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Developing a Monitoring Program for Bird Populations in the Chiricahua Mountains, Arizona, Using Citizen Observers: Initial Stages

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Abstract

The Madrean Sky Island region is an ecologically important area harboring exceptional biodiversity, including a unique avifauna that supports a thriving ecotourism industry in southeastern Arizona. This area has been impacted by several large wildfires in recent decades. These wildfires have altered vegetation composition and structure in forests and woodlands, and the effects of these changes on bird populations and distribution are not well understood. We studied occupancy and habitat associations of forest and woodland birds within five mountain ranges in southeastern Arizona from 1991 to 1995, before these fires occurred. The resulting data provide a unique opportunity to compare postfire bird populations with populations in these ranges during the 1990s, but funding to accomplish the necessary postfire bird sampling has been limited. Consequently, we are exploring the feasibility of using skilled citizen observers to monitor bird occupancy and distribution. This report documents the early stages of an effort to sample bird populations in the Chiricahua Mountains, Arizona using citizen observers. It describes field methods, presents preliminary results, summarizes early lessons learned, and outlines future steps necessary to design and implement a rigorous monitoring program using citizen observers to sample bird populations in the Madrean Sky Islands.

Keywords: avifauna, biodiversity, bird populations, citizen science, climate change, Madrean, monitoring, wildfire

Cover photo: Cave Creek area, Chiricahua Mountains, Arizona (center). Also shown are selected iconic bird species found in the area, including broad-billed hummingbird, Montezuma quail, buff-breasted flycatcher, Mexican jay, elegant trogon, yellow-eyed junco, Arizona woodpecker and summer tanager (left top to bottom followed by right top to bottom; scientific names for bird species are shown in table 3). Center photo by Jamie S. Sanderlin (U.S. Forest Service), all others by Will Jaremko-Wright (used by permission).

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Contents

Introduction

The Madrean Sky Islands region, located in the southwestern United States and northern Mexico (fig. 1), is an ecologically important area characterized by numerous mountain "islands" (the Madrean archipelago) surrounded by desert and semi-desert "seas" (Flesch 2014; Gelbach 1981; Warshall 1995). This inland archipelago provides a stepping stone between two large mountain chains, connecting the Rocky Mountains and its associated plateaus with the Sierra Madre Occidental (Flesch 2014; Flesch et al. 2016; Gelbach 1981; Warshall 1995), and forming a north-south mountain axis that crosses several climatic zones.

Among the world's sky island complexes, the Madrean Sky Islands are unique in several ways. This region harbors a larger number of sky island mountain ranges than other complexes (variously estimated at 40 ranges by Warshall [1995] and 55 ranges by Deyo et al. [2013]). In addition, it is the only archipelago having the distinct north-south connection to two major mountain chains, extending from subtropical to temperate latitudes (Flesch 2014; Warshall 1995) and straddling two major floristic (Neotropic/Holarctic) and faunal (Neotropic/Nearctic) realms (Halffter 1987; Escalante et al. 2004). The result is exceptional biodiversity, including plants and animals with Madrean, Petran (Rocky Mountain), Sonoran, Chihuahuan, and Sinaloan (e.g., low-land Neotropical) affinities (Ferguson et al. 2013; Flesch 2014; McLaughlin 1995;

Figure 1—General location and extent of the Madrean Sky Island region within the continent of North America. Source: Miguel Villareal, U.S. Geological Survey, Western Geographic Science Center; (http://geography.wr.usgs.gov/science/EcoMod/; downloaded 1 July 2016).

Van Devender et al. 2013; Warshall 1995). Moreover, the vertical relief associated with these mountains allows these species to form a wide variety of ecological communities stratified along elevational gradients (Niering and Lowe 1984; Shreve 1915; Whittaker and Niering 1964). Because of this biodiversity, the Madrean archipelago is recognized as a global resource of high conservation value (Foreman 2000; Spector 2002; Supplee and McFarland 2013; Van Devender et al. 2013).

The avifuana of the Madrean Sky Islands region is of particular conservation interest in the United States (e.g., Balda 1967; Marshall 1957; Supplee and McFarland 2013). Several species with Madrean affinities reach their northern range limits in this region, including iconic species such as the elegant trogon (*Trogon elegans*). These species are much sought after by bird watchers, resulting in a thriving ecotourism industry catering to bird watchers in southeastern Arizona (King and Czech 1995; Leones et al. 1998).

In recent decades, the Madrean archipelago has undergone pronounced changes due to climate change, wildfire, insect outbreaks, border development, and other disturbances (Barton 2005; Kupfer et al. 2005; Lynch and O'Connor 2013; O'Connor et al. 2014; Quinn and Wu 2005), and those changes may threaten some of the unique plants and animals inhabiting this region (Coe et al. 2012; Falk 2013; Flesch et al. 2016; Ganey et al. 1996; Koprowski et al. 2005, 2013). Understanding the impacts of these disturbances on native plants and animals is critical to developing management strategies to conserve species and habitats (Flesch et al. 2016; Ganey et al. 1996; Misztal et al. 2013), yet such knowledge is largely lacking, as is information on population trends for most species.

We studied bird populations and habitats in forests and woodlands of five Sky Island ranges in southeastern Arizona from 1991 to 1995 (fig. 2). This study resulted in a rich data set documenting occupancy and habitat associations of forest and woodland birds in these ranges during that time period (Block and Severson 1992; Block et al. 1992; Ganey et al. 2015; Iniguez et al. 2005; Sanderlin et al. 2013). Many areas that were sampled for birds from 1991–1995 have subsequently burned in wildfires (table 1). This data set thus provides an opportunity to assess changes in occupancy and distribution of birds and the impacts of wildfires on bird communities and associated habitats. Due to funding constraints, however, resampling avian populations over multiple years within the study areas has not been feasible. Therefore, we were interested in exploring sampling approaches that did not require large funding commitments.

Citizen observers have been used in several research efforts and monitoring programs in recent years, and may provide a cost-effective way to collect data that would otherwise not be available (Barrows et al. 2016; Cox et al. 2012; Tulloch et al. 2013).

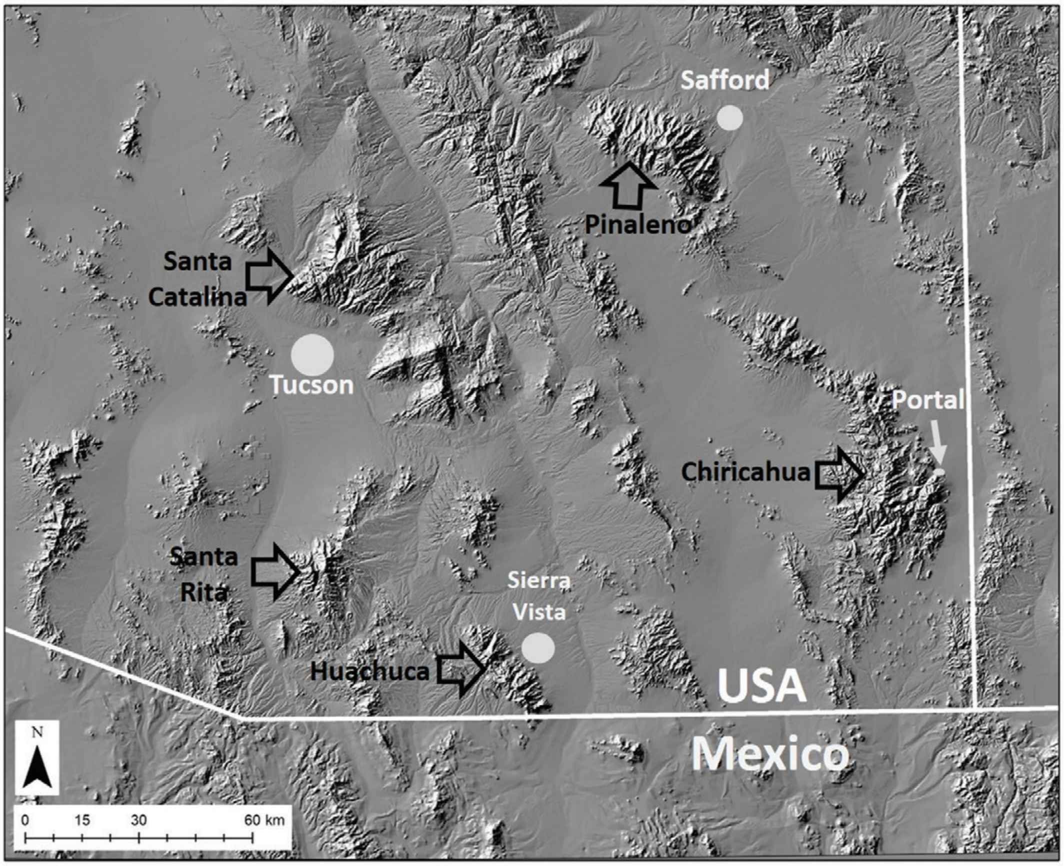


Figure 2—General locations of five mountain ranges (Chiricahua, Huachuca, Pinaleño, Santa Catalina, and Santa Rita mountains) in southeastern Arizona where bird populations were sampled from 1991 to 1995. The vertical white line denotes the Arizona – New Mexico border.

