components of vegetation that are not represented or cannot be differentiated in current GIS datasets, and likely play an important role in habitat preferences and specific habitat requirements for forest species. Identification of habitat needs and habitat associations is critically important for implementing appropriate habitat restoration and management for these priority pine forest species. This kind of modeling work would improve the current understanding of habitat relationships and breeding habitat requirements, determine management actions that may help priority species, and identify high-quality habitat and critical areas for conservation for Red-faced and Grace's Warblers.

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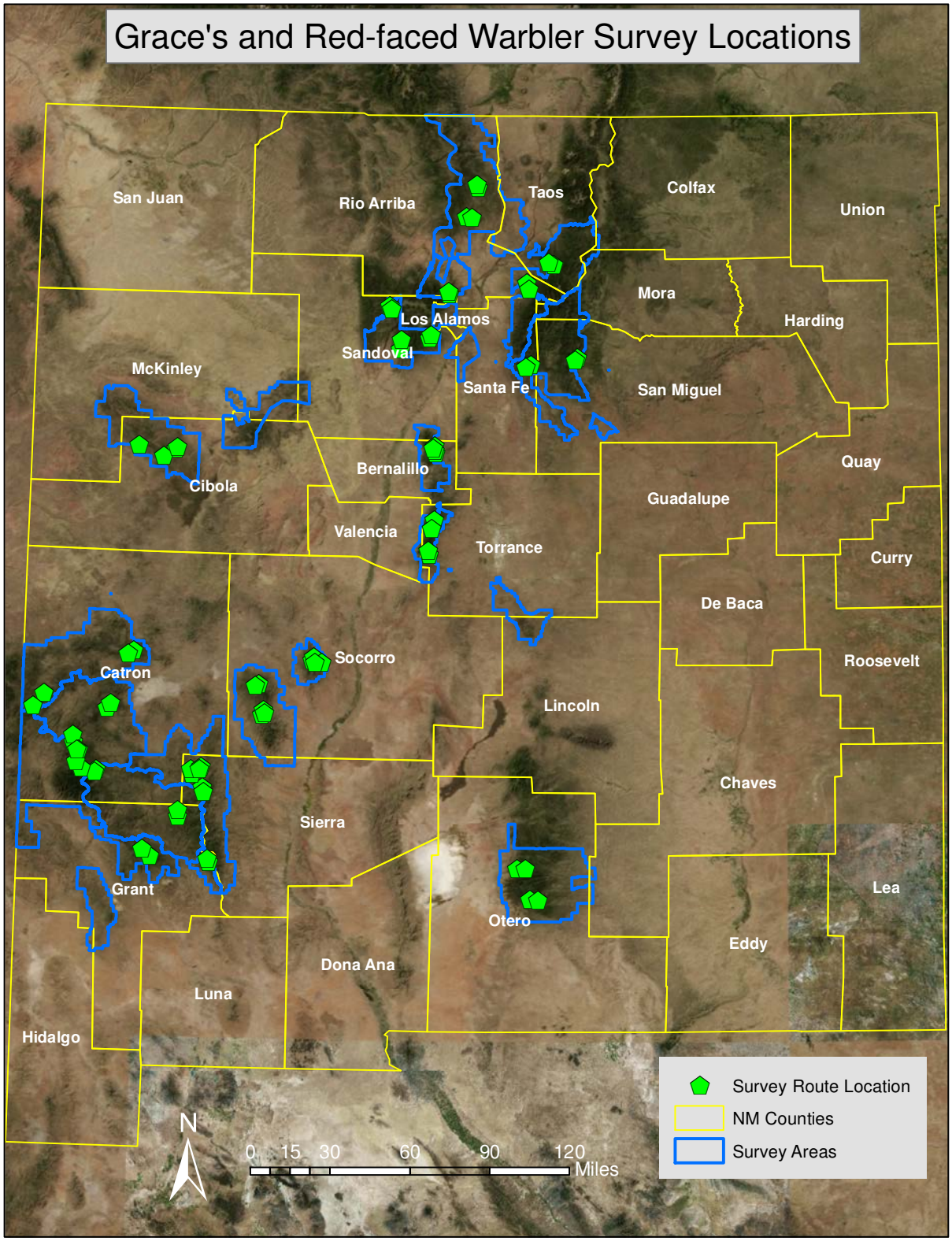
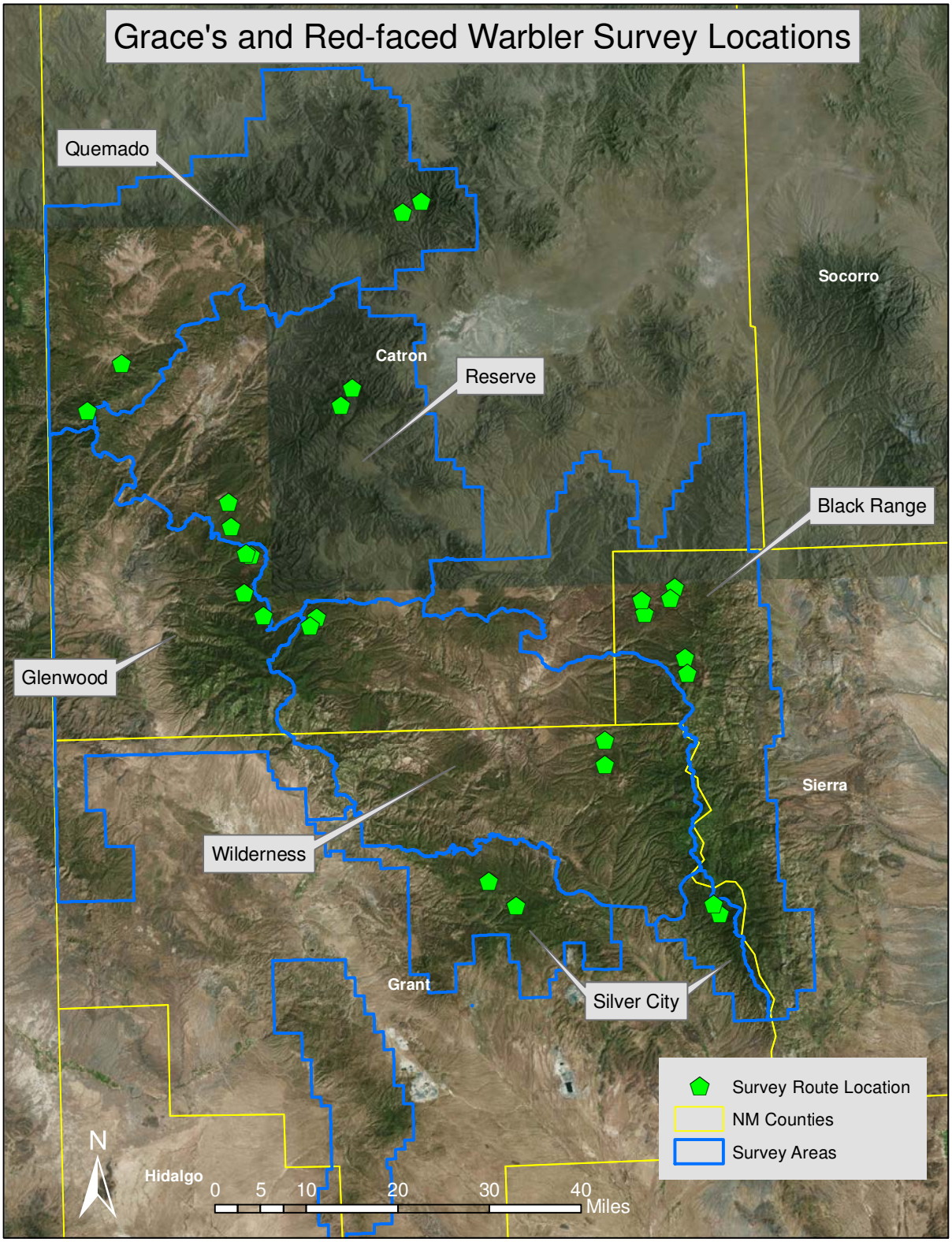
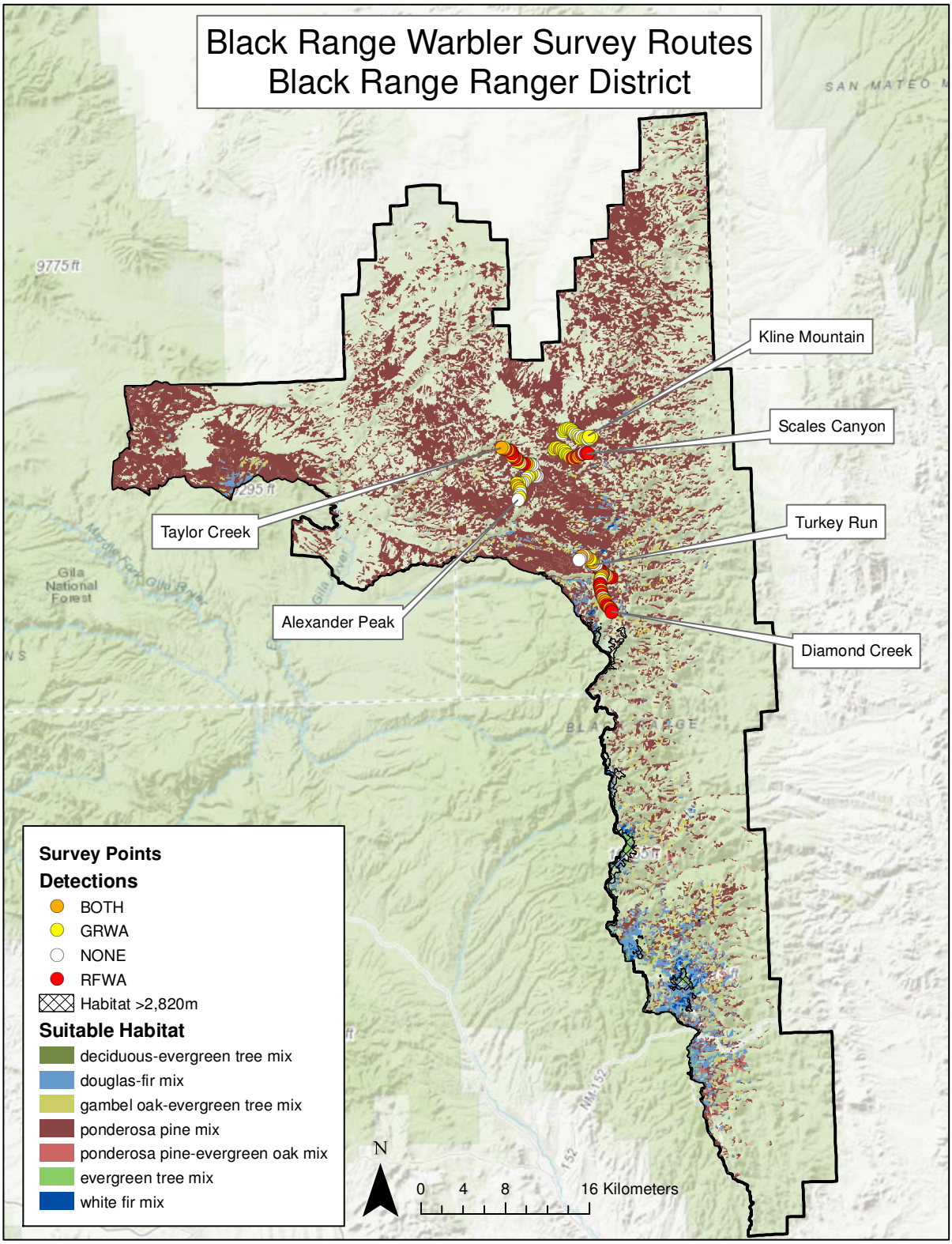
Map 1. Overview of state-wide Grace's and Red-faced Warbler survey route locations in New Mexico, 2015-2017.



