Distribution, Abundance, Habitat, and Biogeography of Breeding Birds in the Sky Islands and adjacent Sierra Madre Occidental of northwest Mexico

FINAL REPORT

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PREFACE

This report summarizes my efforts to describe the distribution, abundance, habitat, and biogeographical relationships of breeding birds in montane vegetation communities in the Sky Islands and adjacent Sierra Madre Occidental of northwest Mexico. Following extensive commercial logging in the early and mid-1900s, vegetation in many Sky Islands in Mexico has matured, land uses are now limited in many ranges, and vast areas of montane forest and woodland in the region are essentially *de facto* wilderness, especially at higher elevations. Nonetheless, threats to montane vegetation communities are increasing due to a range of anthropogenic and other stressors, many of which are linked to global climate change. Thus, current information on wildlife and vegetation communities that is lacking in many areas, is important for guiding management and conservation, for monitoring changes in populations and communities over time, and for understanding the ecology and natural history of this unique and biologically diverse region.

In 2008, the U.S. National Park Service sponsored researchers at the University of Arizona (UA) and University of Montana (UM) to describe bird communities and bird-habitat relationships in the Sky Islands and adjacent Sierra Madre of northwest Mexico in collaboration with Comisión Nacional de Áreas Naturales Protegidas (CONANP). CONANP manages Reserva Forestal Nacional y Refugio de Fauna Silvestre Sierras de los Ajos-Bavispe (hereafter Ajos-Bavispe), which is approximately 180,000 ha in area and includes portions of seven Sky Islands. Soon after, Sky Island Alliance (SIA), a Tucson-based non-profit organization dedicated to conservation of the Sky Islands region, was sponsored by the Veolia Environment Foundation of France to gather and synthesize data on plant and animal distribution and to build capacity for conservation and management in the Sky Islands region of Mexico. Because our projects included similar goals, we collaborated to increase the capacity of our efforts. In 2012, the Southwest Region of the U.S. Fish and Wildlife Service, Division of Migratory Birds, provided important supplementary support to facilitate expanded survey coverage in our final field season and to assist with data analyses and reporting. It is my hope that information summarized here fills important knowledge gaps and is useful for management and conservation in this region.

A high resolution version of this report can be downloaded from the World Wide Web at the following link.

ACKNOWLEDGEMENTS

The Sky Islands of Mexico are awe-inspiring places that I am grateful to have had the privilege to explore. My efforts would not have been possible without the support and dedication of many individuals and agencies in the U.S. and Mexico. First, I thank Larry Norris of the U.S. National Park Service and Desert Southwest Cooperative Ecosystem Studies Unit (now retired) for supporting this project. I also thank Jason Mateljak, Brian Carey, Nancy Wilcox, and Danielle Foster of Chiricahua National Monument for their support and efforts in fostering the “Sister Park” relationship with Ajos-Bavispe that helped motivate this work. I thank Bill Howe and

Cover Image: **Pine forest and pine-oak woodland in the Sierra el Pinito in north-central Sonora, Mexico. The Santa Rita Mountains in adjacent Arizona are in the background.**

Dave Krueper of the U.S. Fish and Wildlife Service, Division of Migratory Birds (Region 2) for important supplementary support that totaled 21% of our budget. I also thank Carol Beardmore of Sonoran Joint Venture for supporting my proposal. Supplementary support for travel and analyses was provided by the U.S. Fish and Wildlife Service, Division of Bird Habitat Conservation under Neotropical Migratory Bird Conservation Act grant 5139.

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I thank CONANP and the entire staff of Ajos-Bavispe for supporting this project. I am especially grateful to Rosa Elena Jimenez Maldonado and Luis Portillo for accompanying me on a field trip to the Sierra los Ajos in 2010, to Mario Cirett Galán and Elvira Rojero Diaz for logistical and other support, and to Guadalupe Flores Piña and others for help with landowner contacts and access. I thank Javier Cruz Nieto of Pronatura for guiding our efforts in Chihuahua, which due to unfortunate circumstances were shorter in duration than planned. Finally, I thank Alejandro Gómez Nísino of the CONANP Campo Verde reserve in Chihuahua for access and support.

Working in the rugged and remote high mountain forests of Mexico is challenging both physically, and at times, mentally. This work would not have been possible without the help and dedication of many field assistants. I am especially grateful to my Mexican associates, Carlos González Sánchez (2009, 2010, 2012), Francisco Javier Valenzuela Amarillas (2011, 2012), Zoila Guerrero Coronado (2010), and Christopher Martinez Reynoso (2009) for their assistance with habitat measurements and logistics, and for their positive attitudes and approach to working in difficult field conditions. I also thank Carlos González Sánchez for assistance with logistics and landowner contacts. Financial support to train and equip my Mexican field associates between 2009 and 2011 was provided by SIA through grants from the Veolia Environment Foundation.

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this report, 63% of survey transects were completed by my field technicians, and they did excellent work despite challenging field conditions and rigorous travel schedules. I thank Josh Goldberg for help developing R scripts to estimate bird density and map bird distribution, and Alan Swanson for additional programming support. I thank Dr. Richard Hutto for suggestions on project design, administrative support, and for being an excellent mentor. I thank Carolyne Vowell, Rebecca Stone, Miranda Leftridge, and Matthew Larson for assistance with data entry, data proofing, spatial analyses, and mapping.

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I thank Tom Van Devender for reviewing and commenting on an earlier draft of this report and for valuable suggestions that improved its content.

This report is dedicated to memory of my friend Dr. Peter Warshall who passed away in April 2013. Peter’s passion for the Sky Islands, his knowledge of their natural history and ecology, and his enthusiasm for this project were great motivating forces.

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ABSTRACT

Information on the status and habitat needs of wildlife is essential for conservation and management but often limited in remote regions with high conservation value. The Madrean Sky Islands region includes more than 40 mountain ranges located between the Sierra Madre Occidental in Mexico and the Mogollon Plateau in the U.S. These disjunct islands of montane vegetation and the broad valleys of desertscrub, thornscrub, and grassland that separate them, span the only gap in the vast highland cordillera that dominates western North America. Although the Sky Islands region is world renowned for its uniqueness, diversity, and conservation value, information on birds is very limited in Mexico and has not been synthesized since the 1950s. Between 2009 and 2012, I assessed the distribution, abundance, diversity, and habitat relationships of breeding birds in 26 Sky Island mountain ranges and six areas in the adjacent Sierra Madre Occidental in Sonora and Chihuahua, Mexico. I estimated the presence, density, and breeding status of birds during the breeding season at 1,562 points (*n* = 1,851 total point counts) along 210 transects (289 km in total length) that spanned all major montane vegetation communities in the region (1,150-2,750 m elevation), and described the composition and structure of vegetation, intensity of land use and disturbance, and other habitat features. Moreover, I evaluated biogeographical relationships among breeding bird communities in montane vegetation across virtually the entire Sky Islands region based on data gathered in Mexico and data from 22 additional mountain ranges in the U.S. My efforts represent the first assessment of biogeographical relationships based on data from across the Sky Islands region, and the first systematic study of bird communities and bird-habitat relationships in this region since Joe Marshall's worked in nine Sky Islands and five areas in the adjacent Sierra Madre in Mexico in the 1950s.

I detected 199 species of birds including 165 species of landbirds that were at least presumably breeding and seven additional species that were possibly breeding. In the Sky Islands, I observed 152 species that were at least presumably breeding, eight additional species of possible breeders, and estimate 169 species breed in montane vegetation communities. Based on a comprehensive review of recent and historical observations, I found strong evidence of spatiotemporal changes in the status and distribution of numerous bird species and that more species seem to have expanded (vs. contracted) their distributions in recent decades. Although some of these patterns could be attributable to variation in survey effort, natural range expansion, changes in vegetation and land management that have affected habitat quality, and the effects of habitat area and isolation on extinction-colonization dynamics seem to have driven these patterns for many species. Many species I observed in the Sky Islands of Mexico or broader study area for the first time have strong Madrean affinities (e.g., Mountain Trogon, Brown-backed Solitaire, Crescent-chested Warbler, Slate-throated Redstart), which as a group have expanded their ranges northward in recent decades. Moreover, many other species I found distributed much more broadly than in the past are dependent on pines (e.g., Northern Goshawk, Hairy Woodpecker, Greater Pewee, Plumbeous Vireo, Grace's Warbler, Olive Warbler) or are subject to hunting pressure by humans (e.g., Wild Turkey). These patterns were likely driven by the cessation of commercial logging and degradation of the extensive network of logging roads present in the past, and subsequent recovery of pines that have matured to varying extents and are now subject to virtually no active logging in the Sky Islands. Despite these auspicious trends, local extinctions of some populations due to natural disturbance, habitat degradation linked to past

logging, the effects of habitat area and isolation on extinction risk, or climate change, have likely driven range contractions of other populations, especially those dependent on mature coniferous forest with large trees and cavities (e.g., Thick-billed Parrot, Flammulated Owl, Purple Martin, Pygmy Nuthatch).

Regional variation in the composition of breeding bird communities was largely spatially and biogeographically coherent but also produced some novel insights. In general, I found evidence of a discrete discontinuity in community composition between the Sierra Madre and Sky Islands but fairly continuous gradients in community composition across the Sky Islands. Nonetheless, I also found significant but variable levels of regionalization across the Sky Islands and evidence for three discrete groups of ranges; a small southwestern group with strong Sonoran and lowland Neotropical affinities, a larger southern group, virtually all of which were in Mexico, with stronger Madrean affinities, and an even larger northern group that had much higher levels of internal regionalization and strong Sonoran, Chihuahuan, Great Basin, or Petran affinities. These patterns reflect high levels of biogeographical complexity in the region that are driven by the convergence of two faunal realms and several major biogeographical provinces, steep but variable elevation profiles, and by Madrean and Petran influences at higher elevations and Sonoran, Chihuahuan, Great Basin, and lowland Neotropical influences at lower elevations.

I derived a large number of inferences on bird-habitat relationships that conformed to varying degrees with those from past studies in Madrean forest and woodland communities. Densities of most species (65% of 72) varied markedly among eight major montane vegetation communities, which ranged from oak savannah and oak woodland at the lowest elevations to mixed-conifer forest at the highest elevations. Much larger proportions of species occurred at peak densities in mixed-conifer forest and montane riparian vegetation, and more species were fairly restricted to these communities indicating their importance for conservation. In contrast, fewer species occurred at peak densities or were restricted to oak, oak-pine, or pine-oak woodland, or showed little evidence of variation in densities among communities, suggesting lower levels of habitat specialization. Habitat models that described variation in densities of 30 bird species most frequently included the effects of cover of conifers (10 species), a synthetic variable representing increasing tall-tree cover and decreasing shrub cover (9 species), and cover of broadleaf deciduous trees (7 species). Moreover, cover of broadleaf deciduous trees, fire severity, and tree density only had positive effects on bird densities among species. Collectively, these results and the remote and wild character of many Sky Islands in Mexico, suggest high conservation value and the importance of preserving this diverse and ecologically unique region for future generations.

INTRODUCTION

The Madrean Sky Islands region includes more than 40 distinct mountain ranges that arise from broad lowland valleys between the Sierra Madre Occidental in northwest Mexico and the Mogollon Plateau and adjacent Rocky Mountains in the southwestern U.S. (Marshall 1957, McLaughlin 1995, Warshall 1995, Deyo et al. 2013). These valleys create the only gap in the vast highland cordillera that forms the backbone of western North American between northern Alaska and southern Mexico. Mountains that span this cordilleran gap have been referred to as Sky Islands because they support disjunct patches of montane vegetation dominated by pines (*Pinus* spp.) and oaks (*Quercus* spp.) that arise from a lowland matrix or "sea" of desertscrub and grassland in the north and subtropical thornscrub in the south, which create movement barriers to some montane taxa (Heald 1951, Gehlbach 1981, Warshall 1995). These montane habitat islands and the lowland vegetation that surrounds them have expanded and contracted over the millennia, creating varying levels of isolation that has affected the diversification and distribution of many taxa (Findley 1969, Van Devender 1977, Lomolino et al. 1989, Maddison and McMahon 2000, Masta 2000, Holycross and Douglas 2007, Bryson et al. 2011). In addition to its physiographical uniqueness and historical complexity, the Sky Islands region also spans portions of a broad transition zone between the Nearctic and Neotropical faunal realms (Halffter 1987, Escalante et al. 2004), is situated near the convergence of several major biogeographic provinces and thus supports taxa with Madrean, Petran (Rocky Mountain), Sonoran, Chihuahuan, and Sinaloan (e.g., lowland Neotropical) affinities (McLaughlin 1995, Warshall 1995), and is bisected by the U.S.-Mexico border. These complex biogeographical and historical influences combined with steep topographic and climatic gradients promote high biological diversity and make this region a conservation priority of global significance (Felger and Wilson 1995, Foreman et al. 2000, Spector 2002, Coblintz and Riitters 2004, Mittermeier 2004).

Because of its uniqueness and proximity to the U.S.-Mexico border, the Sky Islands region has been the focus of numerous efforts to describe the distribution and abundance of plants and wildlife (see review by Van Devender et al. 2013). Many of these efforts, however, were conducted before 1960 and most have been of relatively short duration and limited spatial extent, despite important exceptions (e.g., Mearns 1907, Marshall 1957). Thus, current information on the distribution and abundance of plants and animals is sparse in some portions of the region, especially in the more remote Sky Islands in Mexico (Lomolino et al. 1989, Flesch 2008a, Van Devender et al. 2013). Moreover, investigations of factors that drive distribution, abundance, diversity, and biogeographical relationships of montane species are limited to few taxa, and the majority of studies have focused in the U.S. (DeBano et al 1995, Gottfried et al. 2005, 2013, Bryson et al. 2013). These gaps of knowledge present a range of challenges for resource managers and conservation planners focused in the Sky Islands region and have limited our understanding of the natural history, ecology, and biogeography of this region.

With regard to birds, Marshall (1957) described the distribution, abundance, and habitat associations of breeding birds in pine-oak woodlands and adjacent riparian vegetation across the Sky Islands region based on extensive field work in the early 1950s. His efforts were focused in six Sky Islands in the U.S., nine Sky Islands in Mexico, and five general areas in the adjacent Sierra Madre, and also synthesized information from past efforts in the region (e.g., Lumholtz 1902, Mearns 1907, Van Rossem 1945, Friedmann et al. 1950). Decades later, Russell and

Monson (1998) synthesized observations of birds from throughout the state of Sonora but conducted little additional field work in montane vegetation in the Sky Islands. More recently, Flesch and Hahn (2005) and Flesch (2008a, b) described the distribution and abundance of birds in portions of the Sky Islands region but focused in areas at the western and southern edges of the region, and in lowland vegetation communities. Thus, although baseline information on distribution and abundance of breeding birds is available for the Sky Islands of Mexico, much of it has not been updated for nearly six decades and bird communities in some Sky Islands, including ones that are large and significant, have never been described. Additionally, although data on birds in the Sky Islands of Sonora is available, data from neighboring portions of western Chihuahua are much more limited and most studies have focused only on a few species of conservation concern (Lumholtz 1902, Lanning and Shiflett 1983, Lammertink et al. 1996, Young et al. 1998, Monterrubio Rico and Enkerlin Hoeflich 2004). Moreover, quantitative information on bird-habitat relationships in montane vegetation communities is available for very few species in the Sky Islands region, including those in the U.S. (e.g., Ganey and Balda 1989, Stromberg 1990, Hall and Mannan 1999, Martin and Morrison 1999, Monterrubio Rico and Enkerlin Hoeflich 2004, Hughes 2007, Kirkpatrick and Conway 2010), and biogeographical relationships of faunal communities across the region have never been described based on detailed distributional data. Thus, our knowledge of important habitat features, limiting resources, and other factors that drive distribution and abundance of breeding birds is limited despite its importance for management and conservation (Sonoran Joint Venture 2005, Ruth and Rosenberg 2009). Filling these information gaps is important given the significance of the region and threats to biodiversity that are focused along the U.S.-Mexico border (Cordova and Parra 2007, Flesch et al. 2010a) and at high elevations where drought, insect outbreaks, wildfire, and other stressors linked to global climate change are increasing (Westerling et al. 2006, Seager et al. 2007).