Table 1—List of large (>400 ha) wildfires that burned from 1994 to 2014 in areas where RMRS crews sampled bird populations from 1991–1995 in four Madrean Sky Island mountain ranges. Year in which the fire occurred and area contained within the fire perimeter are also shown. Data from Monitoring Trends in Burn Severity (MTBS 2017). Several large wildfires also burned in the Huachuca Mountains during this period, but these did not overlap with the RMRS bird transects.

Mountain range	Fire name	Year	Area burned (ha)
Chiricahua	Rattlesnake	1994	10,210
	Horseshoe I	2010	1,248
	Horseshoe II	2011	91,501
Pinaleño	Nuttall Complex	2004	12,901
	Grapevine	2012	7,101
Santa Catalina	Shovel	1995	497
	Bullock	2002	12,860
	Aspen	2003	32,361
Santa Rita	Florida	2005	6,620
	Greaterville	2011	778

Southeastern Arizona is home to many citizens who are interested in conservation issues and skilled at identifying birds by sight and sound. Consequently, we are exploring the feasibility of designing a program to monitor occupancy and distribution of birds using skilled citizen volunteers. This paper describes initial stages of this ongoing effort, and is focused on a pilot study in the Chiricahua Mountains, Arizona. We describe field methods used, present preliminary data resulting from this effort, summarize some early lessons learned, and describe future steps necessary to design and implement a scientifically rigorous citizen-science based monitoring program.

Case Study: Implementing Citizen Science

Study Area

Initial sampling during the 1990s covered the five largest sky islands in Arizona (fig. 2), but here we focus on a pilot study in one of those ranges. The Chiricahua Mountains are located in southeastern Arizona, just west of the border with New Mexico and just north of the border with Mexico. This range is oriented along a north-south axis that spans approximately 56 km. Elevation ranges from approximately 1,175 to 2,975 m. The Chiricahua Mountains are an uplifted fault block containing Precambrian basement rocks and Paleozoic and Cretaceous sedimentary rocks around a caldera complex formed by volcanic eruptions and intrusions (du Bray et al. 1999). A major eruption approximately 27 million years ago left a massive layer of volcanic ash that fused into welded rhyolite tuff (Nations and Stump 1981). Subsequent erosion has created steep mountain ridges and deep canyons.

Our study area consisted of oak and pinyon-juniper woodlands, pine-oak forests (*Pinus* spp. – *Quercus* spp.), pine forests, and mixed-conifer forests within the Coronado National Forest, at elevations between 1,650 m and 2,650 m. Dominant tree species included Arizona white (*Q. arizonica*), silverleaf (*Q. hypoleucoides*), Emory (*Q. emoryi*), Gambel (*Q. gambelii*), and netleaf (*Q. reticulata*) oaks; ponderosa (*P. ponderosa*), Arizona (*P. ponderosa var. arizonica*), Apache (*P. engelmanni*), Chihuahua (*P. leiophylla*), Mexican white (*P. strobiformis*), and border pinyon (*P. discolor*) pines; alligator-bark juniper (*Juniperus deppeana*); white fir (*Abies concolor*); Douglas-fir (*Pseudotsuga menziesii*); quaking aspen (*Populus tremuloides*); and Arizona cypress (*Cupressus arizonica*) (Iniguez et al. 2005).

Three large wildfires have burned in the Chiricahua Mountains since 1994, including the 1994 Rattlesnake fire, the 2010 Horseshoe fire, and the 2011 Horseshoe II fire (table 1). The Horseshoe II fire, which burned over 91,500 hectares, overlapped the entire Rattlesnake fire and parts of the Horseshoe I fire (fig. 3). An evaluation based on remotely sensed data (MTBS 2017) classified 58 percent, 30 percent, and 11 percent of the Horseshoe II fire area as having burned at low, moderate or high burn severity, respectively.

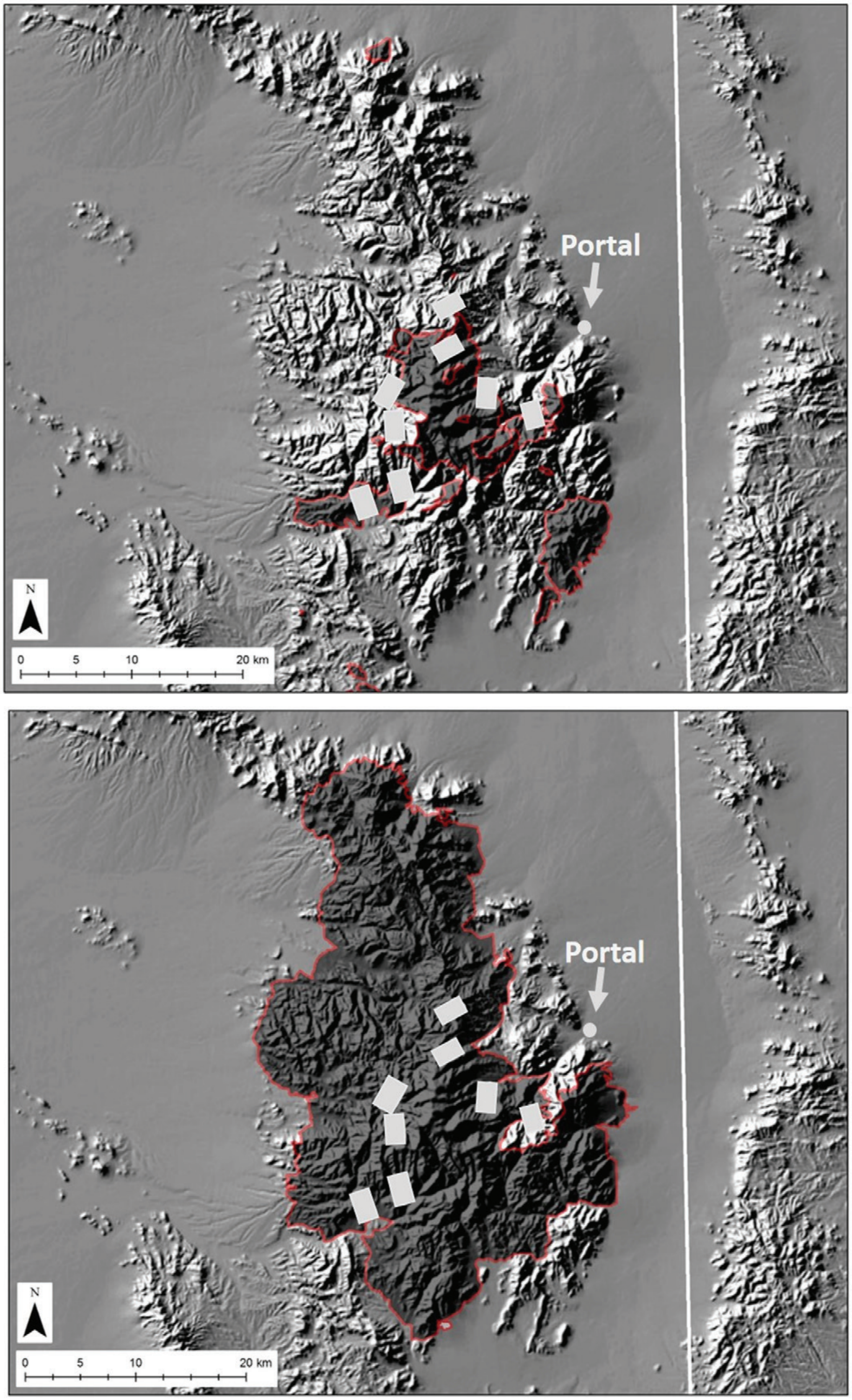


Figure 3—Perimeters of recent large wildfires (dark polygon outlined in red) within the Chiricahua Mountains, and locations of the original transects (squares) where bird populations were sampled from 1991 to 1995. Top: Perimeters of fires that occurred from 1991 to 2010. Bottom: Perimeter of the Horseshoe II fire, which burned in 2011.