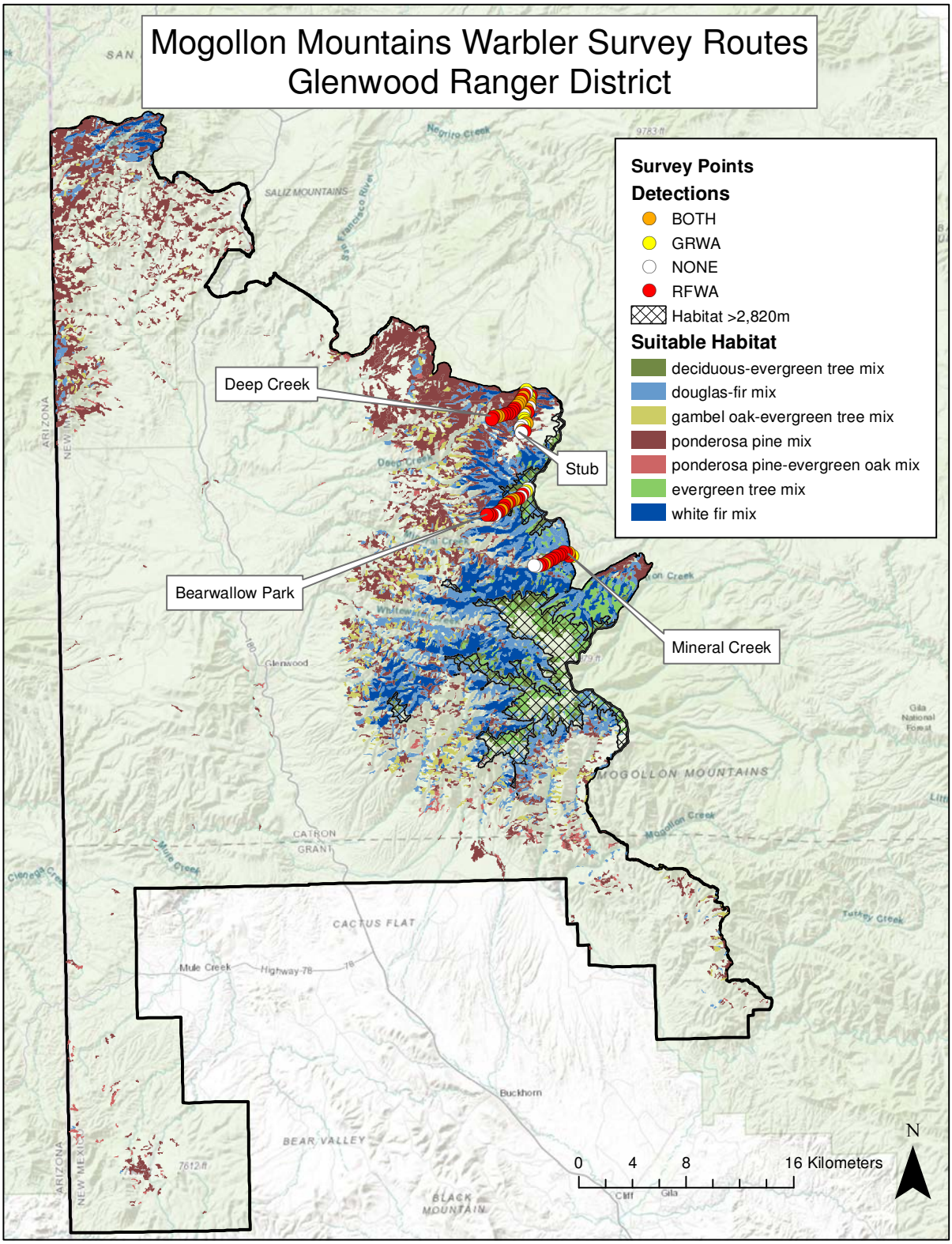
Map 2. Overview of Grace's and Red-faced Warbler survey route locations in the Gila and Apache National Forests of New Mexico.



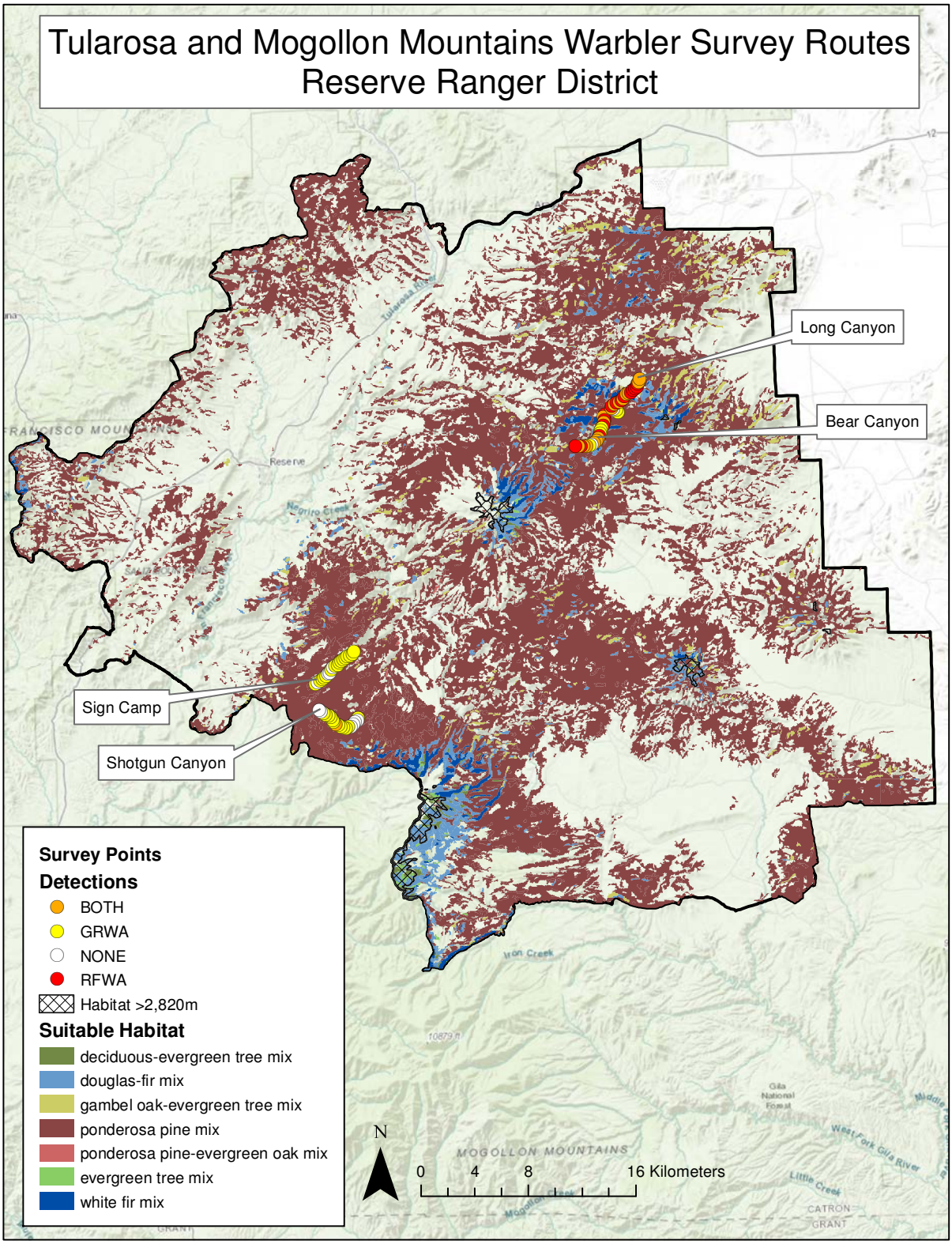
Map 3. Location and name of Grace's and Red-faced Warbler survey routes and type and extent of suitable habitat in the Black Range, Black Range Ranger District, Gila National Forest, New Mexico.