This report summarizes my efforts to document the distribution, abundance, and biogeographical and habitat relationships of breeding birds in the Sky Islands and adjacent Sierra Madre Occidental in the states of Sonora and Chihuahua, Mexico. Within this region, I surveyed birds and habitat features in montane vegetation communities dominated by oak woodland and oak savannah at the lowest elevations and by mixed-conifer forest at the highest elevations in portions of 26 mountain ranges and six areas in the adjacent Sierra Madre over four years (2009-2012). Additionally, I also evaluated recent and historical data from across the region and assessed spatiotemporal changes in the status and distribution of breeding birds, and compiled recent distributional data on breeding birds in 22 additional mountain ranges in southern Arizona and assessed biogeographical relationships across nearly all Sky Islands. Mountain ranges I considered were of sufficient elevation and area to support evergreen oaks and most can be considered Sky Islands (*sensu* Flesch and Hahn 2005) because they provide habitat that promotes the occupancy and persistence of species found in the adjacent Sierra Madre or Mogollon Plateau. Because my efforts were broad and systematic, they represent the most extensive effort to date to describe bird communities in montane vegetation communities in the Sky Islands of Mexico. Thus, information reported here establishes important baselines for monitoring future spatiotemporal changes in bird communities and provides data useful for management, conservation planning, and for understanding the natural history, ecology, and biogeography of this extraordinary region.

METHODS

Study Region and Design.—Definitions of the exact extent of the Sky Islands region and the dividing line between the Sky Islands and Sierra Madre Occidental vary somewhat (Marshall 1957, McLaughlin 1995, Flesch and Hahn 2005, Brusca and Moore 2013, Deyo et al. 2013, Ferguson et al. 2013). I considered mountain ranges in Mexico that were tall enough to support oaks in a region bounded by the Sierra el Humo to the west, Sierra Aconchi, Sierra Oposura (la Madera), and Sierra Bacadéhuachi to the south, and the Sierra Madre Occidental to the east, which has traditionally been considered the Madrean Sky Islands region of Mexico (Marshall 1957, McLaughlin 1995, Flesch and Hahn 2005). To provide a context for understanding the distribution, abundance, and habitat and biogeographical relationships of birds in the Sky Islands region, I also sampled areas in the adjacent Sierra Madre Occidental. These study sites included mountain ranges that are connected to the Sierra Madre by high ridgelines dominated by pine-oak woodland (e.g., Sierra Huachinera and Sierra Cebadilla) and other areas in the Sierra Madre proper (El Poleo and Sierra Cinco Millas).

For the purposes of sampling, I considered mountain ranges that were separated from the Sierra Madre by significant breaks in montane vegetation to be Sky Islands. For example, I considered the Sierra Bacadéhuachi to be a Sky Island because it is separated from the Sierra Cebadilla by desert grassland and rocky ridges with little tree cover at elevations ranging from 1,100 to 1,340 m. I considered the Sierra Púlpito (Hachita Hueca and Ojos Azules) to be a Sky Island because it is separated from the region west of Mesa de las Guacamayas by ridges and drainages as low as 1,400 m that are dominated largely by desert grassland and oak savannah. Although some Sky Islands that I considered to be distinct are connected by oak woodland along north-south ridgelines (e.g., Sierra los Ajos and Púrica, Sierra Elenita and Mariquita), I defined Sky Islands based largely on the distribution of pine-oak woodland and pine forest, which have much lower levels of connectivity in the region. For biogeographical analyses, I also considered 22 mountain ranges in the Sky Islands region of southern Arizona. All of these ranges supported at least some oak woodland and were bounded by the Baboquivari Mountains to the west, Santa Teresa Mountains to the north, and Peloncillo Mountains to the east, which has traditionally been considered the Sky Islands region in the U.S. (Marshall 1957, McLaughlin 1995).

I initially used a two-stage stratified-random sampling design to select mountain ranges and survey transects within each major vegetation communities that was present in each mountain range. Although randomization can facilitate broader scope of inference, initial efforts indicated surveys in most mountain ranges were possible with available resources, which made randomized selection of ranges largely unnecessary. Thus, I prioritized mountain ranges that were high enough to support pines for sampling and surveyed virtually all of these ranges with the exception of the rocky Sierra Buenos Aires (2,300 m), Sierra Jucaral (1,920 m; west of Banámichi) and Pinito-Sombreretillo complex (2,280 m; northeast of Nacozari) where Marshall (1957) mapped small areas of pine-oak woodland, and Sierra el Carmen (1,950 m; east of Sinoquipe), which may support small patches of oak-pine woodland. I did not attempt surveys in some mountain ranges that support oak woodland but are too low for pines due to limited resources (e.g., Sierra el Bellotal, Sierra las Palomas, Sierra Manzanal). Attempts to randomly select survey transects within each major vegetation community in mountain ranges proved to be difficult due to major constraints on access and lack of accurate vegetation maps. Thus, I selected transects non-randomly in representative areas within each major vegetation community. Moreover, because areas at high elevations often support rare habitats and specialized habitat features, I also attempted to survey areas around the highest peak in each range, and where possible, focused these efforts on more mesic north- and east-facing aspects.

To assess vegetation communities that were available for sampling in each mountain range, I used roads, trails, and high points to observe vegetation, evaluated satellite imagery, and interviewed local residents and land managers. Major vegetation communities I considered were (1) mountain scrub, (2) oak woodland, (3) oak-pine woodland, (4) pine-oak woodland, (5) pine forest, (6) mixed-conifer forest, and (7) montane riparian woodland and forest. Despite a nearly continuous gradient between them, I differentiated oak-pine from pine-oak woodland on the basis of relative dominance of oaks vs. pines. Additionally, I also sampled areas I classified as oak savannah and areas that included patches of desertscrub or thornscrub at the lower-elevation margins of montane vegetation in some mountain ranges. Moreover, I also targeted vegetation associations that were typically rare and distributed locally within those broader communities; they included aspen (*Populus tremuloides*) forest, woodlands of Gambel's oak (*Quercus gambelii*) and pinyon pine (*Pinus* spp.), and mountain scrub dominated by deciduous shrubs such as New Mexican locust (*Robinia neomexicana*). Plates 1 through 7 illustrate most major vegetation communities that I sampled and depict some mountain ranges.

Because bird communities in larger mountain ranges with more vegetation communities required more effort to describe, I allocated sampling effort in approximate proportion to the size of ranges and the number of major vegetation communities they supported. The basic sampling units I considered were transects along which I placed survey stations at largely fixed intervals. I placed transects slopes, ridges, and flats in uplands, and alongside drainage channels in riparian areas largely within mountain ranges or at their immediate bases rather than on surrounding outwash plains. Some transects followed small roads, trails, ridgelines, or other natural landforms, and most transects traversed more than one major vegetation community. Where possible, I avoided placing transects in areas that degraded listening conditions such as in natural depressions or on exposed ridgelines, and in other areas such as next to steep cliffs that complicated habitat sampling.

Bird Surveys.—I used several methods to estimate the presence, abundance, and breeding status of birds between early May and mid-July when most species of birds were breeding. To estimate abundance, I used distance-sampling methods (Buckland et al. 2001) at 4-11 point-count stations per transect that I placed 200-300 m apart or occasionally closer on the steepest slopes. Distance sampling involves measuring distances to all birds that are detected during the count period, which allows estimates of abundance to be adjusted for variation in detection probability (Thomas et al. 2010). I surveyed stations for 8 minutes and used a laser rangefinder to measure the minimum horizontal distance from surveys stations to the actual or estimated initial location of each individual or center of each pair or flock. For each bird detection, I noted the number of individuals, sex (if known), and detection type (visual, calling, singing, wings, or drumming). I surveyed from 30 min before local sunrise to as late as 3.5 hrs after sunrise but often terminated surveys if bird activity declined markedly 2.5-3 hrs after sunrise. I recorded wind speed (Beaufort scale), cloud cover (%), noise (scale of 0-3), and precipitation (scale 0-6) at the first

Plate 1: Vegetation communities found at the highest elevations in the Sky Islands and adjacent Sierra Madre Occidental in Mexico. Mixed-conifer forest on north slopes in the central Sierra el Tigre (top left), mixed-conifer and adjacent montane riparian forest on the east side of the Sierra los Ajos (bottom left), and mixed-conifer, aspen, and pine forest on the highest slopes in the Sierra Cebadilla in the Sierra Madre Occidental (right).

Plate 2: Pine forest on the east side of Sierra Azul (top left), pine forest and adjacent pine-oak woodland in the central Sierra el Pinito, pine forest on the east side of the Sierra Purica (middle left) and in the Sierra Bacadéhuachi (middle right), view north across pine forest and pine-oak woodland along the high ridge of the Sierra Oposura (lower left), and pine forest on slopes in the central Sierra el Tigre (lower right).

Plate 3: Pine-oak woodland on the north side of the Sierra Elenita (top left), along the main ridges of the Sierra Bacadéhuachi (top right) and Sierra Aconchi (middle left), and on the upper slopes of the Sierra el Pinito (middle right, bottom left) and the Sierra la Madera (lower right) above Magdelena de Kino, Sonora.

Plate 4: Oak-pine woodland on slopes or flats in the Sierra Cíbuta (top left), Sierra San Antonio (top right), and Sierra Bacadéhuachi (center left), and areas dominated by oak-pine, pine-oak, and oak woodland looking north across the main ridgelines of the Sierra la Madera, Sierra Aconchi, and Sierra Oposura (from center right to lower right).

Plate 5: Oak woodland on north-facing slopes of the Sierra el Humo (top left), oak-juniper woodland in the Sierra San Luis (top right), and various associations of oak woodland in the Sierra Oposura (center), Sierra Cebadilla in the Sierra Madre Occidental, and on slopes of the Sierra Juriquipa.

Plate 6: Vegetation communities found at the lowest elevations in the Sky Islands of Mexico including mountain scrub on the west sides of the Sierra Mariquita (top left) and Sierra San Luis (top right), dense oak-juniper woodland and mountain scrub in the Sierra Chivato (center left), open oak woodland and mountain scrub in the Sierra el Humo (center right), oak woodland and oak savannah on lower slopes of the Sierra Azul (lower left), and oak woodland and oak savannah on slopes below the summit of the Sierra San Juan (lower right).

Plate 7: Montane riparian forest on the east side of the Sierra los Ajos (left) and north side of the Sierra Cebadilla in the Sierra Madre Occidental (top right), and montane riparian woodland of sycamore and oak in the Sierra Chivato (center right) and of walnut, pine, cypress, and oak on the west side of the Sierra San Luis (bottom right).

and last stations along each transect. So as to maximize coverage across the region, most transects were surveyed only once.

In addition to point-count surveys, I also estimated the number of individuals, pairs, or flocks of each species that was detected while walking transects and during point counts. These estimates included observations made before, during, and after the point-count period and species detected incidentally in the immediate vicinity of transects. This method facilitated estimates of abundance of rare or uncommon species and is similar to the method used by Marshall (1957) in the region. Additionally, I also noted all species and individuals of rare species that were detected incidentally away from transects and used these observations when compiling species lists and estimating species diversity within each mountain range. To classify breeding status, I observed bird behavior during and mainly after surveys and used standardized techniques (North American Ornithological Atlas Committee 1990) and information from the region (Russell and Monson 1998, Corman and Wise-Gervais 2005, Flesch 2008a) to classify breeding status as possible, presumed, or confirmed, or as non-breeding. Species that were present or singing in potential breeding habitat during the breeding season but were outside their known breeding ranges or observed when migrants were still moving through the region were considered possible (vs. presumed) breeders unless more substantial evidence of breeding was observed . To estimate occupancy of nocturnal species, I broadcasted recorded vocalizations at night along transects and in camp on an opportunistic basis.

Habitat Sampling.—I measured a broad range of environmental factors at survey stations to describe the structure and composition of vegetation, other habitat features, and the presence and intensity of land use and disturbance. At the largest scale, I estimated the proportion of area within 100 m of stations covered by each major vegetation community and the dominant community at each point in the following categories: desertscrub or thornscrub, mountain scrub, oak savannah, oak woodland, juniper-pinyon woodland, oak-pine woodland, pine-oak woodland, pine forest, mixed-conifer forest, aspen forest, and montane riparian vegetation. To describe land use and disturbance, I classified the intensity of wildfire, grazing, woodcutting, and other natural or anthropogenic disturbance on a scale from zero (not present) to three (high intensity) at each station based on the degree of vegetation disturbance. I estimated distances to nearest significant cliff face (>2-m tall), house, and surface water, and estimated the height of cliff faces to the nearest meter. To estimate slope, aspect, elevation, and distance to the nearest drainage, I extracted these data from digital elevation models with use of ArcGIS (ESRI 2011).

I used standardized and rapid assessment techniques to describe vegetation structure and composition. To measure basal area of live woody trees at breast height, I used a keyhole prism with basal area categories of 5, 10, 20, and 40 ft^2/ac. I used two methods to estimate vegetation cover, physiognomy, and composition. First, I used point-intercept methods (Elzinga et al. 1998) to estimate cover within six horizontal strata (0-1, 1-3, 3-6, 6-12, 12-20, and >20 m) above ground at points I placed every 6 m along four, 48-m lines placed at 90-degree intervals from a random bearing and at each center point, which totaled 33 point-intercept measurements per station. For each “hit”, I classified dominant vegetation in the following physiognomic categories: 1) conifer, 2) evergreen oak, 3) other broadleaf evergreen (e.g., Madrone; *Arbutus* spp.), 4) broadleaf deciduous, 5) succulent, 6) dead woody vegetation, 7) grass, 8) forb, or 9) *Dodonaea viscosa*. Second, I estimated cover and mean height of vegetation in each of four horizontal strata: 1) grass-forb layer, 2) shrub layer, 3) short-tree layer, and 4) tall-tree layer. I classified pines as tall trees if they emerged from a canopy layer of short trees that were often oaks. To describe vegetation composition, I estimated the proportion of total volume comprised by each dominant tree species in both the tall- and short-tree layers; for shrubs I estimated the proportion of total volume comprised by each physiognomic category (see above). Finally, I used the point-quarter method (Cottam and Curtis 1956) to estimate the density and size of canopy trees (e.g., trees in the tallest horizontal vegetation stratum) and snags at each station; only snags >8 inches in diameter at breast height (dbh) were considered. I classified trees and snags into size classes based on dbh and used the midpoints of each size class to estimate average sizes. I classified the amount of decay of each snag in five categories from one (recently dead) to five (rotting trunk >2-m tall). All measurements were made within 50 m of stations unless noted, all proportions were measured to the nearest 10% when between 20-80% or to the nearest 5% otherwise, and all distances were measured with laser rangefinders or global positioning systems.

ANALYSES

Diversity.—I calculated observed breeding species diversity for each mountain range, region (Sky Islands vs. Sierra Madre Occidental), and for the overall study area by summing all species that were presumed or confirmed breeding during the study. When estimating diversity, I excluded observations of waterfowl and other waterbirds, and considered all species detected including those associated with adjacent lowland vegetation communities because all survey points included some dominant attributes of montane vegetation communities (e.g., oaks). Because all species are not detected perfectly during surveys (Boulinier et al. 1998), I used observed abundance distributions (no. of individuals, pairs, or flocks detected that were at least presumably breeding), the jackknife estimator (Burnham and Overton 1979), and program SPECRICH (J. E. Hines, available at http://www.mbr- pwrc.usgs.gov/software.html) to estimate species diversity. To assess the range of likely values of estimates, I calculated 95% confidence intervals. Estimates of diversity based on the Chao 1 estimator (Chao 1984) computed with program EstimateS (Colwell 2013) were typically within 1-2% of those based on the jackknife estimator and thus not reported. To provide insights on species that may have been present but were undetected in each mountain range, I also noted species that were not detected during the study but had been observed during recent efforts (e.g., Flesch 2008a, Flesch, *unpubl. data*).

Spatiotemporal Variation in Status and Distribution.—I mapped the occurrence and breeding status of each species across the region and qualitatively evaluated patterns of status and distribution of each species. To evaluate potential changes in status and distribution across time at both the scale of mountain ranges and the broader study area, I compared data gathered during the study with historical information from relevant published literature (e.g., Van Rossem 1945, Marshall 1957, Lammertink 1996, Russell and Monson 1998, Flesch 2008a), unpublished reports (e.g., Cirett Galán and Rogero Diaz 1993, Flesch 2008b), online databases (e.g., Madrean Archipelago Biodiversity Assessment database, eBird), based on personal communication with other biologists with experience in the region, and by evaluating my own unpublished data.

Biogeographical Relationships.—Inferences on biogeographical affinities and regionalizations have traditionally been based on qualitative techniques and expert opinion. Thus, quantitative approaches are useful for objective assessments of biogeographical patterns and for identifying unique species assemblages with high potential conservation values. I used multivariate techniques to describe variation in the composition of breeding bird communities among 48 mountain ranges in the U.S. and Mexico and six areas in the adjacent Sierra Madre Occidental. To describe variation among communities, I computed a pair-wise dissimilarity matrix among species' assemblages for each mountain range based on presence-absence data. I used Simpson's beta (β_{sim}) to quantify dissimilarities because it does not consider shared absences (zero values) and is largely unaffected by differences in species richness among sites (Lennon et al. 2001). β_{sim} varies from 0, which indicates identical species assemblages (e.g., low turnover) to 1, which indicates no shared species (e.g., high turnover). For data on the presence and absence of birds in Mexico, I used information gathered during the study (2009-2012) and considered only those species observed to be at least possibly breeding in montane vegetation communities (e.g., oak woodland) in each mountain range. As distributional data for birds in the U.S., I used data gathered during the Arizona Breeding Bird Atlas project (1993-2001; Corman and Wise-Gervais 2005) that were provided by the Arizona Natural Heritage Program, considered species that were at least possibly breeding in each mountain range, and eliminated species that are not associated with montane vegetation communities. Recent information on breeding bird communities in three mountain ranges in southwest New Mexico (Animas, Big Hatchet, Alamo Hueco) was unavailable and is being sought to expand inferences. The pair-wise β_{sim} dissimilarity matrix was based on a total of 153 species and included 2,916 estimates.