Methods

1991–1995 Study

In 1991, RMRS installed eight transects to sample bird populations in the Chiricahua Mountains (figs. 3 and 4). Transect starting points were randomly located and transects followed random compass bearings. Each transect included 12 point-count stations spaced at 300 m intervals along two parallel survey lines of 6 points each, except for one transect (E, fig. 4) of a single line with 8 stations (total n = 92 points). We counted birds at these points each year from 1991–1995, using the variable-radius point-count method (Reynolds et al. 1980). Birds were sampled at each point two to three times during the sampling season (April–July). Transects were surveyed by single observers, but we rotated observers among transects between survey occasions to reduce potential observer effects. Counts lasted 5 minutes at each point and were completed between sunrise and 4 hours after sunrise.

We sampled vegetation characteristics at each point-count station and used the resulting data to classify point-count stations to cover types based on species composition and basal area (details in Iniguez et al. 2005). We recognized seven cover types, which collectively sampled a broad elevational range (figs. 5 and 6). Arizona cypress

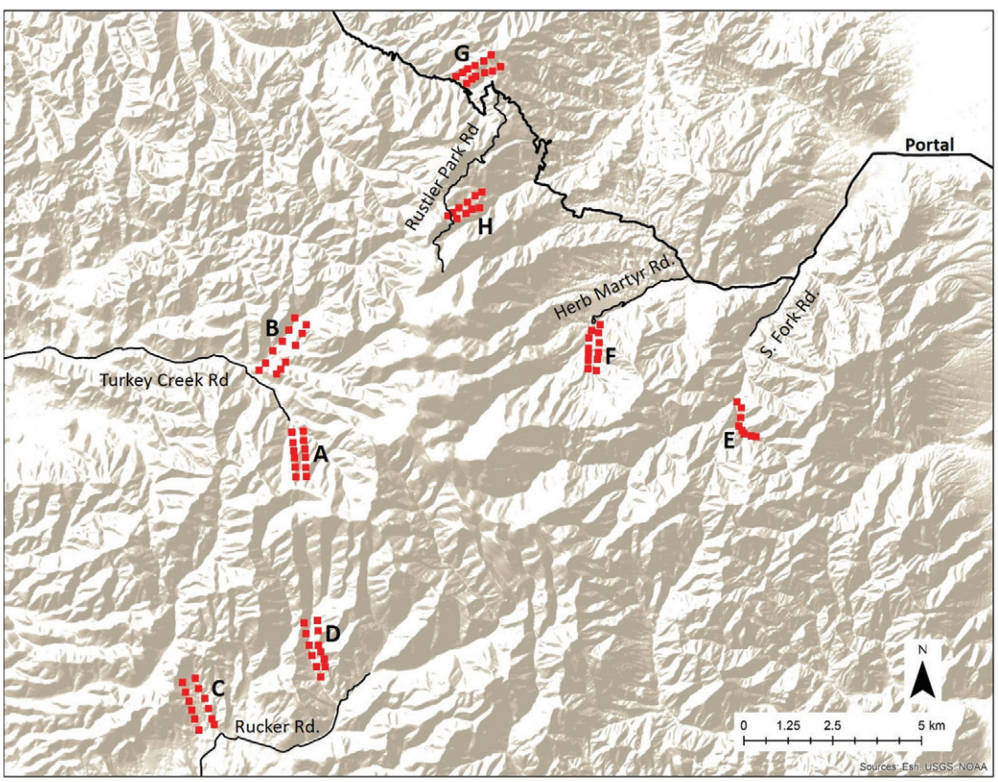


Figure 4—Detail map of the central portion of the Chiricahua Mountains showing locations of original point-count stations (red squares) along transects (labeled A to H) established in 1991 to sample bird populations.

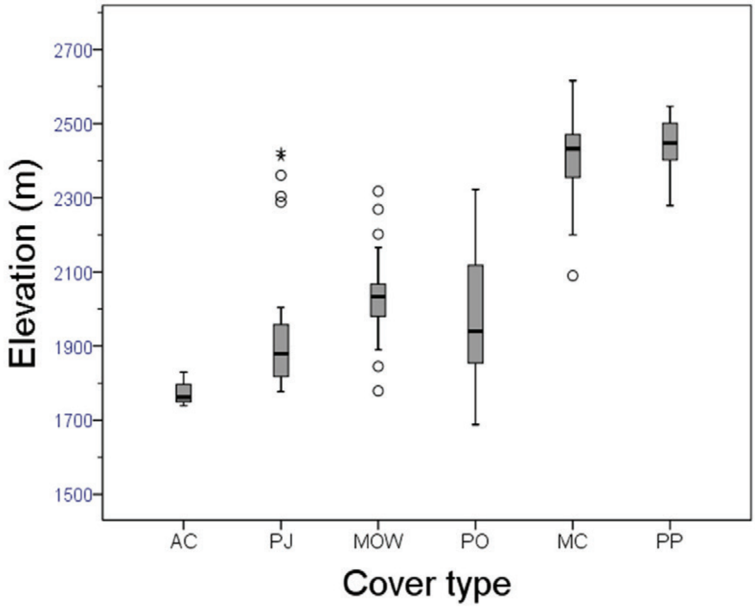


Figure 5—Elevation distribution by cover type for point-count stations (n = 91) in original transects established in 1991 to sample bird populations in the Chiricahua Mountains, Arizona. The box indicates the range from the 25th percentile to the 75th percentile, the solid line within the box indicates the median (50th percentile), and the exterior lines denote the range in the data excluding outliers and extreme values (circles and asterisks, respectively, defined as observation >1.5 or >3 times the box length outside the box). Cover type acronyms and names (with number of point-count stations in parentheses): AC = Arizona cypress (4), PJ = pinyon – juniper woodland (25), MOW = Madrean oak woodland (17), PO = pine – oak forest (24), MC = mixed-conifer (10), and PP = ponderosa pine (9). Not shown is one plot in aspen forest (elevation = 2346 m).

forest was dominated by Arizona cypress, was generally restricted to riparian canyon bottoms, and occurred at the lowest elevations sampled. Three cover types primarily occurred at mid elevations: pinyon-juniper woodland was dominated by border pinyon and alligator-bark juniper, Madrean oak woodland was dominated by various oaks including silverleaf, Arizona white, and Emory oaks, and pine-oak forest was dominated by conifers such as Chihuahua and Apache pine along with Madrean oaks. Three additional cover types occurred primarily at higher elevations: (1) mixed-conifer forest, which was dominated by Douglas-fir and/or white fir, and sometimes contained Mexican white pine; (2) ponderosa pine forest, which was dominated by ponderosa or Arizona pine but sometimes contained other pines and Gambel oak; and (3) aspen forest, which was dominated by quaking aspen.

Figure 6—Examples of major forest cover types recognized. A. Aspen forest, B. Arizona cypress forest, C. Madrean oak woodland, D. Mixed-conifer forest, E. Pine-oak forest, F. Pinyon-juniper woodland, G. Ponderosa pine forest. Photo credits: Rocky Mountain Research Station (A); Jamie S. Sanderlin (B, C); Joseph L. Ganey (D–G).


E
F
G

2012 Study

Early in 2012, we were contacted by concerned residents of the Chiricahua Mountains, including members of Friends of Cave Creek Canyon (2017) seeking information on how the 2011 Horseshoe II fire might impact the avifauna and local ecotourism. We shared information about the design of the RMRS study (1991 to 1995) and the resulting data with residents. We noted that the existing data set provided an opportunity to compare prefire data with postfire data, but that we lacked funding to collect postfire data.

Community leaders from Portal, Arizona, located at the eastern edge of the Chiricahua Mountains (fig. 3), expressed interest in conducting bird counts themselves if RMRS would assist with the study design and analysis. Consequently, we relocated the original eight transects established in 1991 using old topographic maps, transect descriptions, and pictures of point-count stations, and re-marked 89 of the 92 original point-count stations. We also provided the sampling protocols used in the 1991 to 1995 study, trained citizen observers in point-count methodology and data collection, and agreed to analyze the data collected. The citizen group began conducting point counts in May 2012. Steep uneven terrain proved to be a major challenge, however, and only 10 person days of sampling were accomplished during 2012 (table 2). Citizen observers remained interested in conducting point counts, but only if those counts could be conducted in less treacherous terrain.