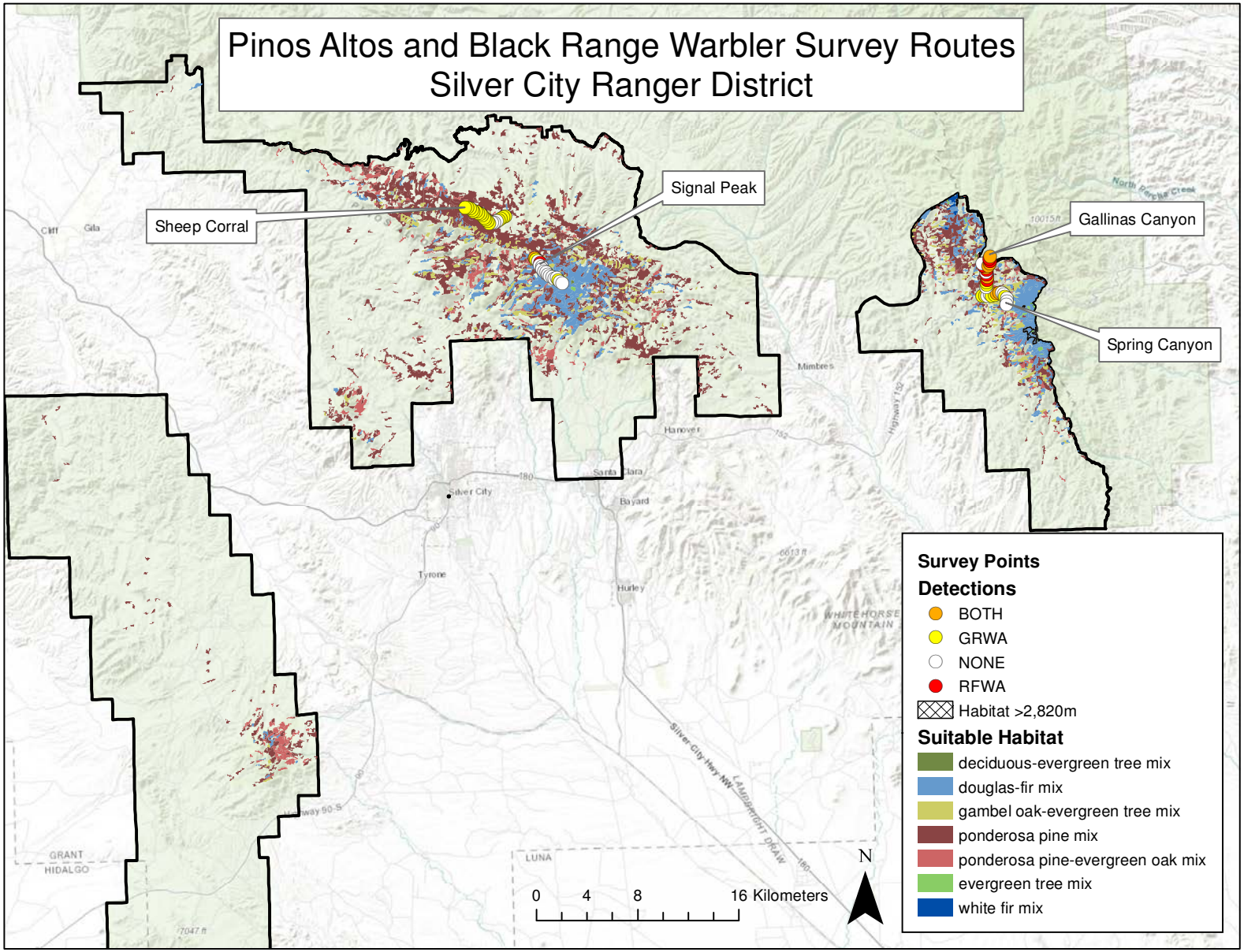
Map 4. Location and name of Grace's and Red-faced Warbler survey routes and type and extent of suitable habitat in the Mogollon Mountains, Glenwood Ranger District, Gila National Forest, New Mexico.



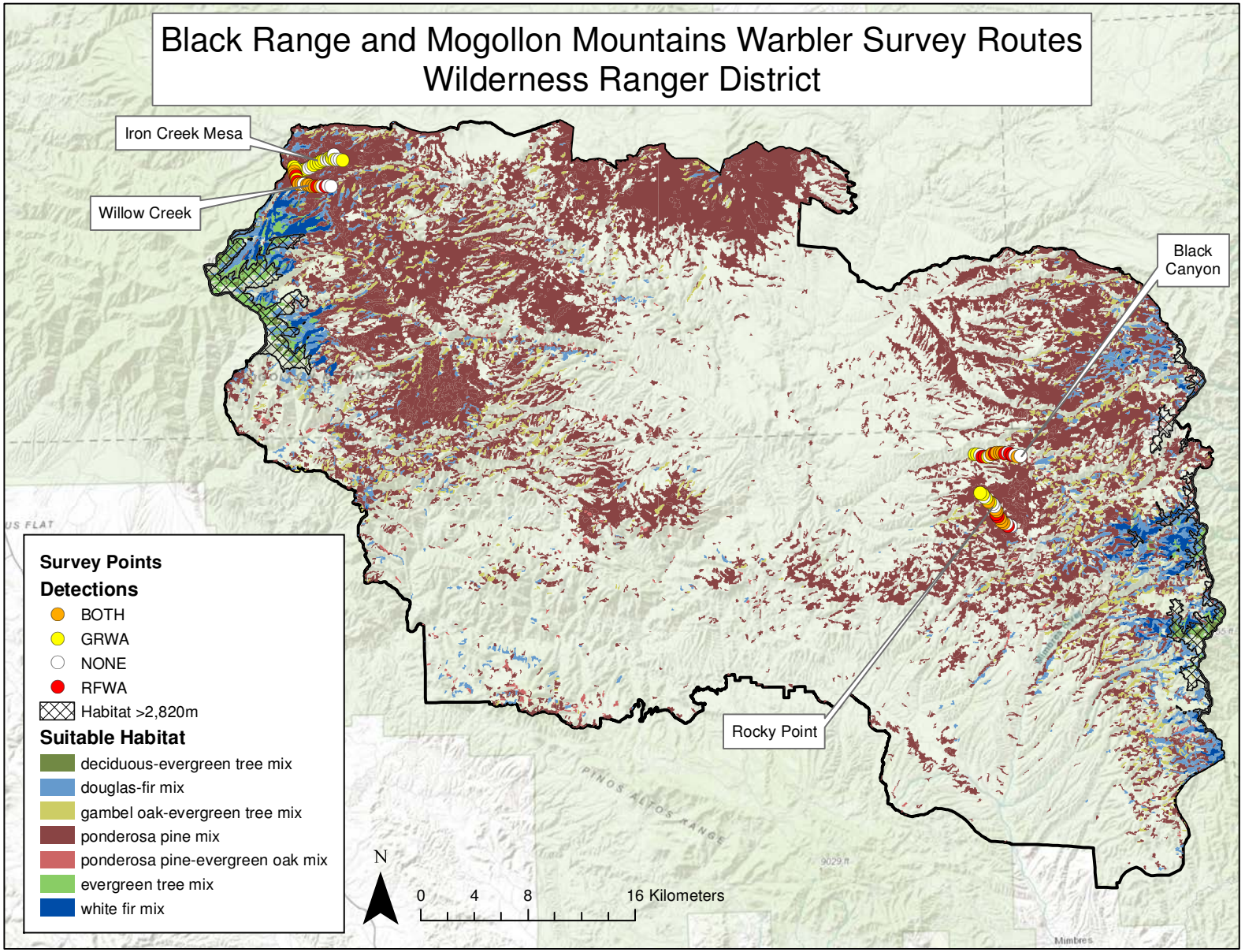
Map 5. Location and name of Grace's and Red-faced Warbler survey routes and type and extent of suitable habitat in the Tularosa and Mogollon Mountains, Reserve Ranger District, Gila National Forest, New Mexico.