To identify groups of mountain ranges with similar species assemblages that could be considered potential biogeographical sub-regions, I used the agglomerative hierarchical clustering technique UPGMA (unweighted pair-group method using arithmetic averages) on the β_{sim} dissimilarity matrix. In UPGMA, distance between clusters equal the average distance between all objects in clusters. Unlike other techniques for delimiting biogeographical regions, UPGMA does not require *a priori* specification of the number of groups to be found by the algorithm and often yields the best overall performance (Sneath and Sokal 1973, Kreft and Jetz 2010). To visualize variation in community composition across space, I used non-metric multidimensional scaling (NMDS) on the β_{sim} dissimilarity matrix and plotted results in ordination space. NMDS is considered the most robust unconstrained ordination technique, in part, because it does not make assumptions regarding the distribution of the underlying distance matrix and because it often summarizes data more effectively in fewer dimensions (Ludwig and Reynolds 1988, Legendre and Legendre, 1998). I performed NMDS in 1-5 dimensions, assessed how well each configuration of points in ordination space matched the original distance matrix based on stress values (e.g., sum of the squared differences between fitted and original distances), and selected the most appropriate solution by identifying when stress reached an asymptote across a gradient of increasing dimensionality (Legendre and Legendre 1998). To avoid local minima and improve interpretation, I considered one hundred random starting values when searching for a stable solution, standardized scaling of ordination results by rotating scores to maximize variance, and moved the origin to the average of the axes. I conducted multivariate analyses with the *metaMDS* and *agnes* functions in the vegan (Oksanen et al. 2011) and cluster (Maechler et al. 2011) libraries in R (R Development Core Team 2013).

To visualize geographical gradients that were potentially correlated with spatial variation in community composition, I used the *envfit* function in the vegan library. As geographical gradients I considered the latitude, longitude, and maximum elevation of each mountain range. This procedure derives vectors that point in the direction a variable is most rapidly changing in ordination space and that have lengths scaled to the strength of correlation between ordination scores and the variable. Thus, "weaker" predictors have shorter vector lengths. For each vector, I computed goodness-of-fit statistics (R^2) equaled to squared correlation coefficients and p-values based on 999 random permutations.

Abundance.—I derived detectability-corrected estimates of density of individuals, pairs, or flocks of each bird species at three spatial scales (station, transect, and mountain range) with use of the mrds library in R (Laake et al. 2012). Distance analyses use frequency histograms of distance data to model a detection function, which adjusts estimates of density for variation in detection probability (Buckland et al. 2001). This approach is useful for comparing abundance estimates among and within species across space and time because variation in detection probability can confound inferences based on raw counts (Lancia et al. 1994, Williams et al. 2002). Before analyses, I excluded observations of all bird species detected in mountain ranges where they do not breed and estimated density for only those species with ≥30 total encounters. In all cases, frequency histograms of distance data were of suitable shape to model detection functions. Because estimating detection functions requires a sufficient number of encounters, which were limited for rare species, I also calculated relative abundance (no. encounters/no. stations) at the scale of each mountain range for each species.

I used two general approaches to fit detection functions and analyze distance data. First, I fit a single detection function for each species with use of conventional distance sampling methods (CDS). Second, for species with ≥50 encounters, I also used multiple covariates distance sampling methods (MCDS; see Marques et al. 2007), which allow the scale of detection functions to vary with potential covariates other than distance that could affect detection probability. When using MCDS, I considered up to four potential covariates depending on sample sizes because preliminary analyses suggested more complex models were estimable only with a sufficient number of encounters. I considered up to two covariates for species with 50-139 encounters, three covariates for species with 140-399 detections, and up to four covariates for species with ≥400 encounters. As potential covariates, I considered time-of-day (minutes after local sunrise), time-of-year (Julian date), noise level (average of wind and noise scores), detection type (visual, aural-calling or wings, or aural-singing or drumming), and sex (male, female, both, or unknown). For species with ≥140 encounters, I also considered vegetation covariates that could affect detectability by obstructing visibility (e.g., dominant vegetation community, percent tall and short tree cover, and percent cover between 1 and 3 m above ground). To improve rates of model convergence, I standardized (z-scored) all continuous covariates prior to analyses.

To model the shape of detection functions, I considered uniform, half-normal (HN) and hazard-rate (HR) functions for CDS models, and HN and HR functions for MCDS models. When fitting HN and HR functions, I considered models without adjustment terms and with up to two cosine or simple polynomial adjustment terms; in models with a uniform function, I also considered up two hermite polynomial adjustment terms. When developing models of detection functions that included covariates, I considered all possible additive combinations of covariates. To select a final model for each species, I used Akaike information criterion adjusted for small sample sizes (AIC_c) to rank models, visually inspected the shapes of detection functions, confirmed standard errors for parameter estimates were reasonably precise, and evaluated goodness-of-fit tests and the precision of density estimates, and selected the best overall model (see Thomas et al. 2010). Before analyses, I inspected histograms of distance data and established sets of cut points or bins that smoothed histograms. To constrain the tails of distributions and improve model fit, I right truncated 0-5% of encounters.

Spatial Variation in Abundance.—To describe spatial variation in abundance across the region, I assessed variation in densities of each species across elevation, latitude, and longitude. To describe spatial variation in abundance, I considered station-specific estimates of density computed with the mrds library in R (see above), fit models with linear and quadratic terms for elevation, latitude, and longitude for each species, and evaluated the magnitude of *p*-values for each term to assess evidence for linear or curvilinear trends in densities for each factor. To adjust for correlations in densities among stations along the same transects and transects within the same mountain ranges, I used linear mixed-effects models with a nested random intercept (transects nested in mountains) that I fit with the nlme library in R (Pinheiro et al. 2012); AIC_c values for models with other potential forms of the random effects (e.g., random intercept for islands or transects) fit with restricted maximum likelihood, confirmed models with this nested random intercept was optimal. All estimates of fixed effects are based on maximum likelihood methods. For all analyses, I considered species for which the number of encounters was sufficient to estimate density.

Bird-Habitat Relationships.—I used two general approaches to assess bird-habitat relationships. First, I assessed variation in densities of each species among major vegetation communities. I first classified each station based on the dominant vegetation community found within 100 m of stations in the following categories: oak savannah (OS; which included adjacent desertscrub or thornscrub, oak, oak-juniper, or oak-juniper-pinyon woodland (OW), mountain scrub (MS), oak-pine woodland (OPW), pine-oak woodland (POW), pine or pine-aspen forest (PF), mixed-conifer forest (MCF), and montane riparian woodland or forest (MR). Riparian communities were considered dominant if coverage was ≥20%. To assess variation in densities among communities, I fit vegetation community as a nominal factor in a linear mixed-effect model for each species with the same nested random effects noted above (e.g., transects nested in mountains). Second, I assessed environmental factors that explained variation in densities among transects along which each species was present and at least possibly breeding. I considered densities at the transect scale because data were too sparse to reliably estimate density at the scale of stations and because I was interested in factors that explained abundance (vs. occurrence). Moreover, by censoring observations from transects where species were not present, I eliminated issues associated with zero inflation (Martin et al. 2005). I did not assess environmental factors that explained species presence at the scale of individual stations because resources to complete those analyses were insufficient. These models, however, can be developed with additional support and offer great potential for informing our understanding of bird-habitat relationships and guiding conservation and management in the region. For all analyses, I considered species for which the number of encounters was sufficient to estimate density.

Table 1: Definitions and units of environmental variables used to model relationships between bird density and habitat in the Sky Islands and adjacent Sierra Madre Occidental of Sonora and Chihuahua, Mexico, 2009-2012.

Variable group	Variable names	Definition; formula	Units
Disturbance intensity	Fire or grazing intensity	Intensity of fire or grazing (0-none, 1-low, 2-mod., 3-high). Woodcutting not considered because >50% of data were zeros	rank
Water availability	Distance to water	Proximity index for surface water; 10000 m sq./(distance to nearest water^2)	ln no./ha.
Cliff faces	Cliff dominance	Proximity index for cliff faces >3 m tall;(10000 m sq./ (distance to nearest cliff^2))* cliff height	ln no./ha.
Drainage proximity	Distance to drainage	Distance to nearest drainage based on analysis of a 30-m digital elevation model	ln m
Tree density and size	Tree density	Number of canopy trees per ha based on point-quarter measurements	ln no./ha.
	Tree dominance	Mean basal area of 4 point quarter trees x tree density	sq. in/ha.
Snag density, size, and condition	Snag density	Number of snags >8 in. dbh per ha based on point quarter measurements within 100 m	ln no./ha.
	Snag dominance	Mean basal area of 4 point quarter snags x snag density	sq. in/ha.
	Snag decay class	Score between 1 (recently dead) and 5 (rotting trunk >2 m tall).	rank
Number of tree species	Tree species diversity	Number of tree species that comprised ≥5% of vegetation volume within the short or tall tree vegetation layers	no.
Vegetation cover	PC1: tall tree vs. shrub cover	Principal component correlated with % vegetation cover in 5 of 6 height strata above ground based on point intercept measurements (see text)	none
	PC2: short tree cover	Principal component correlated with % vegetation cover in 1 of 6 height strata above ground based on point intercept measurements (see text)	none
Vegetation physiognomy	Broadleaf deciduous, broadleaf evergreen, conifer, oak, or grass-forb cover	Proportion of total hits comprised by each physiognomic class of vegetation noted based on 33 point intercept measurements within each of 6 height strata above ground at each station	proportion

To model factors that explained variation in bird densities, I used data obtained during habitat sampling and developed a linear-mixed effects model for each species. I log transformed density estimates to normalize response data and developed models for only those species detected along ≥50 transects; modeling efforts for rarer species yielded limited inferences due to low spatial variation in densities. I fit models with the nlme library in R and included a random intercept for mountain range. Because the number of potential explanatory factors was high and information for developing sets of candidate models *a priori* was limited, I used stepwise variable selection with mixed variable selection to select sets of explanatory factors for each species with use of the *stepAIC* function in the MASS library in R (Venables and Ripley 2002). I used Bayesian information criterion (BIC) to guide variable selection because it penalizes model complexity more heavily than other procedures (e.g., AIC) and thus reduces the chances of overfitting. In a few cases where models developed with stepwise selection based on BIC included no fixed effects, I used AIC to guide variable selection.

I considered a total of 18 potential explanatory factors when developing models to explain variation in bird densities (Table 1). This group of factors was developed by eliminating one factor from correlated ($r \geq 0.60$) pairs of factors that I considered to be less biologically relevant or measured less precisely, and by using multivariate techniques to generate synthetic variables from multiple correlated factors. For example, I eliminated tree basal area and tree species composition because they were correlated with tree dominance or vegetation physiognomy, respectively. To describe vegetation cover, I performed principal components analysis on point-intercept data from all six horizontal strata above ground, which reduced those correlated variables into two uncorrelated components that described 61% of variation in vegetation cover. A component representing increasing tall-tree cover and decreasing shrub cover (PC-1; eigenvalue = 2.34) was positively correlated with cover 6-12 ($r = 0.79$), 12-20 ($r = 0.84$), and >20 ($r = 0.60$) m above ground and negatively correlated with cover 0-1 ($r = -0.52$) and 1-3 ($r = -0.60$) m above ground. A second component representing increasing short-tree cover (PC-2; eigenvalue = 1.32) was positively correlated with vegetation cover 3-6 m above ground ($r = 0.93$) and largely uncorrelated with cover in other strata ($r = -0.31$-0.38). To describe vegetation physiognomy, I computed the proportion of all point intercept "hits" in each of five categories (conifer, evergreen oak, broadleaf evergreen, broadleaf deciduous, and grass or forb). Because these catagories sometimes summed to one, I removed the category with the least explanatory power from the stepwise procedure to avoid unit-sum constraints. Because snag density and snag dominance were correlated ($r = 0.78$) but I was unsure which factor was most important, I considered them separately and selected the model with the lowest overall BIC. Because the effects of snags may depend on how decayed they are, I considered interactions between snag density or snag dominance and decay class when developing models. Because only 18% of stations and 32% of transects showed any sign of recent woodcutting or logging that rarely approached even moderate levels of intensity, I did not consider these factors. In contrast, because disturbance due to fire (40 and 55%, respectively) and grazing (43 and 60%) had much higher frequencies of occurrence, I considered those factors when fitting models. I log transformed some factors before modeling to reduce the influence of extreme values.

RESULTS

Survey Effort and Access.—I surveyed birds in 26 Sky Islands and six areas in the adjacent Sierra Madre Occidental over four years (2009-2012) in May-July (Fig. 1, Table 2). I completed 1,851 point-count surveys at 1,562 stations along 210 transects between 1,150 and 2,750 m elevation and covered virtually all montane vegetation communities I observed in the region. In the Sky Islands, coverage extended to within 100 m of the maximum elevation of each range in 69% of ranges and within 200 m in 84%. On average, transects were 1,369 ± 22 (± SE) m in length (range = 614-2,335 m) and included 7.3 ± 0.1 stations placed 215 ± 2 m (range = 162-295 m) apart. Total length of all transects combined was 288.9 km. I surveyed 181 transects in the Sky Islands and 29 transects in the adjacent Sierra Madre Occidental. Effort was higher in large mountain ranges that supported a greater number of vegetation communities such as in the Sierra el Tigre (15 transects), Sierra Oposura (la Madera; 14 transects), and Sierra los Ajos (12 transects). Effort was low in small mountain ranges, which typically supported only oak woodland (Sierra San Juan, 4 transects; Sierra el Humo, 3 transects), or in some cases, pine-oak

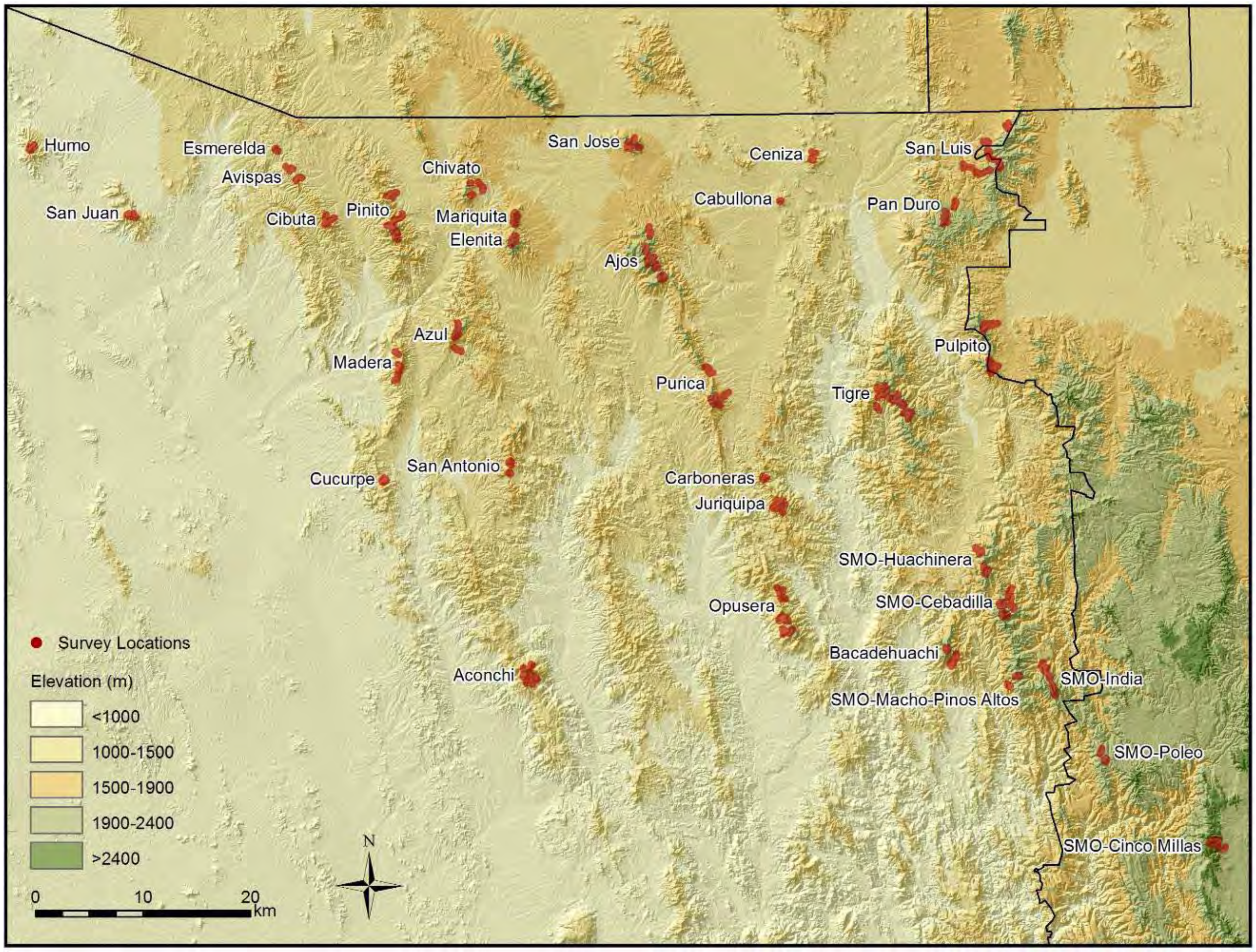


Figure 1: Map of study area and survey locations in the Sky Islands and adjacent Sierra Madre Occidental in Sonora and Chihuahua, Mexico, May-July 2009-2012. Red polygons show the location of transects, which covered portions of 26 mountain ranges in the Sky Islands region and six areas in the adjacent Sierra Madre Occidental. Color ramp shows five elevation bands and is somewhat lighter in the legend than on the map due to the presence of hill-shade, which illustrates topographic variation.

woodland (e.g., Cerros las Carboneras, east of Nacozari de Garcia, 2 transects). Effort was lowest in the Sierra Ceniza and on Cerro Cabullona (south of Agua Prieta) where only scattered patches of oaks that were typically in poor condition were observed. Effort in the Sierra Púlpito was located in both the Sierra Huchita Hueca (5 transects to 2,360 m) in the south and the Sierra Ojos Azules (6 transects to 2,390 m) in the north, which was visited by Marshall (1957).