Table 2—Survey effort by crew type and year. Citizen science observers struggled with the terrain on the original transects and completed fewer transects.

Year	Crew type[a]	Transect type[b]	Number of transects	Number of observers	Person days[c]
1991	RMRS	O	6	3	18
1992	RMRS	O	8	4	24
1993	RMRS	O	8	2	16
1994	RMRS	O	8	3	24
1995	RMRS	O	8	6	24
2012	CS	O	7	8	10
2013	CS	N	8	8	18
2014	RMRS	O	8	4	40
2014	RMRS	N	8	4	18

[a] RMRS indicates surveys were conducted by bird crews employed by the U.S. Forest Service, Rocky Mountain Research Station. Citizen science (CS) indicates that surveys were conducted by skilled volunteer observers.

[b] O = original transect established in 1991 (counts were not completed on all of these transects in 1991), N = new transect established in 2013.

[c] Calculated as number of transects surveyed by times each transect was surveyed by number of observers. Surveys from 1991 to 1995 were conducted by a single observer. Some transects were surveyed by single observers in 2012 and 2013, whereas others were surveyed using double observers. All 2014 surveys involved double observers.

2013 Study

Given continued interest by citizens in conducting point counts, we established a new set of transects early in 2013 that were on gentler terrain. Each new transect was located along a forest road or trail near an existing transect. We attempted to locate new transects in the same kinds of vegetation and topography as the original transects (fig. 7), to allow comparisons between the old and new data sets. New transects were shorter than the original transects, containing 6 to 11 point-count stations each (fig. 7). Feedback from citizen observers suggested that it would be more feasible to complete these shorter transects between sunrise and 4 hours after sunrise.

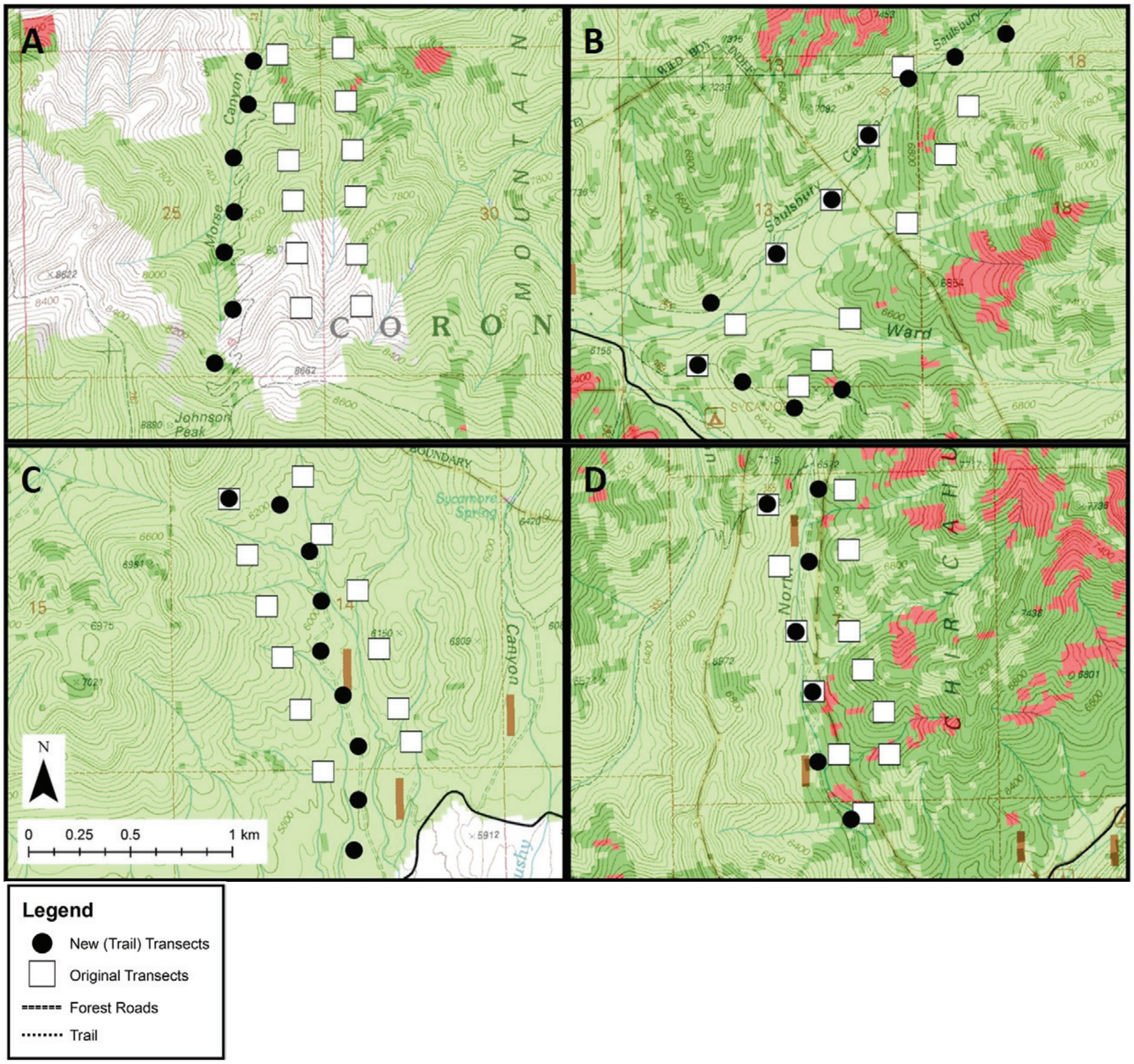
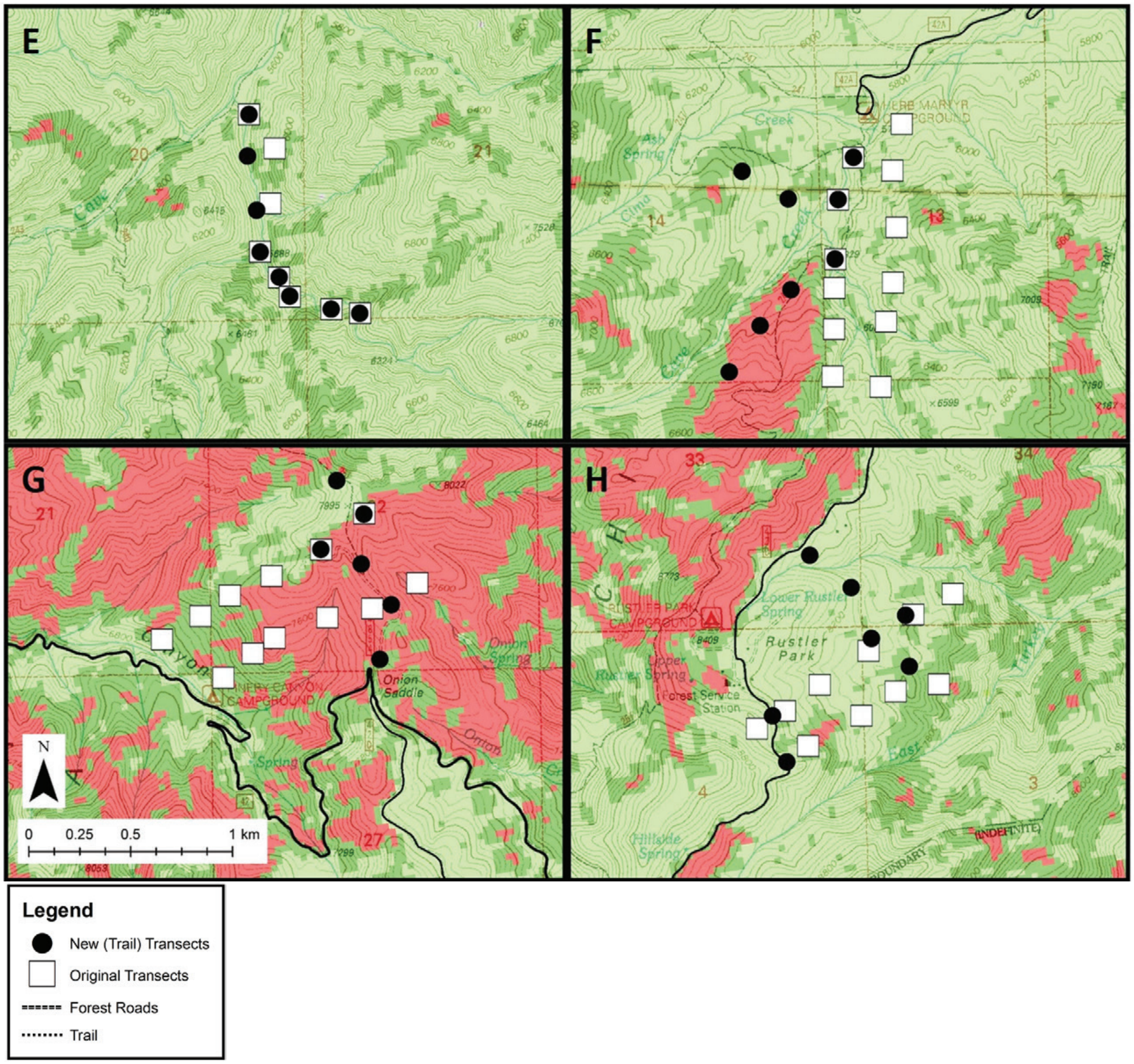