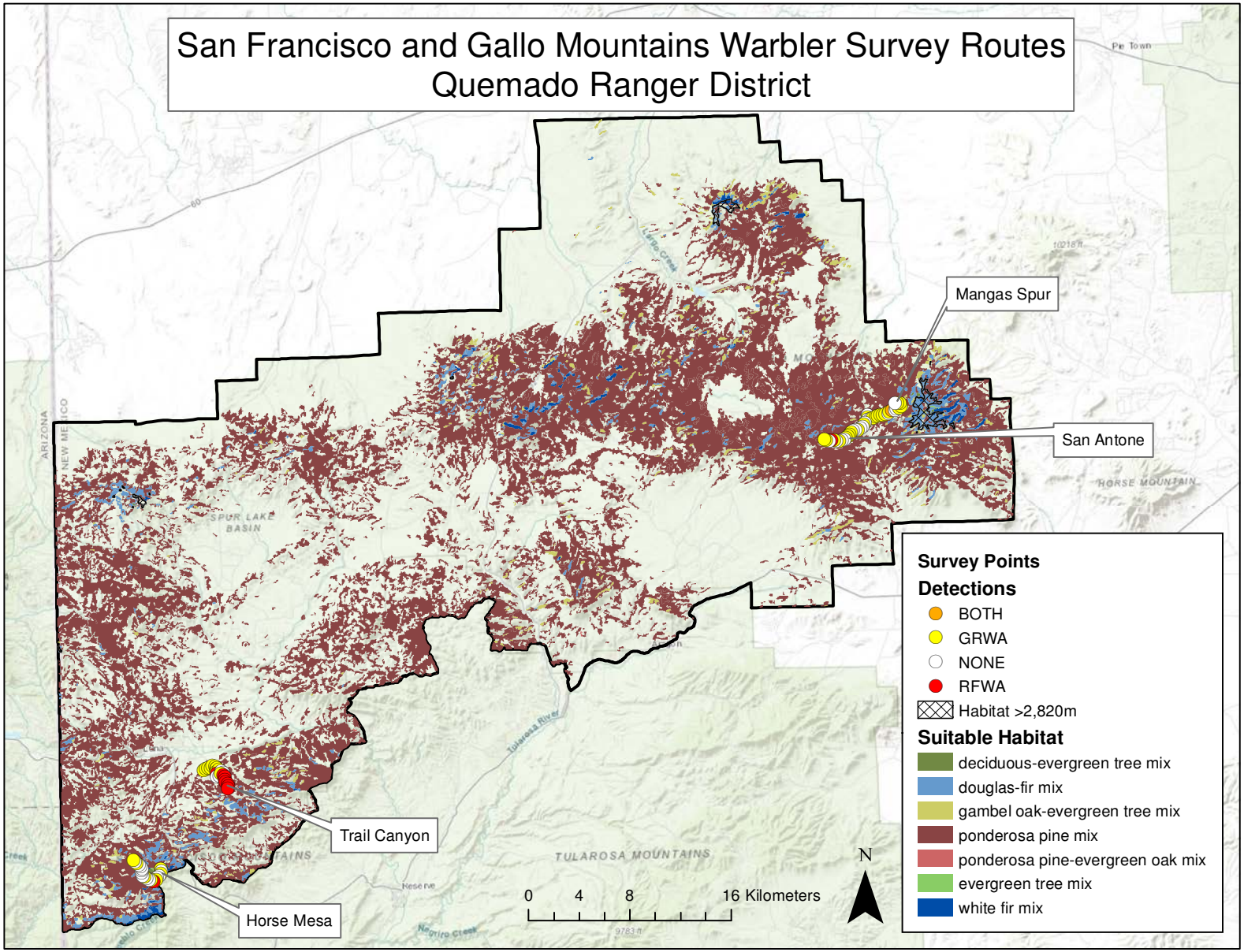
Map 6. Location and name of Grace's and Red-faced Warbler survey routes and type and extent of suitable habitat in the Pinos Altos and Black Range, Silver City Ranger District, Gila National Forest, New Mexico.



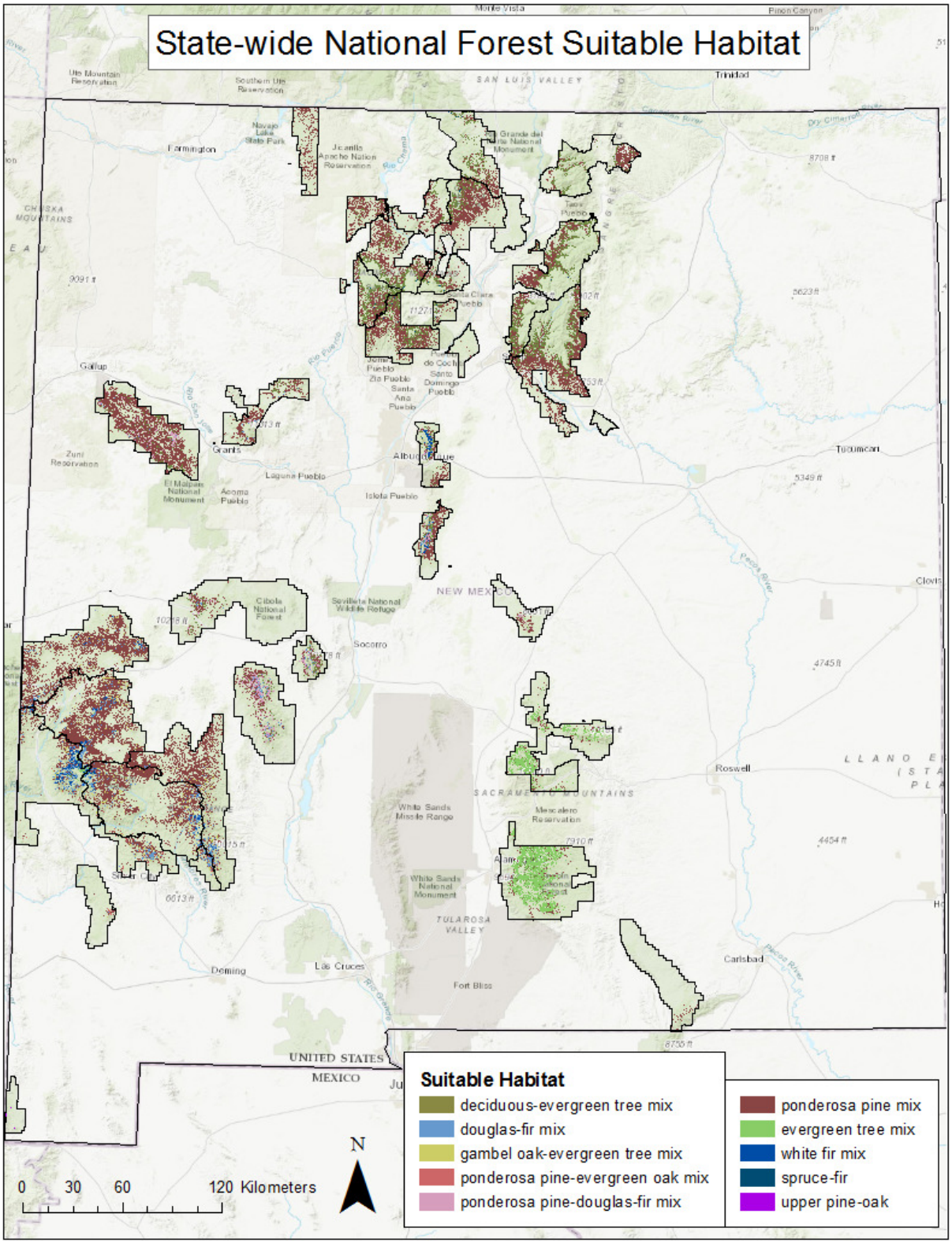
Map 7. Location and name of Grace's and Red-faced Warbler survey routes and type and extent of suitable habitat in the Black Range and Mogollon Mountains, Wilderness Ranger District, Gila National Forest, New Mexico.