I was largely successful in obtaining access to areas I intended to survey but did not survey all areas where access was obtained. For example, efforts to locate oak woodland in the Sierra Basomari (south of Agua Prieta) largely failed, landowners reported that many stands of oaks had been killed by recent drought or frost events, and thus no surveys were conducted in the range. Access to the Sierra el Carmen (east of Sinoquipe) could not be coordinated with the landowner and thus no surveys were completed in the range, which likely supports small patches of oak-pine woodland. Access to areas around the highest peak in the Sierra San Antonio (2,200 m; west of Arizpe) was denied by the landowner but access to the southern portion of the range was obtained, which facilitated surveys at elevations as high as 2,000 m. Access to one canyon in the Sierra Chivato that likely supports pines was denied but surveys in oak woodland at elevations ≤1,790 m were completed. Access to the southern portion of the Sierra el Tigre was precluded by an impassable road from the east side of the range, but access to extensive areas of high country in the central portion of the range was obtained from the west side. Despite success in Sonora, we experienced a range of challenges obtaining access to private lands in Chihuahua. For example, access to portions of the Sierra Madre north of El Largo, Chihuahua was denied by community officials and could not be facilitated by our partners at Pronatura. A scheduled trip to Mesa de las Guacamayas in Chihuahua in early July 2012 was cancelled by Pronatura, who recommended we not attempt to access the area due to safety issues. Thus, surveys in the Sierra Madre were more limited than proposed. Nonetheless, effort was sufficient to provide the necessary context for interpreting results from the adjacent Sky Islands.

Sampling effort was largely proportional to the relative coverage of each major montane vegetation community in the study region. Accordingly, effort was highest in oak woodland types (41.9% of stations) and fairly high in pine-oak woodland (19.1%), which are the dominant vegetation communities in the region. Effort in areas with significant coverage of montane riparian vegetation (e.g., ≥20%) was moderate (9.5%), and effort in areas dominated by pine forest (8.1%) and oak-pine woodland (8.1%) was also moderate. In contrast, effort was relatively low in mountain scrub (5.4%) and especially in mixed-conifer forest (2.1%), which is rare in the study area. Moreover, effort in oak savannah that occurs at the lower-elevation ecotone between montane vegetation and grassland was also moderate (5.7%) despite relatively high coverage.

Species Diversity and Breeding Status.—I detected 199 species of birds including 165 species that were at least presumably breeding in the study area. In the Sky Islands, I observed 152 species that were at least presumably breeding including 71 (47%) species that I confirmed breeding (Table 2). Based on the observed abundance distribution, I estimate that 169 species breed in montane vegetation communities in the Sky Islands of Mexico and that as many as 180 species could breed (95% CI = 158-180; Table 2). In adjacent portions of the Sierra Madre Occidental, I observed 117 species that were at least presumably breeding including 35 (30%) species that I confirmed breeding. Based on the observed abundance distribution, I estimate 135 species breed in the areas I considered in the Sierra Madre and that as many as 147 species could breed (95% CI = 123-147).

I classified eight additional species as possible breeders in the Sky Islands. These species were observed in potential breeding habitat during the breeding season but were outside of their known breeding ranges and evidence was insufficient to presume breeding. They include Northern Saw-whet Owl (Sierra San Luis, 3 June 2011, 1,780 m; see Appendix A for Latin names), Tufted Flycatcher (Sierra Aconchi, 3 June 2012, calling at 1,800 m), Gray Vireo (Sierra San Luis, 14 May 2011, 1,810 m), Violet-green Swallow (Sierra Pan Duro, 22 May 2011, calling at 2,060 m), Audubon's Warbler (Sierra Mariquita, 27 June 2009, singing at 2,440 m), Chipping Sparrow (Sierra San Luis, 17 May 2011, 1,780 m; Sierra Púlpito, 11 June 2012, 1,740 m), Pine Siskin (Sierra Elenita, 6 May 2011, pair courting at 2,340 m), and Red Crossbill (Sierra Púrica, 24 May 2012, three in pine forest at 2,400 m). Additionally, Gray Flycatcher (*Empidonax wrightii*) in the Sierra Juriquipa (21 May 2012, two calling in oak-juniper woodland at 1,880-1,970 m) and Sierra Pan Duro (25 May 2012, in riparian woodland at 1,700 m) were thought to

Table 2: Survey effort and diversity of breeding birds in the Sky Islands and adjacent Sierra Madre Occidental of Sonora and Chihuahua, Mexico 2009-2012. Elevations are rounded to the nearest 5 meters and are based on a digital elevation model. Species diversity was estimated based on observed species abundance distributions and the jackknife estimator. Observed and estimated species diversity does not include observations of species that were possibly breeding.

	Effort			Observed Species Diversity					Estimated Breeding Species Diversity			
Location – elevation	Transects	Min. Elevation	Max. Elevation	Non-breeding	Possibly Breeding	Presumed Breeding	Confirmed Breeding	Total Breeding	*N*	SE	95% CI LB	95% CI UB
Sky Islands	181	1,155	2,600	0	8	81	71	152	169	5.8	157.6	180.4
Humo - 1,640	3	1,180	1,535	1	1	32	2	34	46	4.7	36.8	55.2
San Juan - 1,630	4	1,260	1,610	2	0	57	2	59	72	5.1	62.0	82.0
Esmeralda - 1,620	2	1,300	1,540	0	0	33	4	37	50	5.7	39.2	61.6
Avispas-Cíbuta - 2,070	8	1,170	2,060	1	0	70	8	78	94	5.5	83.2	104.8
Pinito - 2,230	12	1,400	2,180	8	4	53	8	61	71	4.5	62.2	79.8
Madera - 2,030	4	1,290	2,020	1	0	49	7	56	66	4.5	57.2	74.8
Chivato - 2,190	4	1,440	1,785	1	0	55	11	66	79	5.1	69.0	89.0
Azul - 2,450	8	1,320	2,435	1	1	57	11	68	81	5.1	71.0	91.0
Cucurpe - 1,720	3	1,155	1,520	1	0	39	1	40	46	3.5	39.1	52.9
Mariquita - 2,480	7	2,070	2,480	1	2	51	2	53	62	4.2	53.8	70.2
Elenita - 2,460	6	1,875	2,455	6	2	51	2	53	64	4.5	55.2	72.8
San Antonio - 2,200	3	1,435	1,955	11	1	43	0	43	55	4.9	45.4	64.6
San José - 2,530	5	1,675	2,360	1	0	35	4	39	48	4.2	39.8	56.2
Ajos - 2,630	12	1,700	2,600	2	0	50	12	62	73	4.7	63.8	82.2
Aconchi - 2,190	12	1,285	2,170	4	2	72	14	86	103	6.1	91.1	114.9
Púrica - 2,460	9	1,370	2,450	6	1	80	3	83	100	5.8	88.5	111.5
Cabullona - 1,880	1	1,720	1,855	2	0	30	0	30	37	3.7	29.7	44.3
Ceniza - 1,820	2	1,440	1,600	5	0	41	2	43	49	3.5	42.1	55.9
Carboneras - 1,920	2	1,640	1,920	1	1	35	2	37	48	4.7	38.8	57.2
Juriquipa - 2,180	9	1,525	2,165	7	3	49	4	53	61	4.0	53.2	68.8
Oposura - 2,320	14	1,505	2,240	1	1	64	12	76	89	5.1	79.0	99.0
Tigre - 2,440	15	1,280	2,385	4	0	67	20	87	98	4.9	88.4	107.6
Pan Duro - 2,300	6	1,680	2,150	8	2	58	0	58	73	5.5	62.2	83.8
San Luis - 2,520	13	1,425	2,310	7	4	77	3	80	91	4.7	81.8	100.2
Púlpito - 2,460	11	1,580	2,390	1	2	64	18	82	100	6.0	88.2	111.8
Bacadéhuachi - 2,400	6	1,420	2,320	1	0	74	10	84	98	5.3	87.6	108.4
Sierra Madre Occidental	29	1,400	2,750	3	3	82	35	117	135	6.0	123.2	146.8
Huachinera - 2,420	6	1,565	2,302	2	0	53	8	61	72	4.7	62.8	81.2
Cebadilla - 2,640	9	1,400	2,620	1	3	69	20	89	105	5.5	94.2	115.8
El Macho-Pinos Altos - 2,360	2	1,465	2,202	1	0	60	6	66	84	6.0	72.2	95.8
La India - 2,560	6	1,595	2,480	0	0	57	13	70	88	6.4	75.5	100.5
El Poleo - 2,340	2	2,180	2,320	1	0	34	8	42	51	4.2	42.8	59.2
Cinco Millas - 2,800	4	2,310	2,750	1	0	43	5	48	71	8.9	53.6	88.4

be late migrants despite being present in or near potential breeding habitat after the vast majority of migrants had passed through the region.

In the adjacent Sierra Madre, I classified three additional species as possible breeders. They included Northern Parula (Sierra Cebadilla, 15 June 2012, singing in riparian forest at 1,470 m) and Hooded Warbler (Sierra Cebadilla, 16 June 2012, singing in tall riparian forest in pine-oak woodland at 1,890 m) that were not observed in the Sky Islands, and Indigo Bunting (Sierra Cebadilla, 15 June 2012, two in riparian vegetation at 1,420-1,470 m) that was presumed to breed in only one Sky Island (Sierra Púrica, 24 May 2012, two singing in deciduous brush in pine-aspen forest at 2,260-2,300 m). Additionally, J. Yerger described the loud raucous calls of at least two chachalacas that may have been Rufous-bellied Chachalaca (*Ortalis wagleri*) in the Sierra Cebadilla (16 June 2012, in dry oak and pine-oak woodland near la Tinaja at 1,850 m). This observation was excluded because the birds were not positively identified to species and could have been caged birds, because of their preference for subtropical lowland vegetation that is located >20 km away in the Riíto Valley, and because the nearest known locality is in thornscrub northwest of Sahauripa that is >100 km to the southwest (Flesch, *unpubl. data*).

Breeding species diversity was generally higher in larger and more southern Sky Islands and those closest to the Sierra Madre. For example, observed diversity was highest in the Sierra el Tigre (87 species), which is the largest Sky Island, and was also high in the Sierra Aconchi (86 species) and in the Sierra Bacadéhuachi (84 species), which are among the southernmost Sky Islands (Table 2). Among northern Sky Islands, diversity was highest in the Sierra Púlpito (82 species) and Sierra San Luis (80 species), which are relatively large and close to the northern end of the Sierra Madre, and in the Sierra las Avispas-Cíbuta complex (78 species), which supports large numbers of montane riparian species and the westernmost pines in the Sky Islands of Mexico. In comparison, diversity was low on Cerro Cabullona (30 species) and in the Sierra Ceniza (43 species) where oak woodland is poorly developed and where too few species of montane affinity were observed to classify them as true Sky Islands. Both of those mountains largely supported only lowland species with the exception of Acorn Woodpecker in the Sierra Ceniza and Montezuma Quail, Blue-gray Gnatcatcher, Spotted Towhee, and Hepatic Tanager on Cerro Cabullona (Table 3). In contrast, although diversity was also low in the Sierra el Humo (34 species), Sierra la Esmeralda (37 species), and Sierra Cucurpe (40 species), they supported significant but isolated stands of oak woodland and associated species such as Arizona Woodpecker, Dusky-capped Flycatcher, Mexican Jay, Hutton's Vireo, Bridled Titmouse, and Bushtit (Table 3).

Patterns of estimated species diversity largely tracked those of observed species diversity (Table 2). In the Sky Islands, estimated species diversity averaged 19.9 ± 1.1% greater than that observed with estimates ranging as high as 36% greater in the Sierra Esmeralda where survey effort was low and as low as 13% in the Sierra el Tigre where survey effort was high. Estimates of breeding species diversity in some ranges were likely biased somewhat by sampling issues. In the Sierra Púrica for example, estimates were likely biased high somewhat due to relatively high levels of effort at lower elevations at the base of the range. In contrast, estimates for the Sierra los Ajos were likely biased low due to an absence of survey effort at elevations below 1,700 m. Exploratory surveys prior to the beginning of the study indicated the presence of up to nine additional breeding species in the Sierra los Ajos and Sierra Azul that were not detected during the study (Table 3; Flesch 2008a, b).

Distribution.—Distribution patterns varied widely among species and largely matched the distribution of preferred habitat types with some important exceptions. Species associated with oak woodland generally had the broadest distributions whereas those associated with high-elevation forest had the narrowest distributions. Species associated with desertscrub and thornscrub, which were sampled only when found immediately adjacent to oaks, were often detected only in the western or southern portions of the study area. In the Sky Islands, Bewick's Wren, Black-headed Grosbeak, Rufous-crowned Sparrow, and Scott's Oriole were observed in all 26 mountain ranges I surveyed, whereas other species associated with oaks such as Arizona Woodpecker, Dusky-capped Flycatcher, Mexican Jay, Bridled Titmouse, Bushtit, and Hepatic Tanager were observed in 24 mountain ranges (Table 3; see maps in Appendix B). In contrast, Berylline Hummingbird, Warbling Vireo, Hermit Thrush, Slate-throated Redstart, and Flame-colored Tanager, which are associated with high-elevation forest, and Plain-capped Starthroat, Yellow-green Vireo, Fan-tailed Warbler, and Black-vented Oriole, which often occur in subtropical lowland environments, were observed in only one Sky Island. Additionally, 11 species that are associated with high-elevation forest were observed only in the Sierra Madre Occidental including Thick-billed Parrot, Mountain Trogon, Eared Quetzal, Pine Flycatcher, Red-breasted Nuthatch, Pygmy Nuthatch, Orange-billed Nightingale-Thrush, Russet Nightingale-Thrush, Hooded Warbler, Northern Parula, and Black-headed Siskin (Table 3).

Most species associated with oak woodland were observed only as far west as the Sierra San Juan or Sierra las Avispas-Cíbuta complex, but others also occurred to the west in the Sierra el Humo, which is the westernmost Sky Islands region where oak woodland is more isolated, covers less area, and is less structurally developed. For example, Arizona Woodpecker, Dusky-capped Flycatcher, Mexican Jay, Hutton's Vireo, Bridled Titmouse, and Bushtit occurred as far west as the Sierra el Humo, whereas Montezuma Quail, Whiskered Screech-Owl, Western Wood-Pewee, Blue-gray Gnatcatcher, Spotted Towhee, and Hepatic Tanager were observed only as far west as the neighboring Sierra San Juan (Table 3; Appendix B). Band-tailed Pigeon, Northern Pygmy-owl, Elegant Trogon, White-breasted Nuthatch, Brown Creeper, and Black-throated Gray Warbler were observed only as far west as the Sierra las Avispas-Cíbuta complex or in the nearby Sierra Esmeralda. Although often associated with pines, Mexican Whip-poor-will was observed as far west as the Sierra el Humo (one calling on 20-21 May 2010 in dense oak woodland northeast of the summit at 1,430 m) and was also observed in oak woodland and montane riparian vegetation far from pines in the Sierra las Avispas-Cíbuta complex, but not in the Sierra San Juan.