Figure 7—Juxtaposition of original and new transects used to sample bird populations in the Chiricahua Mountains in the 1990s and from 2012–2014, and burn severity around those transects estimated from data obtained from Monitoring Trends in Burn Severity (www.mtbs.gov) for the Horseshoe II fire, which burned in 2011. Some areas contained within the perimeter of this fire also burned in earlier fires, but severity data from those earlier fires was not summarized here. Colors represent burn severity classes: white = data missing for that area (due to cloud cover), light green = unburned to low severity, dark green = moderate severity, red = high severity. Point-count stations are represented by white squares or black circles for original and new transects, respectively. Pairs of transects are labeled A–H in upper left corner.



To evaluate how similar pairs of new and original transects were, we measured topographic characteristics and burn severity at all point-count stations on both original and new transects. We used a 30-m digital elevation model (DEM) to estimate elevation (m), slope steepness (deg), and slope aspect (or direction, deg) at each point-count station. We summarized burn severity around each point-count station using burn severity data from the most recent fire (2011 Horseshoe II fire). Burn severity data obtained from Monitoring Trends in Burn Severity (MTBS 2017) were summarized for a neighborhood of 0.81 ha (90 m x 90 m), centered on each point-count station. We recognized three burn severity classes: low, moderate, and high severity (fig. 8). In general, low burn-severity indicated less than 10 percent mortality in overstory trees and hence little structural change to dominant vegetation. Moderate severity reflected 10–70 percent mortality in overstory trees, with mortality in most areas less than 40 percent, and high severity ranged from greater than 70 to 100 percent tree mortality (Miller and Yool 2002).

A

B

Figure 8—Examples of burn severity classes recognized. A. Two examples of areas that burned at low-severity in ponderosa pine forest. These sites show little change from prefire conditions. B. An example of a ponderosa pine site that burned with moderate severity. This area shows greater change than low severity sites, but still retains considerable overstory cover. C. Examples of areas that burned at high severity. Note the general absence of live overstory. Top: Mixed-conifer forest. Note abundant understory of bracken ferns (*Pteridium* spp.). Bottom: Madrean oak woodland. Note that many of the oaks lost all prefire live canopy but are still alive and are resprouting from the base of the trunk. D. Landscape view showing patches that experienced fire of differing severity. Photo credits: Jose M. Iniguez (A, B, C, top); Jamie S. Sanderlin (C, bottom); Will Jaremko-Wright (D; used by permission).

C

D

We used Mann-Whitney tests (Conover 1999) to test for differences in elevation and slope between each pair of original and new transects, Watson-Williams tests (Zar 2009) to compare aspect between paired transects, and chi-square tests (Conover 1999) to compare composition between original and new transects in terms of burn severity. We also summarized cover type composition for point-count stations on the original transects, using data on species composition and basal area collected during the 1990s (Iniguez et al. 2005). We did not complete vegetation sampling at point-count stations along the new transects, and thus cannot compare cover types between pairs of original and new transects.

2014 Study

We did not continue point counts by citizen observers in 2014, but instead hired an RMRS crew to conduct bird surveys with funding obtained from the Desert Landscape Conservation Cooperative (DLCC 2017). This crew sampled both sets of transects (original and new) in the Chiricahua Mountains. These data provided an opportunity to compare bird occupancy between pairs of original and new transects sampled by the RMRS bird crew in the same year (2014), and to compare point-count results between citizen observers (transects sampled in 2013) and RMRS crews (the same transects sampled in 2014).

Results and Discussion

Survey Effort

Rocky Mountain Research Station crews conducted 116 surveys from 1991 to 1995 (table 2). Citizen observers began counting birds along original transects in May, 2012. Few counts were accomplished in 2012 due to terrain issues. The new transects were easier for citizen observers to navigate, and observers completed 80 percent more bird counts in 2013 than in 2012. RMRS crews sampled both sets (original and new) of transects in 2014.

Comparing Original and New Transects.

Elevation did not differ significantly (Mann-Whitney tests, $P = 0.018$ for transect G with all other P-values ≥ 0.261) between seven of eight pairs of original and new transects, suggesting that most new transects sampled were at the same general elevation belt as the original transects from the 1990s (fig. 9). The sole exception was new transect G (range = 2,338 to 2,423 m), which did not include the lowest elevations sampled by the original transect (range = 2,113 to 2,423 m). Slope steepness did not differ significantly between any pairs of original and new transects (all P-values ≥ 0.100; fig. 10). Slope aspect also did not differ significantly between any pairs of original and new transects (Watson-Williams tests, all P-values ≥ 0.217).

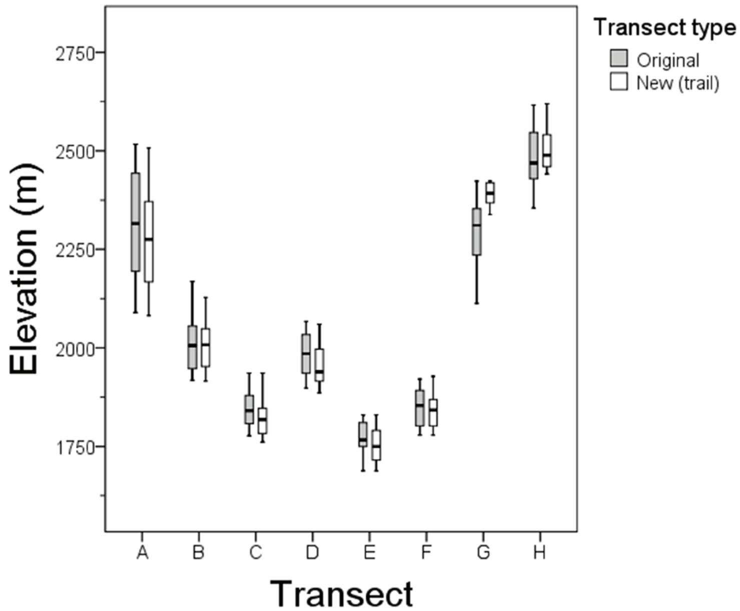


Figure 9—Elevation (m) of original and new transects used to sample bird populations in the Chiricahua Mountains, Arizona. Original transects were established in 1991, and new transects were established in 2013 along forest trails to facilitate surveys by citizens. The box indicates the range from the 25th percentile to the 75th percentile, the solid line within the box indicates the median (50th percentile), and the exterior lines denote the range in the data. No significant differences were detected between any pairs of transects except for transect G.

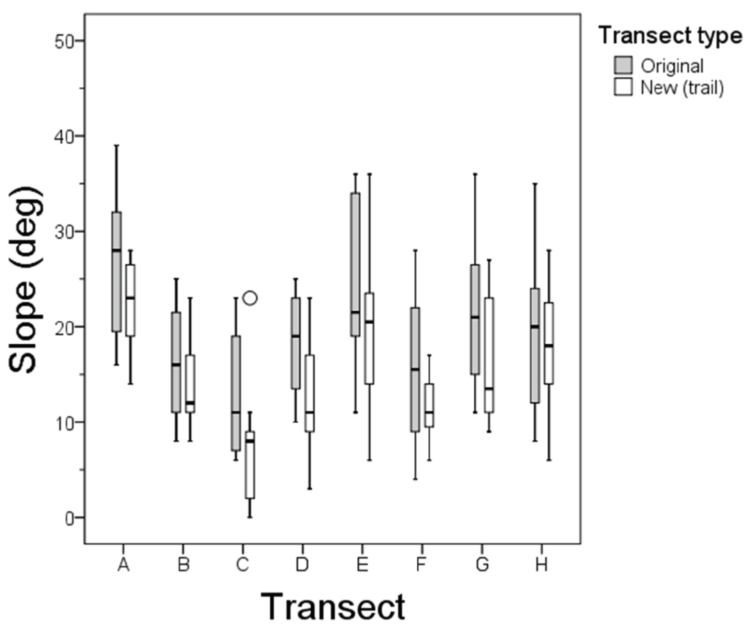


Figure 10—Slope (deg) in original and new transects used to sample bird populations in the Chiricahua Mountains, Arizona. Original transects were established in 1991, and new transects were established in 2013 to facilitate surveys by citizen observers. The box indicates the range from the 25th percentile to the 75th percentile, the solid line within the box indicates the median (50th percentile), and the exterior lines denote the range in the data excluding outliers (circles, defined as observation >1.5 times the box length outside the box). No pairs of original and new transects differed significantly.