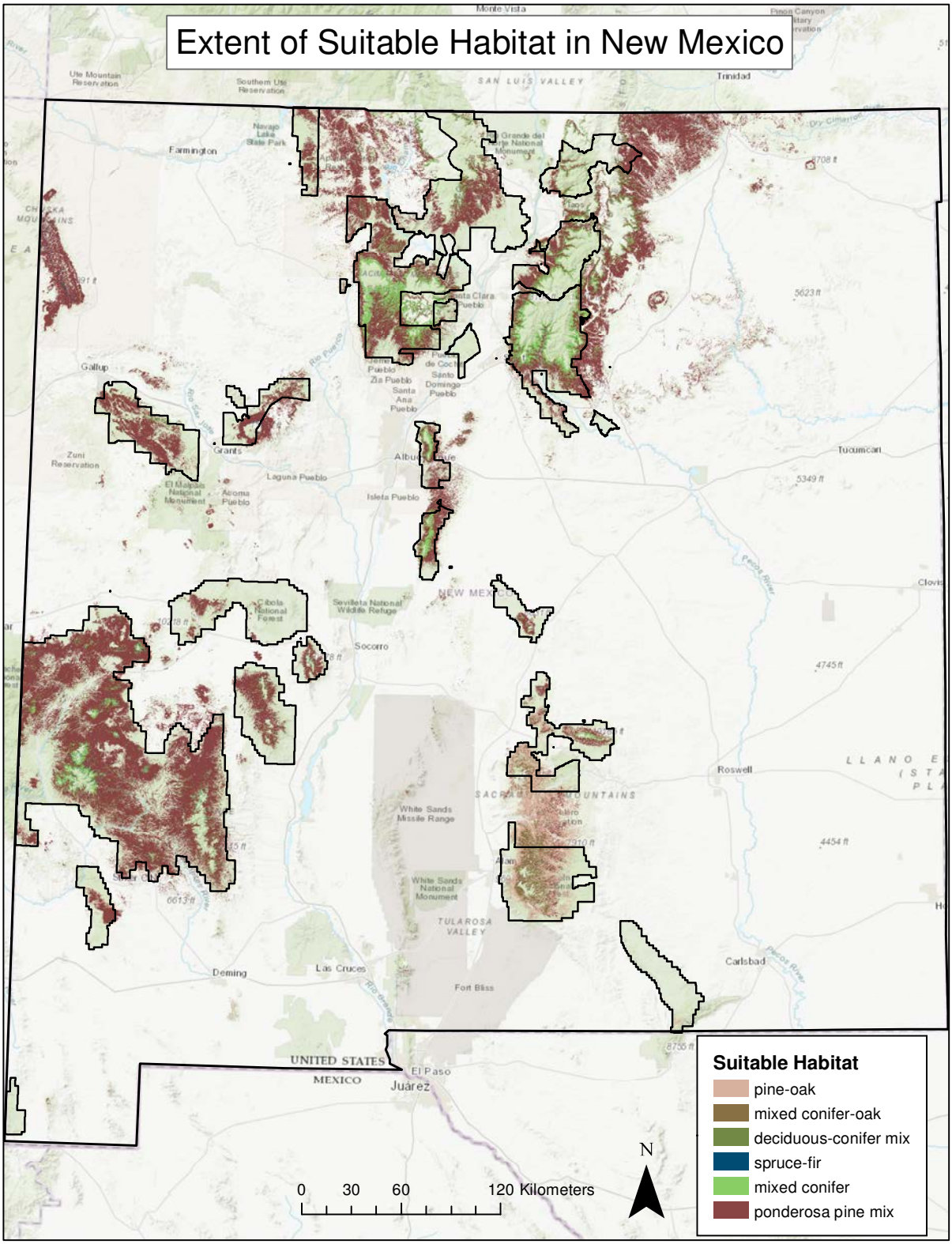
Map 8. Location and name of Grace's and Red-faced Warbler survey routes and type and extent of suitable habitat in the San Francisco and Gallo Mountains, Quemado Ranger District, Apache National Forest, New Mexico.



Map 9. Extent of state-wide suitable habitat in the Apache, Carson, Cibola, Coronado, Gila, Lincoln, and Santa Fe National Forests of New Mexico.



Map 10. National Forest boundaries and extent of suitable habitat types for Grace's and Red-faced Warblers in New Mexico from Southwest ReGAP land cover data (SWReGAP 2016).



Appendix A. State-wide estimates (in ha) of area of suitable habitat in National Forest Ranger Districts surveyed 2015-2017.

National Forest	Surveyed districts	Total size	Suitable habitat	Ponderosa pine mix	Ponderosa pine - Douglas fir mix	Douglas fir mix	White fir mix	Spruce-fir	Deciduous - evergreen tree mix	Evergreen tree mix	Ponderosa pine - evergreen oak mix	Gambel oak - evergreen tree mix
Carson	Camino Real, El Rito, Tres Piedras	407,734	110,487	70,595	*	*	*	396	39,497	*	*	*
Santa Fe	Pecos-Las Vegas, Espanola, Jemez	468,675	175,583	114,759	*	*	*	570	60,254	*	*	*
Cibola	Sandia, Mountainair, Mt. Taylor, Magdalena	853,200	208,377	144,625	24,751	7,708	3,627	*	27,112	555	*	*
Lincoln	Sacramento	222,069	65,561	6,318	*	*	*	*	4,954	54,289	*	*
Gila	Black Range, Glenwood, Reserve, Silver City, Wilderness	1,128,699	334,889	264,828	*	32,474	11,799	*	990	1,964	4,643	18,191
Apache	Quemado	244,180	91,219	84,025	*	3,977	801	*	34	12	9	2,361
	Total	3,324,557	986,117	685,150	24,751	44,158	16,227	966	132,840	56,821	4,652	20,552

* Each forest uses slightly different habitat designations in their geospatial datasets. Habitat designations marked with an asterisk are not used on the National Forest.

Appendix B. Estimates of available habitat in New Mexico National Forest Ranger Districts that were not surveyed 2015-2017, and estimates of density (D; calculated from forest-specific density estimates) and population size with upper and lower 95% confidence intervals (CI).

National Forest	Ranger District	Total size	Suitable habitat	Ponderosa pine mix	Spruce - fir	Deciduous evergreen tree mix	Evergreen tree mix	Upper pine-oak	Grace's Warbler			Red-faced Warbler		
									D ± SE	Abun-dance	95% CI	D ± SE	Abun-dance	95% CI
Carson	Questa	111,732	22,342	13,023	84	9,235	*	*	0.30 ± 0.02	13,374	11.609-15,139	--	--	--
	Canijilon	60,989	14,762	11,755	0	3,007	*	*		8,837	7,671-10,003			
	Jicarilla	63,874	13,588	13,283	0	305	*	*		8,134	7,061-9,207			
Santa Fe	Cuba	103,040	47,243	31,050	72	16,120	*	*	0.28 ± 0.04	26,106	17,983-34,229	--	--	--
	Coyote	108,541	43,459	30,392	212	12,855	*	*		24,015	16,543-31,487			
Lincoln	Smokey Bear	171,367	28,354	5,330	*	749	22,276	*	0.14 ± 0.01	7,854	6,702-9,007	+	+	+
	Guadalupe	116,860	1,737	1,737	*	0	0	*		481	410-552			
Coronado	Douglas	27,825	317	*	*	*	*	317	0.15 ± 0.03	92	54-130	0.05 ± 0.01	35	17-52
	Total	764,226	171,803	106,570	368	42,272	22,276	317		88,892	68,032-109,753		35	17-52

* Each forest uses slightly different habitat designations in their geospatial datasets. Habitat designations marked with an asterisk are not used on the National Forest.
-- Species does not breed regularly in this region.
+ These districts are likely outside of the species regular breeding distribution.

Appendix C. Avian species inventory from 2015-2017 surveys. Species listed in taxonomic order and with NMDGF conservation status.

Common Name	Scientific Name	NM DGF status*	Species detected by location																
			2015						2016					2017					
			W. Jemez	Man-zano	Magda-lena	Sandia	San Mateo	Zuni	Sacra-mento	S. Sangre de Cristo	E. Jemez	San Juan	N. Sangre de Cristo	Black Range	Glen-wood	Re-serve	Silver City	Wilder-ness	Que-mado
Mallard[2]	*Anas platyrhynchos*											X							
Montezuma Quail	*Cyrtonyx montezumae*						X							X	X		X	x	x
Dusky Grouse	*Dendragapus obscurus*											X			X	X	X	x	
Wild Turkey	*Meleagris gallopavo*		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	x	x
Band-tailed Pigeon	*Patagioenas fasciata*		X	X			X	X	X	X	X	X	X		X		X	x	
Eurasian Collared-Dove[3]	*Streptopelia decaocto*																	x	
White-winged Dove	*Zenaida asiatica*		X		X	X		X			X								
Mourning Dove	*Zenaida macroura*		X	X	X	X	X	X	X	X	X	X	X	X		X	X	x	x
Common Nighthawk	*Chordeiles minor*	SGCN								X	X	X	X	X	X	X		x	x
Common Poorwill[2]	*Phalaenoptilus nuttallii*								X		X	X							
Mexican Whip-poor-will[3]	*Antrostomus arizonae*	SGCN												X			X		
White-throated Swift	*Aeronautes saxatalis*		X		X						X			X					
Rivoli's Hummingbird[3]	*Eugenes fulgens*														X				
Blue-throated Hummingbird[3]	*Lampornis clemenciae*													X	X		X	x	
Black-chinned Hummingbird	*Archilochus alexandri*			X		X					X		X						
Broad-tailed Hummingbird	*Selasphorus platycercus*		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	x	x
Rufous Hummingbird	*Selasphorus rufus*								X	X				X	X		X	x	
Turkey Vulture	*Cathartes aura*		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	x	x
Sharp-shinned Hawk	*Accipiter striatus*											X	X		X				x
Cooper's Hawk	*Accipiter cooperii*		X	X					X	X	X	X			X	X	X		
Northern Goshawk	*Accipiter gentilis*						X		X			X	X			X		x	
Common Black Hawk[3]	*Buteogallus anthracinus*	SGCN																x	
Swainson's Hawk	*Buteo swainsoni*								X							X			
Zone-tailed Hawk[2]	*Buteo albonotatus*								X										
Red-tailed Hawk	*Buteo jamaicensis*		X	X		X	X		X		X	X	X	X	X	X	X	x	
Golden Eagle	*Aquila chrysaetos*												X			X	X		
Flammulated Owl	*Psiloscops flammeolus*	SGCN	X	X				X	X										
Western Screech-Owl[3]	*Megascops kennicottii*															X			x
Great Horned Owl	*Bubo virginianus*				X						X	X		X		X	X		x