Species associated with pines were typically distributed only as far west as the Sierra el Pinito and in one case immediately to the south in the Sierra la Madera where pines are distributed more locally and cover much less area. Greater Pewee, Cordilleran Flycatcher, Buff-breasted Flycatcher, Plumbeous Vireo, Eastern Bluebird, Olive Warbler, Grace's Warbler, and Yellow-eyed Junco for example, were observed only as far west as the Sierra el Pinito, and only Cordilleran Flycatcher occurred in the neighboring Sierra la Madera (Table 3) where it was very rare (1 singing, 19 June 2009 at 1,960 m). Notably, only two species that are associated with pines in the region, Short-tailed Hawk and Steller's Jay, were observed and presumed to breed

Table 3: Status and distribution of birds in the Sky Islands and adjacent Sierra Madre Occidental in Sonora and Chihuahua, Mexico, May-July, 2009-2012. Status is noted as confirmed breeding (C), presumed breeding (P), possibly breeding (?), non-breeding (O), and presumed breeding during previous efforts by the author between 2004 and 2008 (#). Only landbird species that were at least possibly breeding in the region are included. Mountain ranges are listed from west to east.

Common Name	Humo	San Juan	Esmeralda	Avispas-Cibuta	Pinito	Madera	Chivato	Azul	Cucurpe	Mariquita	Elenita	San Antonio	San José	Ajos	Aconchi	Púrica	Cabullona	Ceniza	Carboneras	Juriquipa	Oposura	Tigre	Pan Duro	San Luis	Púlpito	Bacadéhuachi	SMO-Huachinera	SMO-Cebadilla	SMO-Pinos Altos	SMO-India	SMO-Poleo	SMO-Cinco Millas
Scaled Quail	P																								P							
Elegant Quail															P						P											
Gambel's Quail		P													P	P		P						P								
Montezuma Quail		P	P	C	P	P	P	P	#	P	P	P	P	#	P	P	P		P	P	P	P	P	P	C	P		P	P	P		
Wild Turkey						P	P	P			P	P		P	P	P			P	P	C	C	P	P	P	P	P	P		P		C
Turkey Vulture	O	P	P	O	P	O	O	O	O	O	O	O	O	O	P	P	O	O	P	O	P	O	O	P	P	P	P	P	P	P	P	O
Sharp-shinned Hawk					?						P			P		P				?		C		P	?							
Cooper's Hawk				P	C	P	C	C		P	P			P	P	P				P	C	C	P	C	P	P	#					P
Northern Goshawk					P						C			C									P		C	P		P				
Common Black-Hawk				#																					P							
Gray Hawk				P	P		P	#				P		P		P													P			
Short-tailed Hawk				P	P	C					P			P	P				P		P	P	P	P	P			P				
Swainson's Hawk							P																		P						O	
Zone-tailed Hawk		P		P	#	P		P		P	P	P		P	P					P	P	P	P	P	C			P				
Red-tailed Hawk	P	C	P	P	P	P	P	P	P	P	P	P	P	P	C	P		P		C	P	P	P	C	P	P	P	P	P	P		
Golden Eagle				P	#	P	P	C		P		P	P	#		P			P	P				P								
American Kestrel			P																													
Peregrine Falcon																								P	P			P				
Band-tailed Pigeon				P	O	P	P	P	P	P	P		P	P	P	P			P	P	P	P	P	P	P	P	P	P		P	P	P
Eurasian Collared-Dove															P	P																
White-winged Dove	P	P	P	P	P	P		#	P			P	P		P	P	P	P	P		P			O	P	P		P				
Mourning Dove	P	P		P	P	P	P	#						#	P	P	P	P	P			P	P	P	P	P		P		P		P
Inca Dove									P																			P	P			
Common Ground-Dove				P	#		P		#							P							P		P	P			P			
White-tipped Dove														#								P										
Thick-billed Parrot																														P		C
Yellow-billed Cuckoo							P	#	P						P							P						P	P			

Common Name	Humo	San Juan	Esmeralda	Avispas-Cibuta	Pinito	Madera	Chivato	Azul	Cucurpe	Mariquita	Elenita	San Antonio	San José	Ajos	Aconchi	Púrica	Cabullona	Ceniza	Carboneras	Juriquipa	Oposura	Tigre	Pan Duro	San Luis	Púlpito	Bacadéhuachi	SMO-Huachinera	SMO-Cebadilla	SMO-Pinos Altos	SMO-India	SMO-Poleo	SMO-Cinco Millas
Greater Roadrunner	P	P		P	P	P	P	P	P	P	P	P			P	P				P			P	P	P			P				
Flammulated Owl																										P				P	P	
Western Screech-Owl	#	#		#		P												P				P	P		P	P						
Whiskered Screech-Owl		P		P	P	P	P	P	P			P	P	P	P	P				P	P	P	P	P	P	P	P	P	P	P		
Great Horned Owl						P	P	P							P	P		P						P				P				
Northern Pygmy-Owl				P	P	P	P	P	P	P	P	P	P	P	P	P				P	P	P	P	P	P		P					
Elf Owl		P		P	P		P	P						P	P	P		P				P		P				P				
Spotted Owl				P	P	P		P	P	P	P	P		P	C					P	P	P		P			P	P		P		
Northern Saw-whet Owl																								?								
Lesser Nighthawk		P													P																	
Common Nighthawk					#		#																	P	P			P		P		
Common Poorwill		P	P	P	P	P		#			P		P		P	P		P		P				P	P							
Buff-collared Nightjar	P	P		P		P			P								P									P			P			
Mexican Whip-poor-will	P			P	P	C	P	P		P	P		P	P	P	P				P	P	P	P	P	P	P	P	P	P	P	P	
White-throated Swift		P		P	P	P		P	P	P	P	P	P	P	P	P	P	O		P		P	P	P		P	P	P				
Broad-billed Hummingbird	#	P	P	P	P	P	P	P	P			P		#	P	P	P	P	P	P	P	P		P	P	P	P	P	P			
White-eared Hummingbird											P										P	P					#	P	P			P
Berylline Hummingbird																					P							P		P		P
Violet-crowned Hummingbird								P						#	P						P	P				P			P			
Blue-throated Hummingbird															P						P	P	P		P		P	P		P		
Magnificent Hummingbird										P				P	P	P				?	P	P		P	P	P	P	P		C		
Plain-capped Starthroat															P																	
Lucifer Hummingbird																		P														
Black-chinned Hummingbird												O		P				P							P							
Anna's Hummingbird	P	P		P			P	P		P			P		P	P				P				P								
Costa's Hummingbird			P															P														
Broad-tailed Hummingbird					P						P	O		P		P		O		?	P	C	P	P	C		P	P	P	P	P	P
Elegant Trogon				P	P	C	P	P	P	P	P	P	P	P	P	P			P	P	P	P		P	P	P	P	P	P	P	P	P
Mountain Trogon																												P		P	P	P

Common Name	Humo	San Juan	Esmeralda	Avispas-Cibuta	Pinito	Madera	Chivato	Azul	Cucurpe	Mariquita	Elenita	San Antonio	San José	Ajos	Aconchi	Púrica	Cabullona	Ceniza	Carboneras	Juriquipa	Oposura	Tigre	Pan Duro	San Luis	Púlpito	Bacadéhuachi	SMO-Huachinera	SMO-Cebadilla	SMO-Pinos Altos	SMO-India	SMO-Poleo	SMO-Cinco Millas
Eared Quetzal																												P				P
Acorn Woodpecker	?		P	P	P	P	P	P		P	P	P	P	P	P	P		P	P	P	C	P	P	P	P	P	P	C	P	P	C	P
Gila Woodpecker		P							#						P		P	P			#	P				P						
Ladder-backed Woodpecker	P	P	P	P	#	P	P	P	P			P	P		P	P	P	P			P	P			P	P						
Hairy Woodpecker								P		P	P			P		P					P			P		P	P	P	C	C	P	P
Arizona Woodpecker	P	P	P	C	C	P	P	C	P	P	P	P	P	P	P	P			P	P	P	P	P	C	P	P	P	P	P	C		
Northern Flicker	P			P	C	P	P	P	P	P	P			P	P	P				P	P	C	P	P	C	P	P	C	P	P	P	P
Gilded Flicker	P	P		C											O																	
White-striped Woodcreeper																										P		P	P	P		
Northern Beardless-Tyrannulet				P	#		P								P						#	P							P			
Tufted Flycatcher															?													C	P	P	C	P
Greater Pewee					P			P		P	P			C	C	P				P	P	C	P	P	P	C	C	C	C	C	C	P
Western Wood-Pewee		P	P	P	P		C	P		P	P	O		C	C	P	O			P	C	P	P	P	P	P	P	P	P	C	P	P
Pine Flycatcher																												P			P	
Cordilleran Flycatcher					?	P		P		P	P			P	?	P					P	C	P	P	P	P	P	P	P	P	C	P
Buff-breasted Flycatcher					?						P			P								C	P	P	P	P		P	P	P	P	
Black Phoebe			P	P	P			P	#					#									P						P	P		
Say's Phoebe				P			P			P								P							C							
Vermilion Flycatcher		P		P			C									P		P			P	P				P			P			
Dusky-capped Flycatcher	P	P	P	P	C	C	P	P	P	P	P	P	P	P	P	P			C	P	P	P	P	P	C	P	P	C	P	P	P	P
Ash-throated Flycatcher	P	P	C	P	P	P	P	P	C			P	P	P	P	P	P	C		P	P	P		P	C	P	P	P		P		
Brown-crested Flycatcher	P	P		P	P		P	P	P						P	P			P		P	P				P		P	C	P		
Sulphur-bellied Flycatcher				P	#		P	P						P	P	P					P	P		P		P	O	P	P	P		
Cassin's Kingbird	P	P	P	C	P	P	P	P		P	P	P	P	P	C	P	P		P	P	P	P	P	P	P	P	P		P	P	P	P
Thick-billed Kingbird				C											P	P					P	P				P			C			
Western Kingbird		P		P	#		#											P							P							
Rose-throated Becard				C											P																	
Loggerhead Shrike						P	#									P																
Bell's Vireo	P	P	#															P														

Common Name	Humo	San Juan	Esmeralda	Avispas-Cibuta	Pinito	Madera	Chivato	Azul	Cucurpe	Mariquita	Elenita	San Antonio	San José	Ajos	Aconchi	Púrica	Cabullona	Ceniza	Carboneras	Juriquipa	Oposura	Tigre	Pan Duro	San Luis	Púlpito	Bacadéhuachi	SMO-Huachinera	SMO-Cebadilla	SMO-Pinos Altos	SMO-India	SMO-Poleo	SMO-Cinco Millas
Gray Vireo																								?								
Plumbeous Vireo					P			P		P	P	O		C	P	P				P	P	C	O	P	P	P	P	P	P	C	P	P
Hutton's Vireo	P	P	P	C	P	P	C	C	P	P	P	P	P	P	C	P			P	P	P	C	P	P	C	P	P	C		C	P	P
Warbling Vireo		O			O						O	O			O	O				O		O	O	O		P		P		P	P	P
Yellow-green Vireo																										P						
Steller's Jay				P	C	P		P		P	P	?	P	P		P				P	P	P	P	P	P	P	P	C		P	P	P
Western Scrub-Jay							P						C						P			P		P	P							
Mexican Jay	P	P	P	P	C	P	P	P	P	P	P	P	P	P	P	P			P	P	P	P	P	P	C	P	P	C		C		
Common Raven	P	P	P	P	P	P	P	P		P	P	P	P	P	P	P	P	P	C	P	P	P	P	P	P	P	P	P	P	P	P	P
Violet-green Swallow											O	O											?	O								
Barn Swallow				P						P							P								P				C			
Mexican Chickadee																						C	P	P	C	P	P	C		P	C	P
Bridled Titmouse	P	P	C	P	C	P	C	C	P	P	P	P	P	P	C	P			P	P	C	C	P	P	P	P	C	C	P	P		
Verdin		P		P													P	P														
Bushtit	P	P	P	P	P	C	P	P	P	P	P	P	P	P	C	P			P	P	P	P	P	P	C	P	P	P	P	P	P	P
Red-breasted Nuthatch																																P
White-breasted Nuthatch			P	P	P	P	P	C		C	P	P		P	P	P			P	P	P	P	P	P	P	P	P	C	P	P	P	P
Pygmy Nuthatch																												P			P	P
Brown Creeper				P	P	P		C		P	P			C	P	P				P	P	P	P	P	P	P	P	P		P	P	P
Cactus Wren		P		P			P	P	P			P			P	P	P	P			P					P	P					
Rock Wren	P	P	P	P	P	P	P		P				P		P	P		P	P		C	P	P	P	P		P	P				
Canyon Wren		P	P	P	P	P		P	P	P	P	P	P	C	C	P	P	P	P	P	P	P	P	P	P	P	P	P		P		
Sinaloa Wren												P			P	P					P											
Bewick's Wren	C	P	C	P	P	P	P	P	P	P	P	P	C	P	C	C	P	P	P	P	C	P	P	P	C	P	P	P		P		P
House Wren										P	P	O		P						O			?	P		C	C	P	P	C	P	C
Blue-gray Gnatcatcher		P		P	P	P	P	P		P	P	P	P	P		P	P		P	P	P	C	P	P	P	P	P	P	P	P		P
Black-tailed Gnatcatcher									P																							
Black-capped Gnatcatcher		P	P												P							P										
Eastern Bluebird					P		C	C			P					P				C	C	P				C		P		P	P	

Common Name	Humo	San Juan	Esmeralda	Avispas-Cibuta	Pinito	Madera	Chivato	Azul	Cucurpe	Mariquita	Elenita	San Antonio	San José	Ajos	Aconchi	Púrica	Cabullona	Ceniza	Carboneras	Juriquipa	Oposura	Tigre	Pan Duro	San Luis	Púlpito	Bacadéhuachi	SMO-Huachinera	SMO-Cebadilla	SMO-Pinos Altos	SMO-India	SMO-Poleo	SMO-Cinco Millas
Western Bluebird																							P	P	P							
Townsend's Solitaire					?					P	?									O		C			P		P	P	P	P	P	P
Brown-backed Solitaire															P							P				C	P	P	P	P		
Orange-billed Nightingale-Thrush																												P				
Russet Nightingale-Thrush																																P
Hermit Thrush					O						O	O		C	O	O				O			O	O								
American Robin				P	P		P	P		P	P			C	P	P				P	P	P	P	P	C	P	P	C	P	C	C	C
Northern Mockingbird	P	P	#	P			P	P	P				C		P	P	P	P	P	P		P		P	P	P	P		P			
Curve-billed Thrasher	#	P				P	C	P	P			P			P		P	P			P	P				P			P			
Crissal Thrasher	#	P			P												P	P					P	P	P							
Phainopepla	P	P		P			P	?								P										O		O				
Olive Warbler					P			P			P			C	P	P			?		P	P	P	P	P	C	P	C	P	P	C	P
Crescent-chested Warbler														P							C					C	P	C		P		P
Lucy's Warbler	#	P	#	P			P					P			C	P		P								P						
Virginia's Warbler					O					P				P																		
Hooded Warbler																												?				
Northern Parula																												?				
Audubon's Warbler					O					?	O					O		O		O		O	O	O				P				
Grace's Warbler					P			C		P	C			P	P	P				P	P	C	P	P	P	P	C	P	P	C	P	P
Black-throated Gray Warbler				P	P		C	P		P	P	O		P		P				P	?	P	P	P	C							
Fan-tailed Warbler																										P		P				
Rufous-capped Warbler				#		P		#				P			C						P	P				P		P				
Red-faced Warbler														C								C	P	P	P	C	C	P	P	C	P	P
Painted Redstart			#	P	C	P	P	C		P	P	P		C	C	P			P	C	C	C	P	P	C	C	P	C	C	C	C	C
Slate-throated Redstart																										P	C	P		P	P	P
Yellow-breasted Chat																								O				P	P			
Spotted Towhee		P		P	P	P	P	C		C	P	P	P	P		C	P		P	P	C	P	P	P	C	C	P	C	P	P	P	P
Rusty Sparrow															P				P	P	C	P				P		P	P			
Rufous-crowned Sparrow	C	P	C	C	P	C	C	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	C	P	P		