Transects sampled a range of forest and woodland cover types, with the most frequently sampled types being pinyon-juniper woodland, ponderosa pine forests, and Madrean oak woodlands (fig. 11). Burn severity differed significantly among vegetation cover types (χ^2_{12} = 23.448, P = 0.024). Most cover types burned primarily at low to moderate severity, whereas ponderosa pine forest burned primarily at moderate to high severity and mixed-conifer forest burned primarily at high severity (fig. 12). Distributions of burn severity classes differed considerably among all transects (fig. 13), but the proportions of transects by burn severity class did not differ significantly between any pairs of original and new transects (chi-square tests, all P-values ≥0.097).

These results suggested that the new transects established in 2013 to facilitate surveys by citizen observers generally sampled the same range of ecological characteristics as the original transects, with the possible exception of transect G, which did not cover the lower elevations sampled by original transect G. Because cover type can vary with elevation, we compared cover types on the five original point-count stations at less than or equal to 2,338 m (the lowest elevation sampled by new transect G) to the distribution at the 7 original point-count stations greater than 2,338 m on transect G.

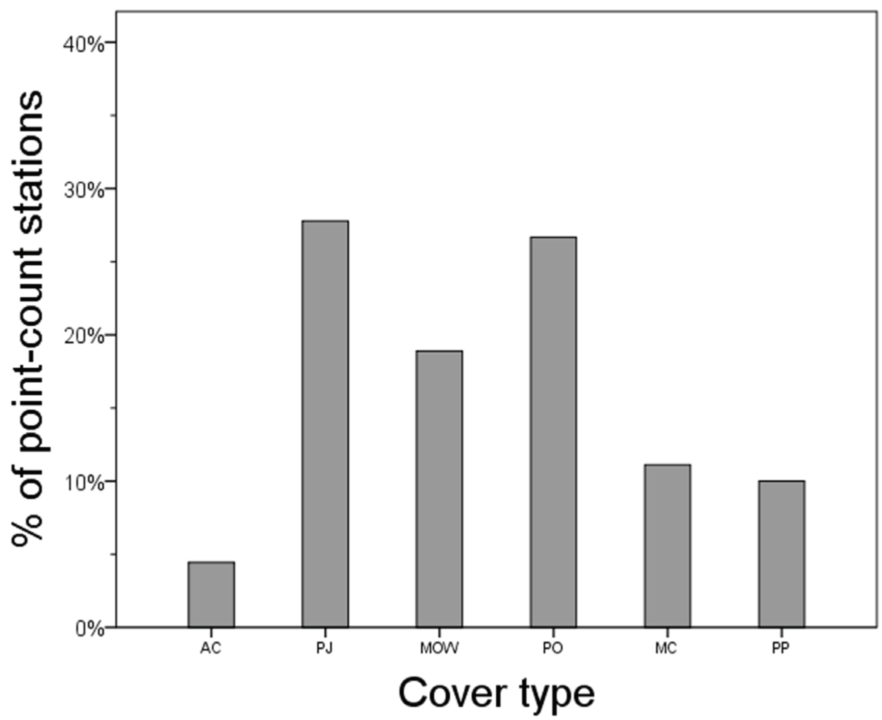


Figure 11—Distribution (%) of point-count stations (n = 91) by forest and woodland cover types on the original transects established in 1991 to sample bird populations in the Chiricahua Mountains, Arizona. Cover type acronyms and names (with number of point-count stations in parentheses): AC = Arizona cypress (4), PJ = pinyon – juniper woodland (25), MOW = Madrean oak woodland (17), PO = pine – oak forest (24), MC = mixed-conifer (10), and PP = ponderosa pine (9). Not shown is one plot in aspen forest. Cover types were assigned based on species composition (% of basal area) sampled at point-count stations following Iniguez et al. (2005), but some types were renamed from Iniguez et al. (2005) to conform to more common naming conventions. All points were sampled before the 2011 Horseshoe II fire, and cover type data were not available following that fire.

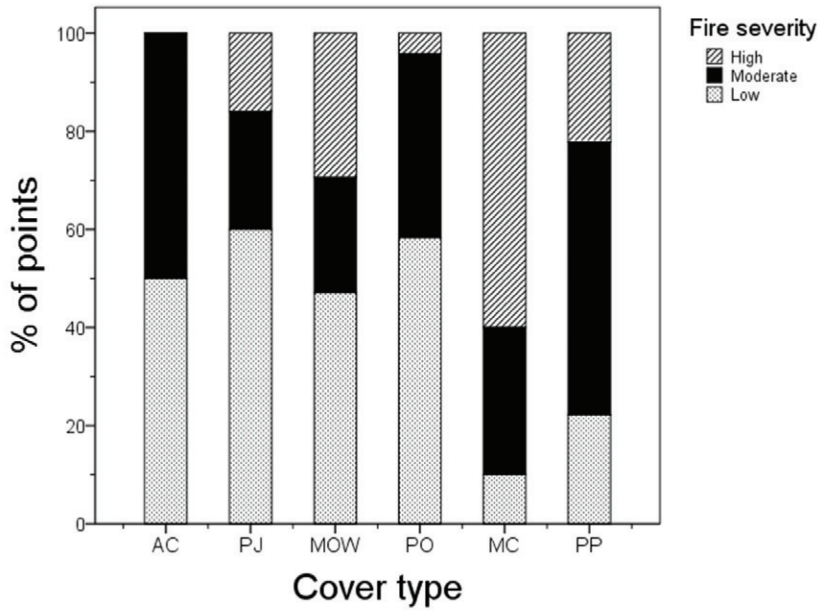


Figure 12—Burn severity (% of point-count stations) by forest and woodland cover types on the original transects established in 1991 to sample bird populations in the Chiricahua Mountains, Arizona. Cover type acronyms and names (with number of point-count stations in parentheses): AC = Arizona cypress (4), PJ = pinyon – juniper woodland (25), MOW = Madrean oak woodland (17), PO = pine – oak forest (24), MC = mixed-conifer (10), and PP = ponderosa pine (9). Not shown is one point-count station in aspen forest which burned at low severity. Cover types were assigned based on species composition (% of basal area) sampled at point-count stations following Iniguez et al. (2005), but some types were renamed from Iniguez et al. (2005) to conform to more common naming conventions. All vegetation sampling occurred before the 2011 Horseshoe II fire, and data on burn severity classes were obtained from Monitoring Trends in Burn Severity (www.mtbs.gov) for the Horseshoe II fire, which burned in 2011. Some areas contained within the perimeter of this fire also burned in earlier fires, but severity data from those earlier fires was not summarized here.

Cover type composition did not differ significantly between these groups ($\chi^2_3 = 3.566$, $P = 0.312$). This result, coupled with the general similarity between pairs of transects in terms of elevation, slope, aspect, and fire severity, suggests that pairs of original and new transects generally sampled similar cover types. Because bird populations and distribution are strongly related to vegetation type (Block and Brennan 1993; Hall et al. 1997), this suggests that pairs of original and new transects provide a good basis for comparing bird communities across time.

Bird Communities

Field crews detected 108 species of birds on transects sampled from 1991 to 1995 and 96 species of birds on transects sampled from 2012 to 2014 (table 3). Twenty-one species of birds were detected from 1991 to 1995, but were not detected from 2012 to 2014, and 12 species that were never detected from 1991 to 1995 were detected from 2012 to 2014 (table 3).