Common Name	Scientific Name	status*	W. Jemez	Man-zano	Magda-lena	Sandia	San Mateo	Zuni	Sacra-mento	S. Sangre de Cristo	E. Jemez	San Juan	N. Sangre de Cristo	Black Range	Glen-wood	Re-serve	Silver City	Wilder-ness	Que-mado
Northern Pygmy-Owl	*Glaucidium gnoma*		X						X							X		x	
Mexican Spotted Owl	*Strix occidentalis lucida*	SGCN					X		X					X	X	X	X	x	
Long-eared Owl[3]	*Asio otus*																	x	
Lewis's Woodpecker[3]	*Melanerpes lewis*	SGCN														X		x	
Acorn Woodpecker	*Melanerpes formicivorus*				X		X	X						X	X	X	X	x	x
Williamson's Sapsucker	*Sphyrapicus thyroideus*	SGCN	X						X	X		X	X		X	X	X		
Red-naped Sapsucker	*Sphyrapicus nuchalis*			X	X	X		X	X	X	X	X	X		X	X		x	x
Ladder-backed Woodpecker[3]	*Picoides scalaris*													X			X	x	
Downy Woodpecker	*Picoides pubescens*		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	x	x
Hairy Woodpecker	*Picoides villosus*		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	x	x
American Three-toed Woodpecker	*Picoides dorsalis*		X							X		X	X	X	X	X	X	x	x
Northern Flicker	*Colaptes auratus*		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	x	x
American Kestrel	*Falco sparverius*						X				X					X			x
Peregrine Falcon	*Falco peregrinus*	SGCN					X						X					x	
Olive-sided Flycatcher	*Contopus cooperi*	SGCN	X	X	X	X					X	X	X	X	X	X		x	
Greater Pewee[3]	*Contopus pertinax*																X	x	
Western Wood-Pewee	*Contopus sordidulus*		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	x	x
Hammond's Flycatcher	*Empidonax hammondii*		X							X	X	X	X	X	X		X	x	x
Gray Flycatcher[3]	*Empidonax wrightii*															X			
Dusky Flycatcher	*Empidonax oberholseri*			X						X	X	X	X	X			X	x	
Cordilleran Flycatcher	*Empidonax occidentalis*		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	x	x
Black Phoebe[3]	*Sayornis nigricans*																	x	
Say's Phoebe	*Sayornis saya*		X			X			X		X								
Ash-throated Flycatcher	*Myiarchus cinerascens*		X	X	X	X	X	X			X			X	X	X		x	x
Cassin's Kingbird[2]	*Tyrannus vociferans*										X								
Western Kingbird	*Tyrannus verticalis*					X										X			
Plumbeous Vireo	*Vireo plumbeus*		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	x	x
Warbling Vireo	*Vireo gilvus*		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	x	x
Pinyon Jay	*Gymnorhinus cyanocephalus*	SGCN			X	X		X						X		X			
Steller's Jay	*Cyanocitta stelleri*		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	x	x
Clark's Nutcracker	*Nucifraga columbiana*	SGCN	X				X	X		X	X	X	X	X	X	X	X	x	x
American Crow[2]	*Corvus brachyrhynchos*								X	X		X	X						

Common Name	Scientific Name	status*	W. Jemez	Man-zano	Magda-lena	Sandia	San Mateo	Zuni	Sacra-mento	S. Sangre de Cristo	E. Jemez	San Juan	N. Sangre de Cristo	Black Range	Glen-wood	Re-serve	Silver City	Wilder-ness	Que-mado
Common Raven	*Corvus corax*		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	x	x
Purple Martin[3]	*Progne subis*														X			x	
Tree Swallow	*Tachycineta bicolor*		X	X		X	X		X		X	X	X	X	X		X	x	x
Violet-green Swallow	*Tachycineta thalassina*		X	X		X		X	X		X	X	X	X	X		X	x	
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*								X		X							x	
Cliff Swallow[3]	*Petrochelidon pyrrhonota*													X		X			
Mountain Chickadee	*Poecile gambeli*		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	x	x
Juniper Titmouse	*Baeolophus ridgwayi*	SGCN				X										X			
Bushtit	*Psaltriparus minimus*			X	X	X	X		X				X	X		X		x	
Red-breasted Nuthatch	*Sitta canadensis*		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
White-breasted Nuthatch	*Sitta carolinensis*		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	x	x
Pygmy Nuthatch	*Sitta pygmaea*	SGCN	X	X		X	X	X	X	X	X	X	X	X	X	X	X	x	x
Brown Creeper	*Certhia americana*		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	x	x
Rock Wren	*Salpinctes obsoletus*										X			X	X			x	
Canyon Wren	*Catherpes mexicanus*		X		X						X			X			X	x	x
House Wren	*Troglodytes aedon*		X		X	X	X	X	X	X	X	X	X	X	X	X	X	x	x
Bewick's Wren	*Thryomanes bewickii*			X	X					X	X	X							
Cactus Wren[2]	*Campylorhynchus brunneicapillus*										X								
Blue-gray Gnatcatcher	*Polioptila caerulea*				X		X		X								X		
American Dipper[3]	*Cinclus mexicanus*																X		
Golden-crowned Kinglet	*Regulus satrapa*		X				X		X	X			X	X	X		X	x	
Ruby-crowned Kinglet	*Regulus calendula*		X	X	X	X	X	X	X	X	X	X	X	X	X	X		x	
Western Bluebird	*Sialia mexicana*	SGCN		X	X		X	X	X	X	X	X	X	X	X	X	X	x	x
Mountain Bluebird	*Sialia currucoides*	SGCN							X	X	X	X		X	X		X		x
Townsend's Solitaire	*Myadestes townsendi*		X	X	X		X	X	X	X	X	X	X	X	X	X	X	x	x
Swainson's Thrush[2]	*Catharus ustulatus*										X								
Hermit Thrush	*Catharus guttatus*		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	x	x
American Robin	*Turdus migratorius*		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	x	x
Northern Mockingbird	*Mimus polyglottos*								X							X		x	
Olive Warbler[3]	*Peucedramus taeniatus*													X	X	X	X	x	x
Evening Grosbeak	*Coccothraustes vespertinus*	SGCN						X		X		X	X	X			X		
House Finch[1]	*Haemorhous mexicanus*				X														