Common Name	Humo	San Juan	Esmeralda	Avispas-Cibuta	Pinito	Madera	Chivato	Azul	Cucurpe	Mariquita	Elenita	San Antonio	San José	Ajos	Aconchi	Púrica	Cabullona	Ceniza	Carboneras	Juriquipa	Oposura	Tigre	Pan Duro	San Luis	Púlpito	Bacadéhuachi	SMO-Huachinera	SMO-Cebadilla	SMO-Pinos Altos	SMO-India	SMO-Poleo	SMO-Cinco Millas
Canyon Towhee	#	P	P	P	P	P	P	P	P			P	P		P	P	P	P	P		P	P		P	P				P			
Rufous-winged Sparrow															P			P				P										
Botteri's Sparrow																				P												
Chipping Sparrow					O											O								?	?					P	P	P
Black-chinned Sparrow													P											P	P							
Lark Sparrow							P									O								P	P							
Five-striped Sparrow	P	P	#	#				#	P						P						P	P	P			P			P			
Black-throated Sparrow		P		P				#										C							C		P					
Yellow-eyed Junco					P			P		P	P			P		C						C	P	P	C	P	C	C	P	P	P	P
Hepatic Tanager		P	P	P	P	P	C	P	P	P	P	P	P	P	P	P	P		P	C	P	C	P	P	P	C	C	C	P	P	P	P
Summer Tanager			P	P			P	P						#	P	P					P	P		P		P		P		P		
Western Tanager		O			O			P		?	O	O		C	O	P		O	O	O	O		O	?	O		O		O			
Flame-colored Tanager														P														P				
Northern Cardinal		P		P											P	P	P	P								P						
Pyrrhuloxia		P																P														
Black-headed Grosbeak	P	C	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	C	P	P	C	P	P	P	P
Blue Grosbeak			P	P		P	P	P	P				P	O	P	P		P	P		P	P		P	P	P	P	P	P	P		
Indigo Bunting																P												?				
Varied Bunting	P	P	P	P		P		P	P						P	P		P	P		P	P				P	P		P			
Bronzed Cowbird				P			P								P	P					P	P							P			
Brown-headed Cowbird	P	P		P	P	P	C	P	P	P					P	P	P	P		P	P	P	P	P	P	P	P		P	P		
Black-vented Oriole															P														P			
Hooded Oriole			P	P	P		P	P	#			P			P		P	P			P	C	O	P								
Scott's Oriole	P	P	P	P	P	C	P	P	P	P	P	P	P	P	C	P	P	P	P	P	P	P	P	P	P	P	P	P	P			
House Finch	P	P	P	P	P	P	P	P	P	P		P	C	P		P	P	P		P	P		P	P	P	P	P			P		
Red Crossbill																?						O										
Pine Siskin					O						?					O							O	O								
Black-headed Siskin																												P				
Lesser Goldfinch	P	P	P	P	P		P	#		P				#	P					P	P	P		P	P	P		P	P	P		

further west. Both species were observed at high elevation in the Sierra Cíbuta, where many adult pines had recently died and many others were in poor condition.

Species associated with high-elevation coniferous forest and especially broadleaf deciduous elements within forest had the most restricted distributions, and were rarely observed west of the Sierra los Ajos. Red-faced Warbler, which prefer areas with deciduous trees and shrubs in coniferous forests, was observed only as far west as the Sierra los Ajos where it was rare (seven individuals or pairs at >2,000 m; Table 3). Warbling Vireo, which prefer montane riparian forest with tall broadleaf deciduous trees at high elevations, was observed only in the Sierra Bacadéhuachi where it was rare (2 singing at >1,810 m) and in the Sierra Cebadilla where it was common in tall forest and adjacent pine-oak woodland on the north side of Sonora's highest peak (32 singing individuals or pairs at 1,440-2,300 m). House Wren, which prefer tall coniferous forest with areas of dense vegetation and woody debris near ground level, occurred west of the Sierra los Ajos only in the Sierra Elenita and adjacent Sierra Mariquita (24 individuals or pairs at >2,100 m). Hairy Woodpecker, which prefer pine forest, was observed farther west in the Sierra Azul where it occurred immediately around the summit (10 individuals or pairs at >2,330 m). In contrast, Red-breasted Nuthatch, which prefer mature mixed-conifer or fir (*Abies* spp.) forest at high elevations was very rare and found only at the highest elevations in the Sierra Cinco Millas.

Also conspicuous were apparent absences of some species in ranges that appeared to support suitable breeding habitat, but which often covered small areas or was isolated from the Sierra Madre by deep lowland valleys. Mexican Chickadee for example, was not detected west of the Sierra el Tigre despite the presence of potential habitat in pine-oak woodland and pine forest in the Sierra los Ajos, Púrica, Elenita, Mariquita, and Azul (where it has never been observed; Russell and Monson 1998, Flesch 2008a). Yellow-eyed Junco was detected only in Sky Islands that supported large stands of pines in the north and east but not to the south in the Sierra Aconchi (where it was collected by A.R. Phillips in 1957 but not detected by Marshall in 1954) or in the Sierra Oposura (where it has never been observed; Russell and Monson 1998). House Wren, which is much less sedentary than the two aforementioned species, was not observed in potential breeding habitat in the Sierra Azul or Sierra Oposura (where it was found in the past), or in the Sierra el Tigre (where it has not been observed; Russell and Monson 1998). Buff-breasted Flycatcher was not observed in the Sierra Azul, Mariquita, Púrica, Oposura, and Aconchi despite the presence of potentially suitable pine forest or tall pine-oak woodland. Pygmy Nuthatch was conspicuously absent from pine-oak woodland and pine forest everywhere in the Sky Islands region despite historic records from five mountain ranges (Table 4).

Spatiotemporal Changes in Status and Distribution.—I documented numerous potential breeding species for the first time in the region and other species that had rarely been observed, which suggested changes in status and distribution. I observed 16 potential breeding species for the first time in the Mexican Sky Islands including 13 that were at least presumably breeding (Berylline Hummingbird, White-striped Woodcreeper, Warbling Vireo, Yellow-green Vireo, Hermit Thrush, Townsend Solitaire, Brown-backed Solitaire, Virginia's Warbler, Crescent-chested Warbler, Slate-throated Redstart, Black-chinned Sparrow, Western Tanager, Flame-colored Tanager) and three that were possibly breeding (Northern Saw-whet Owl, Audubon's Warbler, Chipping Sparrow; Tables 3 and 4). Potential breeding species that were new to the region that have strong Madrean affinities were typically observed only in the southern ranges, with some

Figure 2: Brown-backed Solitaire nest with three young (29 June 2012, Sierra Bacadéhuachi; left) and Townsend's Solitaire nest with two young and one egg (26 June 2010, Sierra el Tigre; right) were the first nests for Sonora and first breeding records for these species in the Sky Islands of Mexico. Nests were placed on the ground in small alcoves in a cliff face (left) and under a pine in an old road cut; locations are noted by arrows with observers for scale. Top right photo by Tray Biasiolli.

Figure 3: Short-tailed Hawk nest with young (19 June 2009, Sierra la Madera; top) was the first nest for Sonora and northwest Mexico, Sharp-shinned Hawk nest with egg and young (28 June 2010, Sierra el Tigre; lower right) was the second nest for Sonora, and recently fledged Slate-throated Redstart (13 June 2012, Sierra Huachinera; lower left) was the first breeding record for Sonora. Top photo by Sky Jacobs; lower left by Tray Biasiolli.

Table 4: Significance of some notable observations of breeding birds in the Sky Islands and adjacent Sierra Madre Occidental in Sonora and Chihuahua, Mexico, 2009-2012 that were evaluated on the basis of the sources noted.

Species	Notable Findings	Sources
Montezuma Quail	First confirmed breeding records (2) in the Mexican Sky Islands	1, 3, 6
Wild Turkey	First confirmed breeding records (2) in Mexican Sky Islands; 13 new Sky Island populations found	1, 3, 6
Sharp-shinned Hawk	Second nest for Sonora; 3 new Sky Island populations documented; reconfirmed in Ajos and San Luis where populations known	1, 3, 6, 7
Northern Goshawk	First nests for Mexican Sky Islands (3); previous record from Ajos, Oposura, and Huachinera; new populations found in Pinito, Elenita, Pan Duro, Púlpito, Bacadéhuachi, Cebadilla.	1, 3
Short-tailed Hawk	First nest for Sonora and northwest Mexico; new populations found in 9 Sky Islands and at Cebadilla, reconfirmed in Ajos, Cananea, Oposura where found in 2006-'08	3, 6, 7, 8
Golden Eagle	Second nest for Mexican Sky Islands and Sonora	1, 3
Thick-billed Parrot	First record in Sonora since 1996 (la India) and only fifth since 1954. Not in Sky Islands (Tigre and Oposura) or in Huachinera, El Macho, or Cebadilla where documented previously	1, 2, 3, 9, 10
Flammulated Owl	Second and third records for Sonora since 1954 (Bacadéhuachi, la India); not found at 3 localities (Ajos, Tigre, San Luis) where documented previously	1, 3, 10
Spotted Owl	Second nest and confirmed breeding record for Sonora; new populations found in Madera, Cucurpe, Mariquita, Juriquipa, San Antonio, Tigre, India, and confirmed in 10 other known localities.	1, 3, 7, 10
Northern Saw-whet Owl	First possible breeding record for Sonora in San Luis	1, 3
Berylline Hummingbird	First record in Mexican Sky Islands	1, 3
Magnificent Hummingbird	Westernmost known likely breeding population in Mariquita	1, 3
Broad-tailed Hummingbird	First and second nests and confirmed breeding records in Sonora (Tigre and Púlpito); new potential breeding populations in Elenita, San Luis, Pan Duro, Pinito, Púrica	1, 3, 6
Mountain Trogon	First records in northern Sierra Madre in Sonora; 190 km range extension but not in Sky Islands	1, 2, 3
Eared Quetzal	Fifth record in breeding habitat in Sonora and first since 1996 (Cebadilla). Not in Sky Islands	1, 2, 3, 7
Acorn Woodpecker	Westernmost record found in Sonora in Humo; extended from neighboring San Juan where not located	3, 4, 6
Hairy Woodpecker	New populations found in Azul, Mariquita, Elenita, Púrica, Bacadéhuachi. Confirmed in Ajos, San Luis, Huachinera where known. First records in Oposura since 1887.	1, 3, 6
White-striped Woodcreeper	First Sky Island and north-westernmost record in Bacadéhuachi.	1, 3, 4, 7
Tufted Flycatcher	Westernmost record in Aconchi; northernmost nesting sites in Sonora at Cebadilla >180 km north of known locations. Not found in Oposura where observed in 1887	1, 3
Pine Flycatcher	Northernmost population in Sonora found in Cebadilla	1, 3
Cordilleran Flycatcher	Second nest for Sonora found in Tigre; new populations found in 11 Sky Islands and reconfirmed in Ajos and Huachinera.	1, 3, 6
Buff-breasted Flycatcher	Second nest or confirmed breeding record for Sonora; new populations found in Pinito, Elenita, Tigre, Pan Duro, Bacadéhuachi and reconfirmed in Ajos, Púlpito, and San Luis where known.	1, 3
Gray Vireo	First possible breeding record for Sonora (San Luis); found singing in nearby Chihuahua in 2005	3, 5
Plumbeous Vireo	Westernmost breeding sites in Mexican Sky Islands found in Pinito, Azul. New populations in Pinito, Azul, Oposura, Tigre, Juriquipa, Pan Duro; reconfirmed in Ajos, Aconchi, Púlpito, Cananea.	1, 3, 6
Warbling Vireo	First likely nesting site in Sky Islands in Bacadéhuachi	1, 3

Yellow-green Vireo	First likely breeding record for Mexican Sky Islands (Bacadéhuachi)	1, 3
Violet-green Swallow	First possible breeding record for Sonora in Pan Duro	1, 3
Mexican Chickadee	Second, third, and fourth confirmed breeding records for Sonora	1, 3
Pygmy Nuthatch	Second record in study region since 1954 (in Cebadilla); 2010 record from Bacadéhuachi. Not found in Azul, Cananea, Tigre, San José , San Luis, or Huachinera where present in 1890s or 1950s	1, 3, 6, 9, 11
Eastern Bluebird	New populations found in Chivato, Juriquipa, Carbonera, Oposura.	1, 3, 6
Townsend's Solitaire	First nest for Sonora and Mexican Sky Islands	1, 3
Brown-backed Solitaire	First nest for Sonora and Mexican Sky Islands; northernmost breeding sites found >180 km north of known localities	1, 3
Orange-billed Nightingale-Thrush	Northernmost population in Sonora found in Cebadilla >300 km north of known potential breeding localities in Sonora	1, 3
Hermit Thrush	Only breeding locality in Mexican Sky Islands in Ajos; second breeding record for mainland Mexico	1, 3, 5, 6
Olive Warbler	New populations found in the Aconchi, Azul, Elenita, Púrica, Pan Duro	1, 3
Crescent-chested Warbler	First records in Mexican Sky Islands in Ajos, Oposura, Bacadéhuachi >180 km north of known breeding localities in Sonora; Second, third, and fourth confirmed breeding records for Sonora	1, 3
Virginia's Warbler	First records in Mexican Sky Islands of probable breeders (in Ajos and Mariquita)	1, 3, 6
Hooded Warbler	Fourth record for Sonora and third in possible breeding habitat during breeding season (in Cebadilla)	1, 3
Northern Parula	Second record in possible breeding habitat in the breeding season (in Cebadilla); first since 1950s	1, 3
Audubon's Warbler	First possible breeding records in Mexican Sky Islands in Mariquita and in Sonora in Cebadilla	1, 3
Grace's Warbler	Ten new Sky Island breeding populations found; not found in Cíbuta or San José where reported before 1945; reconfirmed in Ajos, Oposura, Púlpito, Huachinera, and to southeast	1, 3, 6, 9
Black-throated Gray Warbler	Nine new Sky Island breeding populations found; populations confirmed again in Ajos, Cananea, Púlpito, and San Luis	1, 3
Red-faced Warbler	Three new breeding populations found in Pan Duro, Púlpito, Bacadéhuachi; confirmed again in Ajos, Tigre, San Luis, Huachinera; 9 total confirmed breeding records including first nest for Sonora	1, 3, 6
Slate-throated Redstart	First confirmed breeding record for Sonora; first Sky Island record in Bacadéhuachi; found >180 km north of known localities in Sonora	1, 3
Rusty Sparrow	First confirmed breeding record in Mexican Sky Islands in Oposura	1, 3
Black-chinned Sparrow	First records in potential breeding habitat during the breeding season in Sonora in San Luis, San José , Púlpito	1, 3
Yellow-eyed Junco	Not found in San José or Aconchi where once present; found in all other 7 localities where Marshall observed in 1950s; new populations found in Pan Duro, Púrica, Bacadéhuachi	1, 3, 6
Western Tanager	Third confirmed breeding record in mainland Mexico and second in Mexican Sky Islands; behavior suggests breeding in Azul and Púrica	1, 3, 5
Flame-colored Tanager	First records in Mexican Sky Islands (Ajos) and potential breeding record in northern Sonora	1, 3
Black-vented Oriole	New population found in Aconchi; not found in Oposura where observed in past	1, 3
Pine Siskin	Second possible breeding record in Mexican Sky Islands in Elenita	1, 3, 6

Sources: [1]Marshall 1957, [2]Lammertink 1996, [3]Russell and Monson 1998, [4]Flesch and Hahn 2005, [5]Gomez de Silva 2005, [6]Flesch 2008a, [7]Flesch 2008b, [8]Snyder et al. 2010, [9]Van Rossem 1945, [10]Cirett Galán and Rogero Diaz 1993, [11]S. Jacobs pers. comm.

exceptions. Berylline Hummingbird, for example, was observed only in the Oposura (11 July 2009, one at 2,010 m in pine-oak woodland) whereas White-striped Woodcreeper (27-29 June 2012, 10 calling individuals or pairs at 1,600-1,810 m in oak and pine-oak woodland), Yellow-green Vireo (29 June 2012, singing at 1,620 m in oak and riparian woodland), and Slate-throated Redstart (28 June 2012, pair at 2,100 m in pine-oak woodland) were observed only in the Bacadéhuachi (Table 3). In contrast, other species occurred in northern ranges such as Brown-backed Solitaire in the Tigre (26-29 June 2010, three singing at 1,880-1,970 m in pine-oak woodland), and both Crescent-chested Warbler (15 June 2010, pair at 2,160 m in montane riparian woodland) and Flame-colored Tanager (14-17 June 2010, pair at 2,160 m and singing male at 2,010 m in montane riparian forest) in the Ajos. Also of note was one or possibly two Brown-backed Solitaire singing on the steep southwest face of the highest peak in the Sierra Aconchi (4 June 2012, at 1,920 m), which is the westernmost record, and a nest with three young and three additional singing males in the Bacadéhuachi (29 June 2012, at 1,620-1,820; Fig. 2), which is the first nest for Sonora.