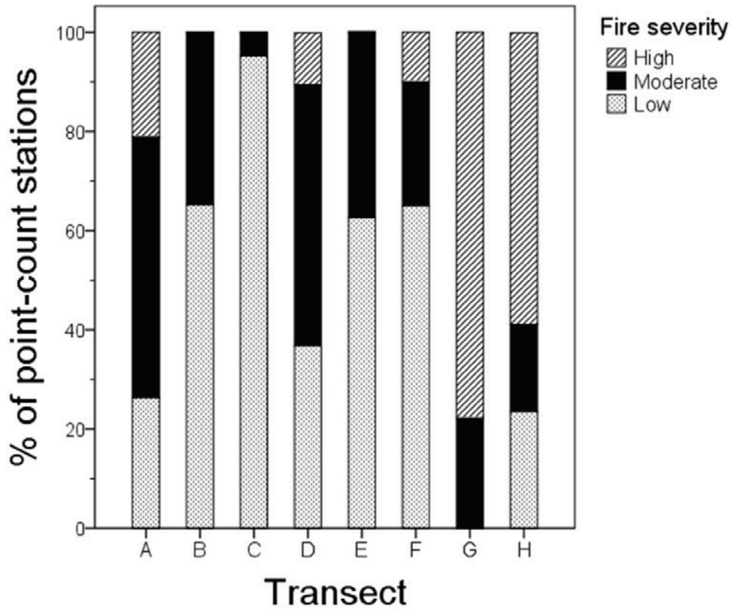


Figure 13—Burn severity (% of point-count stations) on transects established to sample bird populations in the Chiricahua Mountains, Arizona. Data on burn severity classes were obtained from Monitoring Trends in Burn Severity (www.mtbs.gov) data for the Horseshoe II fire, which burned in 2011. Some areas contained within the perimeter of this fire also burned in earlier fires, but severity data from those earlier fires was not summarized here. Data summarized here includes all point-count stations from both original (established in 1991) and new (established in 2013) transects, because the distribution of severity classes did not differ between pairs of those transects. Number of point-count stations ranged from 16 to 23 for pairs of original and new transects.

Table 3—Birds detected during bird surveys on eight transects in the Chiricahua Mountains by time period. Birds are listed in taxonomic order, following the American Ornithologist's Union Checklist of Birds of North and Central America (AOU 2017). One indicates the species was detected, zero indicates the species was not detected.

Common name	Scientific name	1990–1995	2012–2014	Status[a]
Gambel's quail	*Callipepla gambelii*	1	1	
Montezuma quail	*Cyrtonyx montezumae*	1	1	
Wild turkey	*Meleagris gallopavo*	0	1	U, Y
Turkey vulture	*Cathartes aura*	1	1	
Sharp-shinned hawk	*Accipiter striatus*	0	1	NOC
Cooper's hawk	*Accipiter cooperii*	1	1	
Northern goshawk	*Accipiter gentilis*	1	1	
Red-tailed hawk	*Buteo jamaicensis*	1	1	
Zone-tailed hawk	*Buteo albonotatus*	1	0	NOC
Band-tailed pigeon	*Patagioenas fasciata*	1	1	
White-winged dove	*Zenaida asiatica*	1	1	
Mourning dove	*Zenaida macroura*	1	1	
Greater roadrunner	*Geococcyx californianus*	1	1	
Flammulated owl	*Otus flammeoulus*	1	0	U, S
Whiskered screech-owl	*Megascops trichopsis*	1	0	U, S
Great horned owl	*Bubo virginianus*	1	0	NOC
Northern pygmy-owl	*Glaucidium gnoma*	1	1	

(continued)

Table 3—(Continued).

Common name	Scientific name	1990–1995	2012–2014	Status[a]
Spotted owl	*Strix occidentalis*	0	1	NOC
Mexican whip-poor-will	*Antrostomus arizonae*	1	1	
White-throated swift	*Aeronautes saxatalis*	1	1	
Magnificent hummingbird	*Eugenes fulgens*	1	1	
Blue-throated hummingbird	*Lampornis clemenciae*	1	0	U, S
Black-chinned hummingbird	*Archilochus alexandri*	1	1	
Costa's hummingbird	*Calypte costae*	0	1	NOC
Broad-tailed hummingbird	*Selasphorus platycercus*	1	1	
Rufous hummingbird	*Selasphorus rufus*	0	1	
Broad-billed hummingbird	*Cynanthus latirostris*	1	0	NOC
Elegant trogon	*Trogon elegans*	1	1	
Acorn woodpecker	*Melanerpes formicivorus*	1	1	
Ladder-backed woodpecker	*Picoides scalaris*	1	1	
Hairy woodpecker	*Picoides villosus*	1	1	
Arizona woodpecker	*Picoides stricklandii*	1	1	
Northern flicker	*Colaptes auratus*	1	1	
Prairie falcon	*Falco mexicanus*	0	1	NOC
Thick-billed parrot	*Rhynchopsitta pachyrhyncha*	1	0	NOC
Northern beardless-tyrannulet	*Camptostoma imberbe*	1	0	NOC
Olive-sided flycatcher	*Contopus cooperi*	0	1	NOC
Greater pewee	*Contopus pertinax*	1	1	
Western wood-peewee	*Contopus sordidulus*	1	1	
Hammond's flycatcher	*Empidonax hammondii*	1	1	
Gray flycatcher	*Empidonax wrightii*	0	1	U, M
Dusky flycatcher	*Empidonax oberholseri*	1	1	
Cordilleran flycatcher	*Empidonax occidentalis*	1	1	
Buff-breasted flycatcher	*Empidonax fulvifrons*	1	1	
Black phoebe	*Sayornis nigricans*	1	1	
Dusky-capped flycatcher	*Myiarchus tuberculifer*	1	1	
Ash-throated flycatcher	*Myiarchus cinerascens*	1	1	
Brown-crested flycatcher	*Myiarchus tyrannulus*	0	1	C, S
Sulfur-bellied flycatcher	*Myiodynastes luteiventris*	1	1	
Cassin's kingbird	*Tyrannus vociferans*	1	1	
Bell's vireo	*Vireo bellii*	1	0	NOC
Gray vireo	*Vireo vicinior*	1	0	NOC
Plumbeous vireo	*Vireo plumbeus*	1	1	
Hutton's vireo	*Vireo huttoni*	1	1	
Warbling vireo	*Vireo gilvus*	1	1	
Steller's jay	*Cyanocitta stelleri*	1	1	
Western scrub-jay	*Aphelocoma californica*	1	0	NOC
Mexican jay	*Aphelocoma wollweberi*	1	1	
Common raven	*Corvus corax*	1	1	
Violet-green swallow	*Tachycineta thalassina*	1	1	
Mexican chickadee	*Poecile sclateri*	1	1	
Bridled titmouse	*Baeolophus wollweberi*	1	1	
Juniper titmouse	*Baeolophus ridgwayi*	1	1	
Verdin	*Auriparus flaviceps*	1	0	U, Y
Bushtit	*Psaltriparus minimus*	1	1	
Red-breasted nuthatch	*Sitta canadensis*	1	1	
White-breasted nuthatch	*Sitta carolinensis*	1	1	
Pygmy nuthatch	*Sitta pygmaea*	1	1	
Brown creeper	*Certhia americana*	1	1	
Rock wren	*Salpinctes obsoletus*	1	1	
Canyon wren	*Catherpes mexicanus*	1	1	

(continued)

Table 3—(Continued).