Common Name	Scientific Name	status*	W. Jemez	Man-zano	Magda-lena	Sandia	San Mateo	Zuni	Sacra-mento	S. Sangre de Cristo	E. Jemez	San Juan	N. Sangre de Cristo	Black Range	Glen-wood	Re-serve	Silver City	Wilder-ness	Que-mado
Cassin's Finch	*Haemorhous cassinii*	SGCN		X						X		X	X						
Red Crossbill	*Loxia curvirostra*									X		X	X	X	X	X		x	x
Pine Siskin	*Spinus pinus*		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	x	x
Lesser Goldfinch	*Spinus psaltria*		X		X	X								X					
Green-tailed Towhee	*Pipilo chlorurus*			X					X		X	X	X	X	X	X	X	x	
Spotted Towhee	*Pipilo maculatus*		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	x	x
Rufous-crowned Sparrow[2]	*Aimophila ruficeps*										X								
Canyon Towhee[2]	*Melozone fusca*								X		X								
Chipping Sparrow	*Spizella passerina*		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	x	x
Black-chinned Sparrow[1]	*Spizella atrogularis*	SGCN			X														
Lark Sparrow[2]	*Chondestes grammacus*											X							
Song Sparrow[2]	*Melospiza melodia*											X							
Dark-eyed Junco	*Junco hyemalis*		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	x	x
Yellow-eyed Junco[3]	*Junco phaeonotus*	SGCN															X		
Bullock's Oriole[3]	*Icterus bullockii*																	x	
Brown-headed Cowbird	*Molothrus ater*				X	X				X		X	X						
Tennessee Warbler[3]	*Oreothlypis peregrina*																	x	
Orange-crowned Warbler	*Oreothlypis celata*		X	X	X	X	X	X	X	X	X	X	X	X	X				
Virginia's Warbler	*Oreothlypis virginiae*	SGCN	X	X	X	X	X		X	X	X	X	X	X	X	X	X	x	x
MacGillivray's Warbler	*Geothlypis tolmiei*		X	X	X	X		X	X	X			X		X			x	x
Yellow-rumped Warbler	*Setophaga coronata*		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	x	x
Grace's Warbler	*Setophaga graciae*	SGCN	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	x	x
Black-throated Gray Warbler	*Setophaga nigrescens*	SGCN		X	X	X					X	X		X	X	X		x	x
Townsend's Warbler[1]	*Setophaga townsendi*					X	X												
Wilson's Warbler[1]	*Cardellina pusilla*		X	X	X	X													
Red-faced Warbler	*Cardellina rubrifrons*	SGCN			X		X		X					X	X	X	X	x	x
Painted Redstart	*Myioborus pictus*	SGCN			X												X	x	
Hepatic Tanager	*Piranga flava*			X	X									X	X	X	X		
Summer Tanager[1]	*Piranga rubra*			X															
Western Tanager	*Piranga ludoviciana*		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	x	x
Black-headed Grosbeak	*Pheucticus melanocephalus*		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	x	x

[1]species only detected in FY2015, [2]species only detected in FY2016, [3]species only detected in FY2017
*Species of Greatest Conservation Need (SGCN; NMDGF 2016)

Appendix D. Species relative abundance by site (birds/ha) and total abundance and diversity measures for each site including: total number of individuals recorded, total abundance (total individuals/ha), Shannon's index, evenness, and species richness. Relative abundance values for a given site sum to 100%.

	Relative abundance (%) by location																	
	2015						2016					2017						
Common Name	W. Jemez	Manzano	Magda-lena	Sandia	San Mateo	Zuni	Sacra-mento	S. Sangre de Cristo	E. Jemez	San Juan	N. Sangre de Cristo	Black Range	Glen-wood	Reserve	Silver City	Wilder-ness	Quemado
Mallard										0.101							
Montezuma Quail					0.347							0.103	0.101		0.083	0.280	0.272
Dusky Grouse										0.402			0.101	0.165	0.249	0.056	
Wild Turkey	0.060	0.750	0.455	0.475	1.109	0.081	0.927	0.407	0.319	0.251	0.537	0.565	0.505	0.990	0.581	0.783	0.363
Band-tailed Pigeon	0.120	0.058			0.416	0.889	1.562	0.203	0.064	0.050	0.358		0.050		0.498	0.560	
Eurasian Collared-Dove																0.056	
White-winged Dove	0.120		0.834	1.426		0.081			0.128								
Mourning Dove	0.241	0.807	0.758	1.426	0.069	0.081	0.049	1.831	0.830	1.307	2.104	0.206		0.825	0.498	1.567	1.543
Common Nighthawk								0.136	0.192	0.251	0.627	0.360	0.101	0.220		0.056	0.181
Common Poorwill							0.049		0.192	0.050							
Mexican Whip-poor-will												0.103			0.166		
White-throated Swift	0.782		0.076						0.128			0.822					
Rivoli's Hummingbird													0.101				
Blue-throated Hummingbird												0.051	0.050		0.083	0.056	
Black-chinned Hummingbird		0.058		0.119					0.128		0.045						
Broad-tailed Hummingbird	2.526	1.557	4.094	8.378	1.455	2.423	3.514	1.831	2.427	1.508	0.895	1.028	0.505	0.385	1.743	0.951	0.817
Rufous Hummingbird							0.146	0.068				0.103	0.101		0.083	0.056	
Turkey Vulture	4.450	0.173	2.729	0.416	0.208	0.081	0.195	0.068	0.830	0.101	0.045	0.257	0.252	0.165	0.166	0.224	0.272
Sharp-shinned Hawk										0.050	0.090		0.101				0.091
Cooper's Hawk	0.241	0.115					0.098	0.068	0.064	0.050			0.050	0.110	0.083		
Northern Goshawk					0.139		0.049			0.101	0.090			0.110		0.056	
Common Black Hawk																0.056	
Swainson's Hawk							0.098							0.055			
Zone-tailed Hawk							0.049										
Red-tailed Hawk	0.120	0.231		0.059	0.069		1.220		0.575	0.201	0.358	0.051	0.252	0.385	0.166	0.056	
Golden Eagle											0.090			0.110	0.166		
Flammulated Owl	0.060	0.058				0.081	0.049										

	2015						2016					2017					
Common Name	**W. Jemez**	**Manzano**	**Magda-lena**	**Sandia**	**San Mateo**	**Zuni**	**Sacra-mento**	**S. Sangre de Cristo**	**E. Jemez**	**San Juan**	**N. Sangre de Cristo**	**Black Range**	**Glen-wood**	**Reserve**	**Silver City**	**Wilder-ness**	**Quemado**
Western Screech-Owl														0.055			0.091
Great Horned Owl			0.076						0.255	0.050		0.051		0.055	0.166		0.272
Northern Pygmy-Owl	0.120						0.098							0.165		0.056	
Mexican Spotted Owl					0.208		0.146					0.206	0.202	0.055	0.166	0.168	
Long-eared Owl																0.056	
Lewis's Woodpecker														0.055		0.112	
Acorn Woodpecker			0.227		1.663	0.081						0.617	0.101	0.825	1.826	1.847	1.452
Williamson's Sapsucker	0.120						0.098	0.136		0.704	0.179		0.252	0.220	0.249		
Red-naped Sapsucker		0.115	0.152	0.535		0.646	0.634	0.475	0.064	0.704	0.134		0.050	0.550		0.112	0.091
Ladder-backed Woodpecker												0.051			0.083	0.112	
Downy Woodpecker	1.143	0.807	0.834	0.713	0.762	0.646	1.611	1.492	2.299	1.256	1.477	0.051	0.101	0.220	0.166	0.056	0.181
Hairy Woodpecker	0.842	0.980	1.213	0.951	1.317	0.081	1.074	1.831	1.149	0.955	0.403	2.210	3.078	2.144	3.154	2.015	2.904
American Three-toed Woodpecker	0.060							0.136		0.101	0.045	0.051	0.555	0.165	0.415	0.112	0.091
Northern Flicker	2.526	2.307	2.123	1.842	3.812	2.181	4.832	4.814	5.619	4.472	3.223	4.265	3.532	5.113	4.730	5.484	5.808
American Kestrel					0.208				0.383					0.055			0.091
Peregrine Falcon					0.069						0.045					0.056	
Olive-sided Flycatcher	0.060	0.115	0.152	0.059					0.575	0.603	0.179	0.051	0.252	0.055		0.336	
Greater Pewee															0.166	0.504	
Western Wood-Pewee	0.722	1.615	1.820	1.188	0.416	0.404	0.830	0.475	3.065	3.819	4.521	3.237	0.555	1.649	0.747	1.511	1.452
Hammond's Flycatcher	0.541							0.610	0.255	0.151	0.537	0.206	0.101		0.083	0.168	0.091
Gray Flycatcher														0.110			
Dusky Flycatcher		0.058						0.203	0.511	0.352	0.582	0.154			0.332	0.168	
Cordilleran Flycatcher	4.149	3.518	4.776	1.129	4.435	3.312	4.783	2.102	2.363	1.307	1.656	4.522	4.995	2.199	3.817	4.868	1.724
Unk. Empidonax Flycatcher	0.120		0.076		0.069				0.128	0.050					0.083	0.056	
Black Phoebe																0.112	
Say's Phoebe	0.060			0.119			0.146		0.064								
Ash-throated Flycatcher	0.301	0.231	1.365	1.188	0.277	0.404			0.064			0.874	0.202	0.495		0.112	0.181
Cassin's Kingbird									0.192								
Western Kingbird				0.059										0.385			
Plumbeous Vireo	2.165	2.595	8.415	6.239	1.663	1.050	1.074	1.424	2.171	1.809	3.044	3.392	0.353	1.924	1.909	1.847	2.541
Warbling Vireo	3.608	4.325	3.260	1.664	0.832	0.565	3.709	1.492	1.916	2.312	2.014	0.360	2.220	2.364	1.079	1.007	0.544