Potential breeding species I found for the first time in the Sky Islands of Mexico that have stronger Nearctic affinities were typically observed only in northern ranges. I observed a Northern Saw-whet Owl, for example, in dense canyon-bottom forest of pine and cypress (*Cupressus arizonica*) in the Sierra San Luis in June, which is the first observation in potential breeding habitat during the breeding season in Sonora and only the second record for the state. Black-chinned Sparrow was singing in dense mountain scrub in the San Luis and San José in Sonora and observed in similar vegetation in the Púlpito in Chihuahua in June or early July. A Virginia's Warbler was singing in woodland adjacent to low dense deciduous brush in the Ajos (14 June 2010, at 2,080 m) and another individual was observed in woodland adjacent to a large patch of New Mexican locust in the Mariquita (29 June 2009, at 2,100 m). Hermit Thrush was singing, paired, and carrying food in mixed-conifer forest and montane riparian areas in the Ajos (14-17 June 2010, 10 individuals or pairs at 2,120-2,370 m) close to where I observed them exhibiting the same behaviors in early July 2006 (Flesch 2008a, *unpubl. data*). Townsend Solitaire was singing, paired, and nesting in pine-oak woodland and pine forest in the Tigre (26-28 June 2010, nine territories at 2,190-2,400 m; Fig. 2), one was singing in pine-oak woodland in the Mariquita (27 June 2009, at 2,130), another was calling in pine-oak woodland in the Púlpito (12 June 2012, at 2,310), and others were in pine forest in May in the Elenita and Pinto where they could possibly breed. Audubon's Warbler was singing in tall pine forest near the summit of the Sierra Mariquita (27 June 2009, 1-2 at 2,440 m) and three were calling in mixed-conifer forest in the Cebadilla (17 June 2012, at 2,410-2,450 m), which are the only observations of potential breeding birds in Sonora. Western Tanager was singing, paired, and carrying food in mixed-conifer forest and pine-oak woodland in the Ajos (14-17 June 2010, 10 territories at 2,100-2,450 m) in areas where I observed individuals exhibiting these same behaviors in early July 2006 (*unpubl. data*). Other observations of Western Tanager that suggest possible breeding include: 1) five males singing in pine forest or adjacent pine-oak woodland in the Sierra Azul (31 May-1 June 2010, at 2,100-2,390 m) including three that sang for over an hour and were present on the same territories later in the day, 2) five males including one that was paired, singing in pine forest and pine-oak woodland in the Sierra Púrica (24-25 May 2012, at 2,080-2,260 m), 3) a pair in pine-oak woodland in the Sierra San Luis (4 June 2012, at 1,970), and 4) a male calling in pine-aspen (*Populus tremuloides*) forest (26 June 2009, at 2,380) in the Sierra Mariquita. Finally, Warbling Vireo was singing in montane riparian woodland and adjacent pine-oak woodland in the Sierra Bacadéhuachi (25-26 June 2012, one at 1,810 and 2,260 m).

In addition to these new species, I observed other potential breeding species that had been observed in the Mexican Sky Islands only once (Table 4). A Tufted Flycatcher, for example, was calling in montane riparian woodland dominated by sycamore (*Platanus wrightii*) and walnut (*Juglans major*) in the Sierra Aconchi (3 June 2012, at 1,800 m) but not observed in the Oposura where collected by J. C. Cahoon in June 1887 (Van Rossem 1945), which was the only record in the region. A Gray Vireo was in mountain scrub at 1,810 m in the San Luis on 15 May 2010, which was more than a month after the latest spring migration date for Sonora and close to where two singing males were observed on 21 April 2005, which is the only other evidence of potential breeding in region (Russell and Monson 1998, Gomez de Silva 2005). A male Pine Siskin was singing and courting a female that was cocking her tail in a provocative manner at the edge of a meadow in pine forest in the Sierra Elenita (6 May 2011, at 2,290 m). Together with three singing males with developed gonads collected in the Ajos on 1 June 1953, these are the only observations that suggest breeding in the Mexican Sky Islands (Russell and Monson 1998). Otherwise individuals and small flocks were observed before 7 June in four other Sky Islands (Table 3) and no evidence of breeding observed.

I obtained many notable observations of birds in adjacent portions of the Sierra Madre Occidental, which in some cases suggested important changes in status when compared with historical records (Table 4). Three Mountain Trogons, for example, were singing in pine, mixed-conifer, and montane riparian forest in the Sierra Cebadilla (16-17 June 2012, at 2,250-2,550 m) >180 km north of the nearest known localities in Sonora (Russell and Monson 1998) and nine males were in tall pine-oak woodland and montane riparian forest around Cerro de la India, Sonora (19 June 2012, at 2,110-2,470 m). Moreover, in similar vegetation in neighboring Chihuahua, I observed 15 singing Mountain Trogons in the Sierra Cinco Millas (21-23 June 2012, at 2,300-2,760 m) and 8 singing males near El Poleo (20 June 2012, at 2,170-2,320 m). Interestingly, Elegant Trogon outnumbered Mountain Trogon by 11:1 in the more northern Sierra Cebadilla, whereas 25 km to the southeast at Cerro de la India, this ratio declined to only 2:1. In contrast, further southeast in Chihuahua, Mountain Trogon outnumbered Elegant Trogon by ≥5:1. Eared Quetzal was very rare in the study area and observed only once away from Cinco Millas (where it was uncommon), in a deep canyon dominated by montane riparian forest and pine-oak woodland on the north side of the Sierra Cebadilla (15 June 2012, at 1650 m), which was only the fifth record in potential breeding habitat in Sonora and the first since 1995 (Lammertink et al. 1996, Flesch 2008b). Thick-billed Parrot was also very rare in the study area and detected only once away from Cinco Millas (where they were fairly common and nesting), approximately 4 km north of Cerro de la India where a small flock of four to five individuals was flying over pine-oak woodland (19 June 2012, at 2,070 m). This was only the fifth report of Thick-billed Parrot in Sonora since 1954 and first since 1995 (Cirett Galán and Rogero Diaz 1993, Lammertink et al. 1996) although individuals from a small breeding population on Mesa de las Guacamayas in Chihuahua (Monterrubio Rico and Enkerlin Hoeflich 2004) likely cross into Sonora to forage. A Tufted Flycatcher was using a recently constructed nest in an alder (*Alnus oblongifolia*) in tall montane riparian forest on the north side of Sonora's highest peak in the Cebadilla (15 June 2012, at 1,570 m), which is the northernmost record in Sonora and >180 km north of the nearest known breeding population near Yécora (Russell and Monson 1998). A

Slate-throated Redstart was feeding two fledglings in pine forest with a lush understory of ferns and deciduous shrubs in the Huachinera (14 June 2012, at 2,210 m; Fig. 3), which is the first breeding record in Sonora and >180 km north of the nearest known breeding population in Sonora. Also of note was Pine Flycatcher calling in the Cebadilla and at El Poleo, and Orange-billed Nightingale-Thrush, Hooded Warbler, and Northern Parula singing in the Cebadilla (Table 4).

I documented many populations in the study region that had not been described in the past, but failed to observe others where they had been documented (Table 4). I observed Wild Turkey, for example, in 16 Sky Islands including 13 where it had not been observed in the past, confirmed breeding in two Sky Islands, and reconfirmed occupancy in the Ajos, San Luis, and Oposura, which were the only ranges where populations had been documented (Tables 3 and 4; see references in Table 3). I documented three new populations of Sharp-shinned Hawk that were at least presumably breeding, including in the Tigre where I confirmed breeding (Fig. 3); and reconfirmed occupancy in the Ajos and San Luis where populations had been documented in the past. Additionally, I observed Sharp-shinned Hawk in the Pinto (at 2,150 m) and Juriquipa (at 1,730 m) in May and in the Púlpito in June (at 1,710 m) where they could possibly breed. Similarly, Northern Goshawk was rare and distributed locally, observed in five Sky Islands and the Cebadilla where it had not been documented in the past, and occupancy was reconfirmed in the Ajos but not in the Oposura or Huachinera where it was observed in the past (Table 4). I also located Northern Goshawk nests in three Sky Islands (Ajos, Elenita, Púlpito), which are the first nests known in the Mexican Sky Islands. I observed Spotted Owl in a broad range of vegetation communities in 14 Sky Islands and three areas in the Sierra Madre (Table 3). They included records in six Sky Islands and at least one area in the Sierra Madre where it had not been documented in the past, and evidence of the continued existence of 10 other populations (Table 4). I observed Hairy Woodpecker in pine forest or adjacent pine-oak woodland near the summits of five Sky Islands where it was not documented in the past and reconfirmed occupancy in three Sky Islands including in the Oposura where it was last observed in 1887. Cordilleran Flycatcher was rare and distributed locally in 13 Sky Islands, which included 11 ranges where it had not been observed. Buff-breasted Flycatcher was restricted to fewer ranges but somewhat more common where it occurred; I documented five new Sky Island populations and reconfirmed occupancy in three that had been documented. I observed Greater Pewee for the first time in the Pinto (11 individuals) and Tigre (19 individuals) where Marshall worked in the 1950s, and in four other Sky Islands where Marshall did not work including the Púrica (5 individuals), Juriquipa (5 individuals), and Pan Duro (3 individuals) where it was rare, and the Bacadéhuachi (12 individuals) where it was fairly common. Similarly, Broad-tailed Hummingbird, Grace's Warbler, and Black-throated Gray Warbler were distributed more broadly than suggested by past efforts, with less conspicuous patterns for Plumbeous Vireo and Olive Warbler (Table 4).

In addition to those new populations, apparent absences of some species in areas they had been documented in the past were also conspicuous. Thick-billed Parrot, for example, was not detected in two Sky Islands (Oposura and Tigre) or in the Huachinera, Cebadilla, or near El Macho in the Sierra Madre where it was observed in the past (see references in Table 4) nor was Flammulated Owl in two Sky Islands where present in the 1950s or in the Ajos where present in the 1950s and 1993 (Tables 3 and 4). I also failed to detect Eared Quetzal in the Huachinera where Marshall (1957) observed a pair in June 1956 or near El Macho where Lammertink et al.

(1996) observed two in July 1995. Pygmy Nuthatch was not detected in four Sky Islands or in the Huachinera where present in the 1950s (Marshall 1957) or in the San José were it was collected by E. Mearns in 1893, but was observed in pine-oak woodland in the Bacadéhuachi (flock of 10-15 individuals on 3 August, at 2,100 m; Sky Jacobs, *pers. comm.*) where I failed to detect it in June 2012. Purple Martin (*Progne subis*) was not detected in the Sierra Madre despite records of breeding birds in pine forest in the Huachinera and Sierra Nácori in earlier decades (Marshall 1957, Phillips 1986) or in the Sky Islands where it has never been observed. I detected Violet-green Swallow in the Pan Duro (calling in pine-oak woodland at 2,060 m, 22 May 2011) where it could breed but not in three other ranges where it was presumed to breed in the past (e.g., Púlpito by Marshall, Oposura by Cahoon and Marshall, San Luis by Mearns; Van Rossem 1945, Marshall 1957). Steller's Jay was not detected in the Aconchi despite ample effort in areas dominated by pines (*n* = 22 of 96 stations) around the summit where it was observed in 1954 (Marshall 1957). Efforts to locate Grace's Warbler in the few stands of live pines near the summit of the Sierra Cíbuta were unsuccessful despite past records (Van Rossem 1945). Moreover, both Grace's Warbler and Greater Pewee were not detected in the San José where I surveyed the largest grove of ponderosa pine (*Pinus ponderosa var. scopulorum*) encountered in the range despite records from summer 1893 (Mearns 1907, Van Rossem 1945). Finally, House Wren was not detected in the Azul where Marshall (1957) observed six pairs on the steep north face of the highest peak in July 1953, or in the Oposura where collected by Cahoon in 1887 (Russell and Monson 1998).

Other Notable Breeding Records.—I gathered a large number of noteworthy breeding observations in addition to those described above. A Short-tailed Hawk nest with two young in a Chihuahua pine (*Pinus chihuahuana*) in oak-pine woodland in the Sierra la Madera (19 June 2009, at 1,920 m) was the first reported nest for Sonora or northwest Mexico (see details in Snyder et al. 2010; Fig. 3). A Sharp-shinned Hawk nest with three young and one egg in a Douglas fir (*Pseudotsuga menziesii*) in mixed-conifer forest in the Sierra el Tigre (28 June 2010, at 2,020 m) was the second nest and third confirmed breeding record for Sonora (Flesch 2008b; Fig. 3). A Broad-tailed Hummingbird nest with two young in pine-oak woodland in the Sierra Púlpito in Chihuahua (14 June 2012, at 2,230 m) and an adult feeding a fledgling next to a recently occupied nest in pine forest in the Sierra el Tigre (26 June 2010, at 2,270 m) were the first nests and confirmed breeding records for Sonora. A Spotted Owl nest with two young in a silver-leaf oak (*Quercus hypoleucoides*) in pine-oak woodland in the Sierra Aconchi (1 June 2012, at 2,100 m; Plate 8) was the second nest and confirmed breeding record for Sonora. A Buff-breasted Flycatcher nest in an Arizona pine (*Pinus arizonica*) in pine forest in the Sierra el Tigre (26 June 2010, at 2,300 m) was the second nest and confirmed breeding record for Sonora and the first nest for the Sky Islands of Mexico. A Brown-backed Solitaire nest with three young in the Sierra Bacadéhuachi (29 June 2012, at 1,630 m) and a Townsend's Solitaire nest with two young and one egg in the Sierra el Tigre (26 June 2010, at 2,300) were the first nests for Sonora and the first breeding records in the Sky Islands of Mexico (Fig. 3). A female Crescent-chested Warbler was building a nest in dense oak woodland in the Sierra Oposura while a male sang vigorously nearby (7 July 2009, at 1,980 m), which was >150 km north of the nearest known breeding population in Sonora. Moreover, Crescent-chested Warblers were singing, paired, and carrying food in pine-oak woodland in the Sierra Bacadéhuachi (28 June 2012, five individuals or pairs at 2,090-2,160 m). Finally, a Red-faced Warbler nest in the Sierra los Ajos (17 June

2010, at 2,000 m) was the first nest and confirmed breeding record for Sonora; breeding was also confirmed eight more times at four other localities (Tables 3 and 4).

Biogeographical Relationships.—NMDS produced a satisfactory but far from perfect projection of the β_{sim} dissimilarity matrix into two-dimensional ordination space as indicated by moderate stress (0.238; Fig. 4). Correlation between the dissimilarity matrix and the resulting ordination scores and was fairly high ($r = 0.83$) and results explained 94% of variation in the original dissimilarity matrix. Results from NMDS showed a conspicuous and largely disjunct separation in community composition between sites in the Sierra Madre Occidental and the adjacent Sky Islands, which suggested a major biogeographical transition (Fig. 4). In contrast, variation in turnover was much more gradual and continuous among the Sky Islands with some notable exceptions. In general, Madrean affinities seemed to increase and Petran or Great Basin affinities seemed to decrease as scores on the first NMDS axis increased. In contrast, Sonoran or Sinaloan affinities increased and community composition seemed progressively more influenced by lowland subtropical or Sonoran desertscrub elements as scores on the second NMDS axis decreased, with increasing scores indicating stronger Chihuahuan affinities.

All three geographical gradients were correlated with ordination results to vary degrees. A vector representing the latitudinal position of mountain ranges was more highly associated with NMDS results ($R^2 = 0.71$, $P < 0.001$) than vectors for longitude ($R^2 = 0.44$, $P < 0.001$) or maximum elevation ($R^2 = 0.41$, $P < 0.001$). More northerly Sky Islands tended to have lower scores on the first NMDS axis and higher scores on the second NMDS axis, suggesting increasing Petran, Great Basin, and Chihuahuan (vs. Madrean, Sonoran, and Sinaloan) affinities. In contrast, more easterly Sky Islands tended to have higher scores on both the first and second NMDS axes suggesting increasing Madrean and Chihuahua affinities, with similar patterns for elevation.