Common name	Scientific name	1990–1995	2012–2014	Status[a]
House wren	*Troglodytes aedon*	1	1	
Winter wren	*Troglodytes hiemalis*	1	0	NOC
Bewick's wren	*Thryomanes bewickii*	1	1	
Blue-gray gnatcatcher	*Polioptila caerulea*	1	1	
Golden-crowned kinglet	*Regulus satrapa*	1	1	
Ruby-crowned kinglet	*Regulus calendula*	1	0	C, M
Western bluebird	*Sialia mexicana*	1	1	
Townsend's solitaire	*Myadestes townsedii*	1	1	
Hermit thrush	*Catharus guttatus*	1	1	
American robin	*Turdus migratorius*	1	1	
Curve-billed thrasher	*Toxostoma curvirostre*	1	0	U, Y
Northern mockingbird	*Mimus polyglottos*	0	1	
Cedar waxwing	*Bombycilla cedrorum*	1	0	NOC
Phainopepla	*Phainopepla nitens*	1	0	U, Y
Olive warbler	*Peucedramus taeniatus*	1	1	
Orange-crowned warbler	*Oreothlypsis celata*	1	1	
Nashville warbler	*Oreothlypsis ruficapilla*	1	0	U, M
Virginia's warbler	*Oreothlypsis virginiae*	1	1	
MacGillivray's warbler	*Geothlypsis tolmiei*	0	1	NOC
American redstart	*Setophaga ruticilla*	0	1	NOC
Yellow-rumped warbler	*Setophaga coronata*	1	1	
Grace's warbler	*Setophaga graciae*	1	1	
Black-throated gray warbler	*Setophaga nigrescens*	1	1	
Townsend's warbler	*Setophaga townsendii*	1	0	U, M
Hermit warbler	*Setophaga occidentalis*	1	1	
Wilson's warbler	*Cardellina pusilla*	1	1	
Red-faced warbler	*Cardellina rubrifrons*	1	1	
Painted redstart	*Myioborus picta*	1	1	
Spotted towhee	*Pipilo maculatus*	1	1	
Rufous-crowned sparrow	*Aimophila ruficeps*	1	1	
Canyon towhee	*Melozone fusca*	1	1	
Chipping sparrow	*Spizella passerina*	1	1	
Black-chinned sparrow	*Spizella atrogularis*	1	1	
Dark-eyed junco	*Junco hyemalis*	1	1	
Yellow-eyed junco	*Junco phaeonotus*	1	1	
Hepatic tanager	*Piranga flava*	1	1	
Summer tanager	*Piranga rubra*	1	0	U, S
Western tanager	*Piranga ludovicinia*	1	1	
Black-headed grosbeak	*Pheucticus melanocephalus*	1	1	
Lazuli bunting	*Passerina amoena*	1	0	NOC
Brown-headed cowbird	*Molothrus ater*	1	1	
Scott's oriole	*Icterus parisorum*	1	1	
House finch	*Carpodacus mexicanus*	1	1	
Cassin's finch	*Carpodacus cassinii*	1	1	
Red crossbill	*Loxia curvirostra*	1	1	
Pine siskin	*Spinus pinus*	1	1	
Lesser goldfinch	*Spinus psaltria*	1	1	
Evening grosbeak	*Coccothraustes vespertinus*	1	0	NOC

[a] Status based on the 2016 checklist of common birds in Chiricahua National Monument (NPS 2016). Status is shown only for species that were detected in one time period but not the other. The first letter denotes abundance (C = common, U = uncommon), the second letter denotes season of occurrence (M = migratory [nonresident], S = summer resident, Y = year round resident). NOC denotes species that do not appear on the checklist, which shows "…the approximately 100 most common birds of Chiricahua National Monument…".

A few species that were detected during only one time period probably represented local colonization or extinction events. For example, thick-billed parrots were detected during a failed reintroduction effort during the 1990s but not from 2012 to 2014 (Snyder et al. 1994, 1995), and this species likely is extinct in the Chiricahua Mountains at this time (Corman and Wise-Gervais 2005). In contrast, the wild turkey was reintroduced to the Chiricahua Mountains following the 1990s survey period (NPS 2006).

Most other species that were detected during only one decade were species that were detected infrequently, either because they were relatively uncommon or because their typical activity period did not greatly overlap with our bird surveys (for example, owls). For these species, detection during only one decade may or may not indicate local colonization or extinction events, and additional years of monitoring will be required to distinguish between these hypotheses.

Future Directions

Several important steps remain in designing and implementing a rigorous but cost-effective avian monitoring program in the Sky Islands. First, to make valid comparisons between pre and postfire avian count data, we need to verify that original and new transects provide a good basis for comparing bird communities. To address this question, we are currently using single-season, multi-species occupancy models (MacKenzie et al. 2006; Royle and Dorazio 2008: 384–87) in a Bayesian hierarchical framework (Gelman et al. 2004) to compare bird communities sampled in 2014 by RMRS crews along both the original and new transects.

Second, to continue using citizen observers to monitor avian populations and to allow valid comparisons between data collected by citizen observers and by RMRS crews, we must verify that detection probabilities are estimable. To address this question, we are currently comparing data collected on the new transects by citizen observers (in 2012 and 2013) and RMRS crews (in 2014) using multi-season, multi-species occupancy models (MacKenzie et al. 2006; Royle and Dorazio 2008: 384–387).

Third, we need to comprehensively evaluate the strength of potential observer effects (both individuals and type; i.e. citizen observer vs. RMRS crew), as well as the potential effects of transect type (original vs. new) on estimates of detection probability, occupancy, species richness, and local extinction and colonization probabilities. This evaluation is in progress, again utilizing multi-species occupancy models in a Bayesian hierarchical modeling framework. And fourth, we need to use the results of these analyses to design a rigorous but cost-effective monitoring program using citizen observers.

The above analyses relate only to the scientific or technical aspects of designing this monitoring program. Our experience suggests that there are considerable human challenges to overcome as well (e.g., Barrows et al. 2016; Cox et al. 2012; Tulloch et al. 2013). Chief among these is identifying a cadre of suitable observers willing and able to conduct surveys. The work is difficult, people are busy with their lives and work, and it is difficult to find volunteers who will dedicate time to such work both within and especially among years. This problem is exacerbated in our case because of the inherent difficulty in conducting point counts for birds, the difficult terrain involved, and safety issues related to working in mountains along the border with Mexico. Citizen observers conducting point counts must be able to navigate difficult terrain and identify birds by sight and sound, and many observers simply do not possess the necessary skills. Further, some observers who do possess those skills may be unwilling to work in difficult terrain near the border subject to traffic by drug smugglers and migrants entering the U.S. illegally.

These aspects make this study fundamentally different from other citizen science efforts such as eBird (2017) or the Breeding Bird Survey (BBS 2017), two prominent broad-scale efforts that present far fewer challenges to citizen observers. Many BBS routes occur along roads or trails, and have fewer sample points. Similarly, eBird has variable sample efforts. Both BBS and eBird focus on broad-scale trends in bird populations, and do not require as much detail as the fine scale needed in this study to evaluate fire effects on bird populations in one mountain range.

Assuming that interested citizen observers are available, a second challenge is coordinating and scheduling surveys. Our experience suggests that such coordination is critical to success, and would best be accomplished with an on-site coordinator position. We developed a website (Arizona Sky Island Birds 2017) to increase communication about this program and enhance involvement, but more direct outreach likely is required for the project to succeed. Such outreach might consist of regular meetings and presentations about the project to maintain enthusiasm for participation, and identifying creative ways to reward participants and acknowledge that their contributions are highly valued. Involving a social scientist with expertise in working with citizen observers could improve this aspect of the study.

Finding suitable observers is further complicated by the relatively sparse human population residing in the Chiricahua Mountains. Because the number of local residents is limited, it would be helpful to draw on citizen observers from outside the Chiricahua Mountains to broaden the potential pool of observers. Many such individuals would have to travel considerable distances to conduct sampling in the Chiricahua Mountains (and other Sky Islands), and funding to reimburse observers for travel costs would be invaluable. Because the point counts require observers to begin at or near dawn, citizen observers also may need to spend the previous night near transects to be sampled. The ability to provide housing for citizen observers in the vicinity of transects would also be invaluable.

Clearly, paying a coordinator, providing training, housing, and reimbursing citizen observers for their costs raises the cost of conducting the monitoring. The reality, however, is that conducting this type of sampling in this type of terrain is difficult work. Expecting observers to remain involved over time without providing training, coordination, and some level of oversight, and without fair compensation, is unrealistic. Consequently, some level of consistent funding will be required to support a successful monitoring program.

Conclusions

We identified a potential mechanism for involving skilled citizen observers in an ongoing program to monitor communities of forest and woodland birds in the Madrean Sky Islands. We also demonstrated that our newly designated transects sample physical environments similar to those sampled by our original transects. Preliminary results suggest that designing a rigorous program involving these citizen observers may be feasible, but a number of technical and human challenges remain to be overcome. For valid comparisons with prefire data, we must demonstrate that we are sampling the same bird communities with the new trail points and the original points. Other technical challenges include quantifying potential observer and transect effects on community parameters, so that a cost-effective monitoring program could be developed with citizen observers. Human challenges include finding a skilled and dedicated group of observers, coordinating surveys and observers, and maintaining project participation through outreach activities.

These aspects present significant challenges, but we believe that this approach has great potential for accomplishing otherwise impossible data collection in an era of shrinking research budgets. We further believe that many citizens are keenly interested in this type of work and searching for opportunities to contribute and that engaging these citizens has benefits that extend far beyond accomplishing additional data collection. Involving citizens can increase their understanding of and appreciation for conservation science, foster greater appreciation for the land management agencies involved in conservation and the difficulty of their mission, create incentives for citizens to work in the field, and generally leave participating citizens with a sense of accomplishment. For all of these reasons, we believe that our effort to overcome these challenges is a worthwhile endeavor.

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