	2015						2016					2017					
Common Name	**W. Jemez**	**Manzano**	**Magda-lena**	**Sandia**	**San Mateo**	**Zuni**	**Sacra-mento**	**S. Sangre de Cristo**	**E. Jemez**	**San Juan**	**N. Sangre de Cristo**	**Black Range**	**Glen-wood**	**Reserve**	**Silver City**	**Wilder-ness**	**Quemado**
Pinyon Jay			0.152	0.475		5.250						0.925		1.374			
Steller's Jay	3.848	3.172	2.350	4.159	7.484	7.270	6.979	4.136	3.959	3.769	2.731	4.317	3.986	6.432	5.560	6.659	4.991
Clark's Nutcracker	2.285				0.277	0.485		0.136	0.128	0.402	0.627	0.514	0.151	0.110	0.083	0.168	0.091
American Crow							0.049	0.136		0.201	0.985						
Common Raven	2.165	1.499	0.758	0.654	1.733	6.947	6.247	3.864	3.959	3.618	4.790	1.387	3.280	2.969	4.647	1.007	4.719
Purple Martin													0.101			0.616	
Tree Swallow	0.541	0.058		0.178	0.139		0.878		0.255	0.402	0.090	0.360	0.101		0.332	0.616	0.181
Violet-green Swallow	0.842	0.404		0.119		0.081	1.513		0.447	0.653	1.164	0.360	0.252		0.166	3.302	
Northern Rough-winged Swallow							0.195		0.575							0.280	
Cliff Swallow												0.051		0.110			
Mountain Chickadee	5.232	8.939	6.520	8.913	7.554	8.966	6.686	9.220	1.724	4.121	3.044	6.064	9.031	7.257	4.398	3.749	9.800
Juniper Titmouse				0.119										0.055			
Bushtit		0.519	1.516	0.594	0.208		0.488				0.134	0.514		0.055		0.392	
Red-breasted Nuthatch	0.722	0.519	1.213	1.307	0.901	1.939	0.976	6.237	0.575	0.754	0.627	0.154	1.060	0.825	0.166		
White-breasted Nuthatch	3.367	1.615	2.199	4.100	2.911	0.889	1.025	1.085	1.405	2.412	3.671	5.653	2.523	4.178	3.983	3.637	4.446
Pygmy Nuthatch	3.307	0.346		0.594	3.673	3.069	0.439	1.966	1.469	3.015	3.357	10.946	5.298	8.246	7.137	9.737	9.074
Brown Creeper	0.782	0.288	0.076	0.238	1.178	0.081	0.049	0.271	0.064	0.201	0.090	0.565	1.665	0.660	0.996	1.119	0.726
Rock Wren									0.383			0.051	0.050			0.504	
Canyon Wren	0.060		0.758						0.255			0.719			0.747	0.224	0.272
House Wren	0.120		0.607	0.475	1.940	0.162	1.611	0.136	2.490	1.508	0.313	2.210	5.096	0.990	3.154	7.555	0.272
Bewick's Wren		0.058	0.076					0.068	0.128	0.101							
Cactus Wren									0.255								
Blue-gray Gnatcatcher			3.184		0.069		0.098								0.083		
American Dipper															0.083		
Golden-crowned Kinglet	0.060				0.139		0.195	0.271			0.045	0.051	0.505		0.083	0.112	
Ruby-crowned Kinglet	5.111	1.845	0.303	0.772	1.733	1.939	0.586	1.017	0.192	4.221	1.701	0.976	1.715	0.110		0.280	
Western Bluebird		2.076	0.531		1.317	1.212	0.342	0.949	2.235	1.809	2.059	3.854	2.371	3.848	4.564	3.022	4.628
Mountain Bluebird							0.342	0.203	0.255	0.151		0.103	0.101		0.249		0.091
Townsend's Solitaire	0.301	0.173	0.152		0.416	1.535	0.683	0.881	0.511	0.854	0.895	0.206	0.908	0.880	0.083	0.336	1.361
Swainson's Thrush									0.064								
Hermit Thrush	5.713	7.497	4.549	3.565	4.435	5.977	4.197	5.492	2.171	3.869	4.521	2.569	9.687	4.343	2.988	2.238	3.902

	2015						2016					2017					
Common Name	**W. Jemez**	**Manzano**	**Magda-lena**	**Sandia**	**San Mateo**	**Zuni**	**Sacra-mento**	**S. Sangre de Cristo**	**E. Jemez**	**San Juan**	**N. Sangre de Cristo**	**Black Range**	**Glen-wood**	**Reserve**	**Silver City**	**Wilder-ness**	**Quemado**
American Robin	6.314	10.265	2.805	3.684	7.277	3.150	10.054	4.746	4.598	7.337	5.909	4.676	5.096	5.278	5.726	5.204	1.906
Northern Mockingbird							0.049							0.055		0.056	
Olive Warbler												0.565	0.505	0.495	0.415	0.616	1.543
Evening Grosbeak						0.081		1.627		0.503	0.045	0.051			0.166		
House Finch			0.152														
Cassin's Finch		0.058						0.068		0.151	0.045						
Red Crossbill								0.746		1.960	0.492	0.308	0.151	1.154		0.168	1.089
Pine Siskin	4.630	0.923	0.379	5.645	11.088	7.674	2.196	7.797	1.405	4.774	8.326	0.668	1.413	0.330	0.913	0.504	2.087
Lesser Goldfinch	0.241		0.303	0.178								0.103					
Green-tailed Towhee		0.058					0.195		4.662	0.452	0.582	0.103	0.252	0.275	0.166	0.168	
Spotted Towhee	1.443	5.190	6.065	4.694	2.772	0.889	0.488	0.542	9.387	0.101	0.492	1.644	0.605	1.100	2.573	1.847	0.363
Rufous-crowned Sparrow									0.128								
Canyon Towhee							0.049		0.447								
Chipping Sparrow	2.946	2.076	2.047	1.367	0.277	0.969	0.732	1.017	2.235	4.472	3.402	1.079	0.151	0.935	1.245	0.672	1.180
Black-chinned Sparrow			0.303														
Lark Sparrow										0.101							
Song Sparrow										0.050							
Dark-eyed Junco	3.909	4.902	1.137	2.139	6.930	3.473	7.418	4.542	4.470	4.824	4.879	6.526	6.458	7.147	7.386	4.533	5.626
Yellow-eyed Junco															0.083		
Bullock's Oriole																0.056	
Brown-headed Cowbird			0.379	0.772				0.068		0.050	0.358						
Tennessee Warbler																0.056	
Orange-crowned Warbler	0.601	0.750	0.152	0.059	0.069	0.081	0.537	1.763	0.319	0.251	0.448	0.051	0.101				
Virginia's Warbler	0.361	0.173	0.834	0.951	0.347		0.098	0.339	0.575	0.352	0.179	0.360	0.454	0.935	0.415	0.560	0.907
MacGillivray's Warbler	0.421	0.346	0.682	1.307		0.242	0.195	0.271			0.090		0.101			0.112	0.091
Yellow-rumped Warbler	4.209	4.729	2.805	4.575	1.802	1.939	3.123	4.746	3.448	2.663	4.611	2.415	2.371	1.759	0.913	1.287	6.080
Grace's Warbler	7.096	9.631	5.155	7.011	3.119	7.351	3.075	5.695	7.216	6.884	6.088	4.573	1.615	4.728	4.398	3.470	4.719
Black-throated Gray Warbler		0.231	0.531	0.297					0.128	0.050		0.154	0.303	0.275		0.112	0.091
Townsend's Warbler				0.059	0.069												
Wilson's Warbler	0.060	0.058	0.152	0.297													
Red-faced Warbler			3.184		5.544		0.830					3.751	4.995	3.463	1.660	2.798	1.361
Painted Redstart			0.531												0.249	0.112	

	2015						2016					2017					
Common Name	**W. Jemez**	**Manzano**	**Magda-lena**	**Sandia**	**San Mateo**	**Zuni**	**Sacra-mento**	**S. Sangre de Cristo**	**E. Jemez**	**San Juan**	**N. Sangre de Cristo**	**Black Range**	**Glen-wood**	**Reserve**	**Silver City**	**Wilder-ness**	**Quemado**
Hepatic Tanager		0.058	0.986									0.411	0.101	0.055	0.249		
Summer Tanager		0.115															
Western Tanager	4.931	6.978	8.795	5.764	2.841	6.947	5.027	6.034	4.470	5.729	7.028	3.957	7.568	5.168	7.054	4.477	6.171
Black-headed Grosbeak	3.127	3.979	4.246	6.952	2.218	8.320	5.320	4.136	6.066	4.171	2.910	2.107	1.060	2.034	3.154	1.959	1.180
Total individuals of all species	1663	1734	1319	1683	1443	1238	2049	1475	1566	1990	2234	1946	1982	1819	1205	1787	1102
Total abundance of all species (# birds/ha)	4.010	3.704	3.087	4.252	3.281	3.153	4.181	3.427	3.462	4.087	4.501	3.945	4.178	3.712	2.884	3.978	2.354
Shannon's index	3.417	3.191	3.444	3.302	3.281	3.134	3.342	3.339	3.507	3.504	3.444	3.445	3.324	3.439	3.437	3.502	3.281
Evenness	0.857	0.804	0.860	0.840	0.839	0.828	0.813	0.841	0.840	0.843	0.841	0.816	0.796	0.821	0.823	0.809	0.835
Species richness	54	53	55	51	50	44	61	53	65	64	60	68	65	66	65	76	51