Given those general patterns, NMDS results largely reflected the geographic position of mountain ranges and vegetation communities they supported at both the lowest and highest elevations, with some interesting exceptions. In the Sierra Madre, turnover was relatively high between the two most interior sites (El Poleo and Cinco Millas) and those that are part of a major northwest projection of the Sierra Madre west of the Bavispe River (Sierra Huachinera and Cebadilla; Fig. 4). Additionally, a site at the western edge of the Sierra Madre (Pinos Altos-El Macho) was widely separated in ordination space from those in the neighboring Sierra Madre and Sierra Bacadéhuachi likely because it supported species associated with both lowland (e.g., Gray Hawk, Vermilion Flycatcher, Yellow-breasted Chat) and highland (e.g., Hairy Woodpecker, House Wren, Olive Warbler) environments including many with strong Madrean affinities (e.g., White-eared Hummingbird, Tufted Flycatcher, Brown-backed Solitaire). Among the Sky Islands, the Sierra Elenita, Ajos, Mariquita, and Pan Duro supported communities most similar to those found in the interior Sierra Madre (e.g., El Poleo and Cinco Millas) and were somewhat separated in ordination space from other Sky Islands with lower Madrean affinities. Despite being much closer in geographical space to the adjacent Sierra Madre, community composition in the Sierra Bacadéhuachi was more similar to that in three Sky Islands where oak woodland also intermingles with thornscrub at lower elevations (e.g., Sierra Oposura, Carboneras, and Tigre; Fig. 4) but also similar to that in the adjacent Sierra Madre. At the opposite extreme, communities in the Swisshelm, Ceniza, Coyote, and Sierrita Mountains

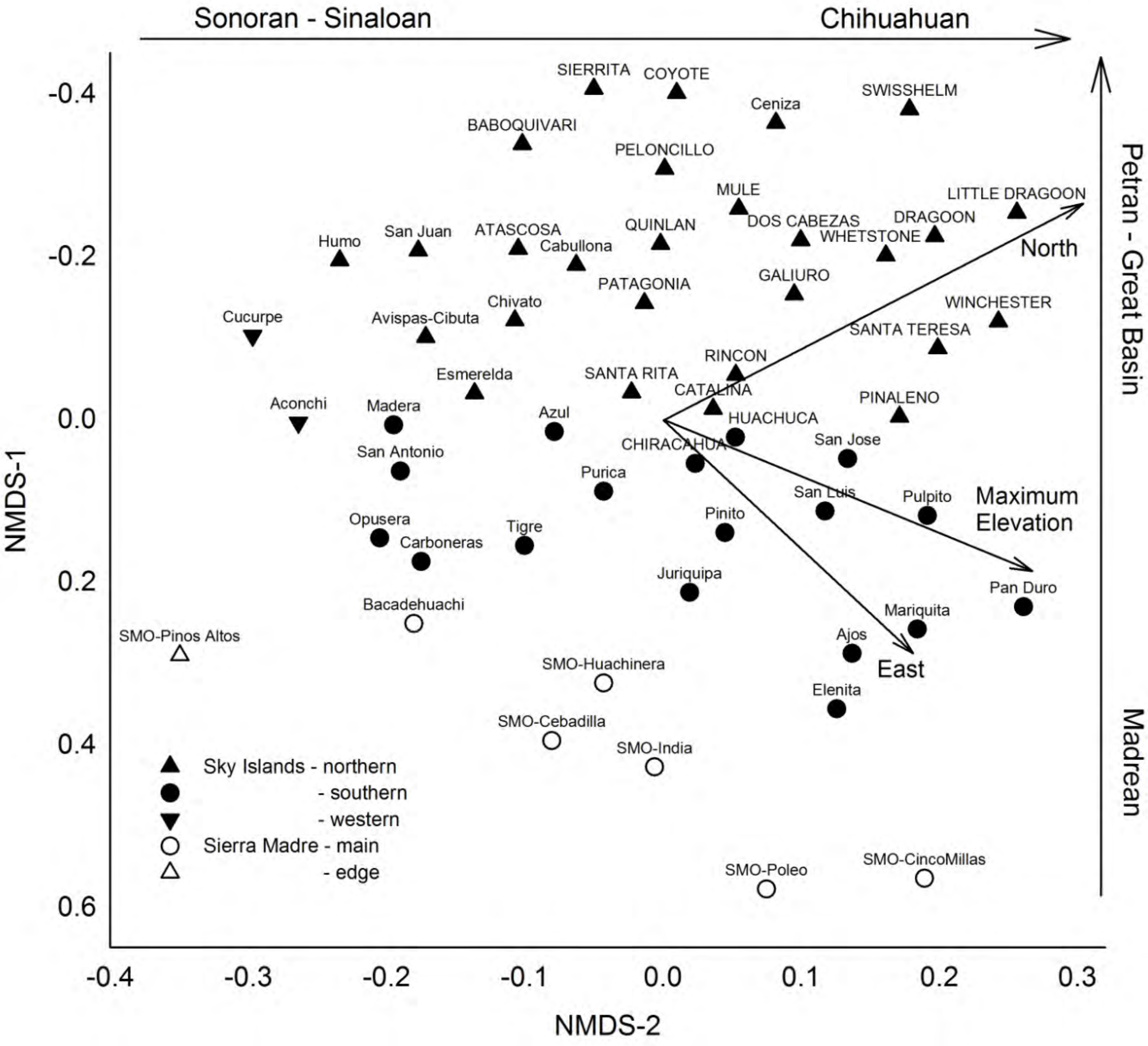
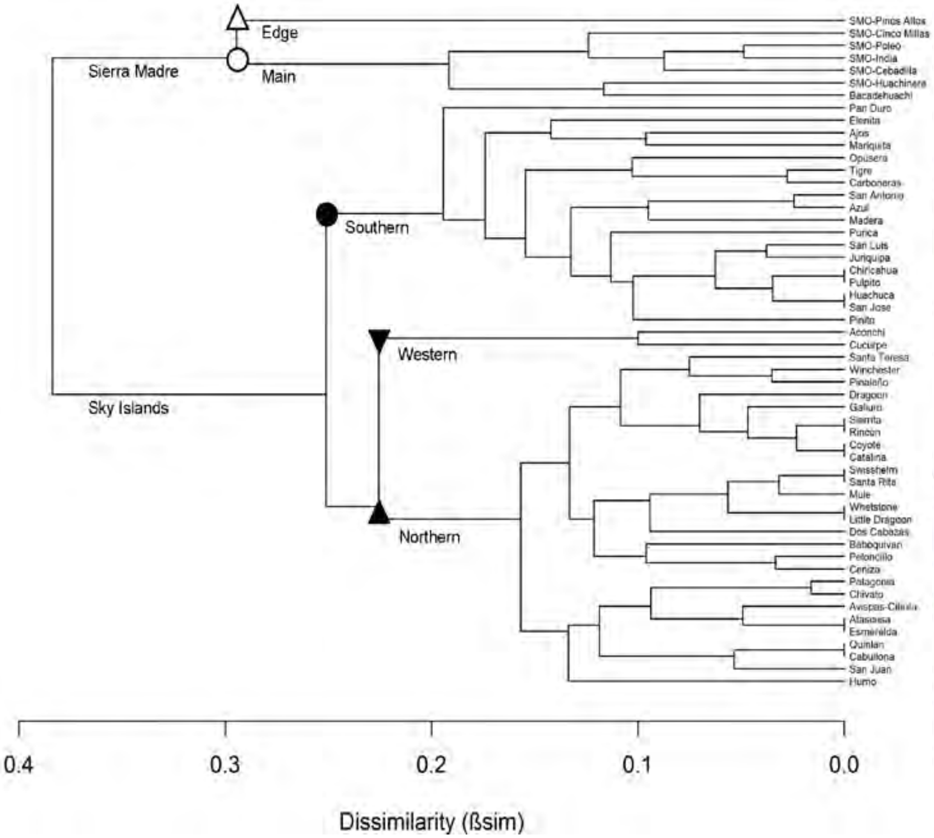


Figure 4: Variation in community composition of breeding bird across the Sky Islands region and the adjacent Sierra Madre Occidental in the U.S. and Mexico. Results are scores from non-metric multidimensional scaling (NMDS) of a Simpson's beta (β_{sim}) dissimilarity matrix based on presence-absence data (stress = 0.238). The direction of the first NMDS axis was flipped to better conform to the geographic position of sites. Labeled vectors for latitude (north), longitude (east), and maximum elevation show geographic gradients that were correlated with ordination scores, with vector lengths scaled to the magnitude of correlation ($P < 0.001$). Names of each mountain range are labeled above points, capital letters indicate mountains that are in the U.S.A., and those preceded by SMO are in the Sierra Madre Occidental. Symbols and colors represent the first and fourth groupings, respectively, based on the hierarchical clustering technique UPGMA performed on the same β_{sim} dissimilarity matrix. Ordination scores were scaled and rotated to maximize variance by moving the origin to the average of axes. Biogeographical interpretations of scores (top and right arrows) were inferred based on qualitative biogeographic patterns. β_{sim} values were based on presence-absence data for species observed to at least possibly breeding in each mountain that occur in montane vegetation communities. Data from the U.S.A. are based on observations gathered during and after the Arizona Breeding Bird Atlas project (1993-2001) whereas data for Mexico were gathered during the study (2009-2012).

that support little oak woodland, had the lowest Madrean affinities. Communities in the Sierra Cucurpe, Aconchi, Humo, and San Juan, which are located at the western edge of the study region and support either thornscrub or Sonoran desertscrub at lower elevations, had the greatest Sinaloan or Sonoran affinities. In contrast, communities in the Little Dragoon, Dragoon, Swisshelm, and Whetstone Mountains, which are situated in the east and support Chihuahuan desertscrub or grassland at lower elevations, had the greatest Chihuahuan affinities. Interestingly, some of the taller Sky Islands in the U.S. that are located north of the geographic center of the Sky Islands region such as the Santa Rita, Chiricahua, Huachuca, and Santa Catalina mountains, were positioned near the center of ordination space, which suggests complex biogeographical influences. Of Sky Islands in the U.S., the Chiricahua and Huachuca Mountains had the greatest Madrean affinities, with similar patterns for the Santa Rita, Santa Catalina, and Pinaleño Mountains.

Agglomerative hierarchical cluster analysis (UPGMA) indicated two primary and five secondary clusters that were largely spatially, biogeographically, and intuitively coherent, and which confirmed the biogeographical transition zones suggested by NMDS (Figs. 4 and 5). A primary division occurred at a β_{sim} value of approximately 0.4 and confirmed the same major separation between assemblages in the Sierra Madre and Sky Islands indicated by NMDS. The Sierra Bacadéhuachi, however, was included in the Sierra Madre cluster (Fig. 5) likely because it is the only Sky Island that supported species that were otherwise restricted to the Sierra Madre (e.g., White-striped Woodcreeper, Slate-throated Redstart) and others that occurred in few Sky Islands (e.g., Crescent-chested Warbler, Brown-backed Solitaire). The Sierra Madre cluster was divided into two groups at a β_{sim} value of 0.3 that separated Pinos Altos-El Macho, which supported large numbers of both lowland and highland species, from other sites in the Sierra Madre that largely supported only highland species. The Sky Islands cluster was divided into three groups at β_{sim} values of approximately 0.20-0.25. It included a small southwestern cluster of two ranges (Aconchi and Cucurpe), a larger southern cluster of 18 ranges, and an even larger northern cluster of 27 ranges (Fig. 5). Only two Sky Islands in the U.S., the Chiricahua and Huachuca Mountains, which support large numbers of Madrean species, were included in the southern cluster of Sky Islands whereas seven ranges in Mexico were grouped in the northern cluster. Dissimilarities among assemblages within the southern cluster of Sky Islands were fairly continuous (Fig. 5). In the northern cluster, however, there was a distinct break at a β_{sim} value of approximately 0.15 that separated nine Sky Islands that are largely in the extreme west-central portion of the study area and support oak (e.g., Sierra el Humo and San Juan) or oak-pine (e.g., Avispas-Cíbuta complex and Atascosa Mountains) woodland at maximum elevations from 18 other ranges located mainly in the north-central and northeast portion of the study area. This larger group was further divided into a group of ranges that support large areas of coniferous forest at high elevations (e.g., Santa Catalina and Pinaleño Mountains) from those dominated by mainly Chihuahuan desertscrub or grassland at lower elevations (Fig. 5).

Abundance.—I completed 1,851 point counts at 1,562 stations along 210 transects. That effort yielded 17,649 encounters of 20,135 individuals of 171 species, including 156 (91%) species that were potentially breeding in the study area. Of those potential breeding species, 72 (46%) were encountered frequently enough to model detection functions and compute detectability-corrected estimates of density based on distance-sampling methods. Additionally, encounter rates were sufficient to consider potential covariates of detection probability when modeling detection



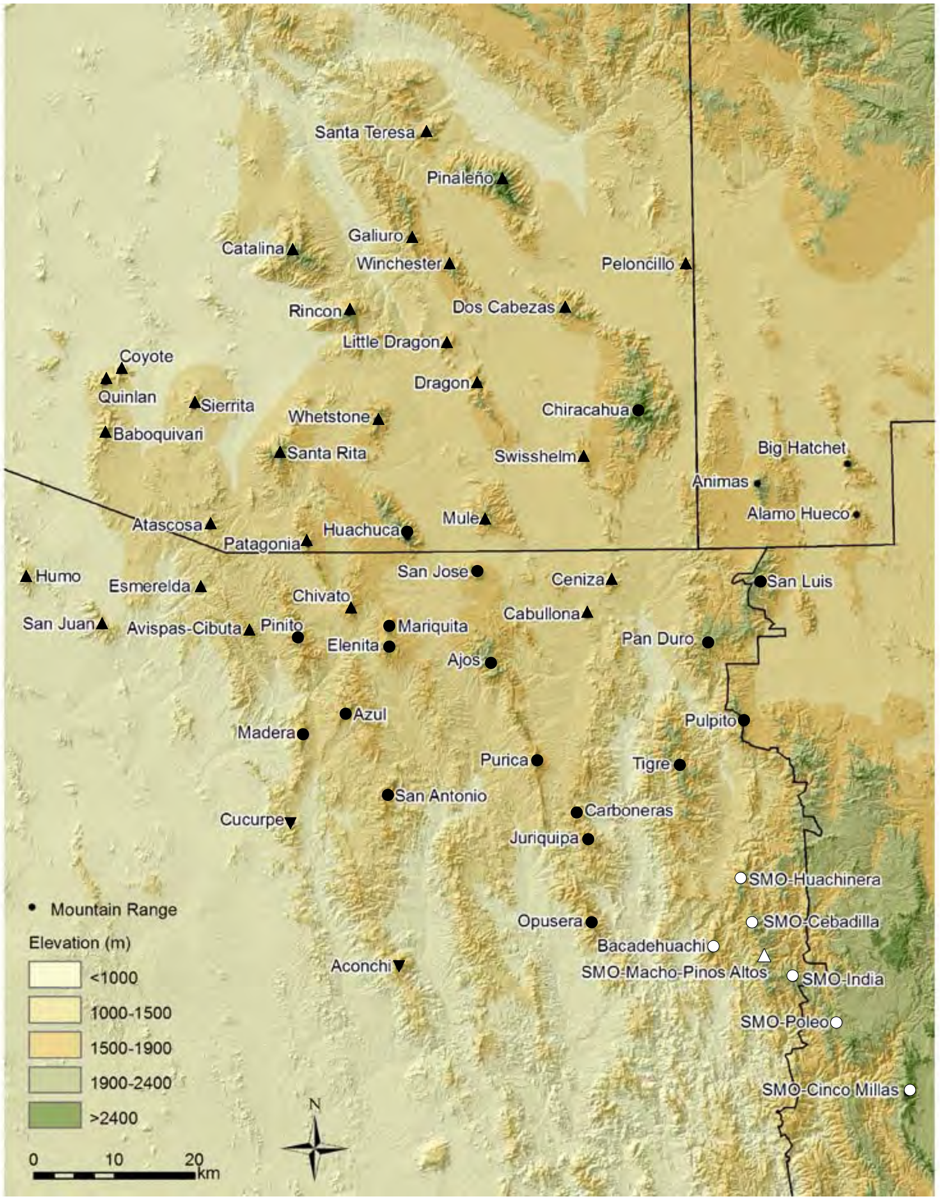


Figure 5: Dendrogram and map illustrating results of agglomerative hierarchical clustering technique UPGMA on a β_{sim} dissimilarity matrix of community composition of breeding bird across the Madrean Sky Islands region and adjacent Sierra Madre Occidental in Arizona, U.S.A and Sonora and Chihuahua, Mexico. Colors and symbols represent the first and fourth groupings, respectively, from UPGMA. β_{sim} values were estimated from presence-absence data for species found to be at least possibly breeding in montane vegetation communities in each mountain range. Data from the U.S.A. are based on observations gathered during the Arizona Breeding Bird Atlas project (1993-2001) and data from Mexico were gathered during the study (2009-2012). Data for three Sky Islands in New Mexico, U.S.A. (show as small points, center right) were not available.

functions for 56 (78%) of those species. Detection functions based on hazard-rate key functions fit best for the majority of species (69%), followed by half-normal (28%) and uniform (3%) key functions. Models of detection function that included covariates fit best for 51 of 56 species (91%) for which they were considered. Detection type (e.g., visual, calling, or singing) was the most important covariate for explaining variation in detection probability and was included in 80% of detection function models that included covariates. Temporal covariates were also important and included in 49% of detection function models that included covariates, with time-of-year (e.g., Julian date) being more important (84% of models) than time-of-day (28%). In contrast, sex (18%), noise level (10%) and especially vegetation covariates (6%) were much less important in explaining variation in detection probability.

Abundance varied markedly among species and was generally higher for species associated with oak woodlands, which covered much larger portions of the study region than woodland or forest types dominated by pines (Table 5). Among songbirds, Rufous-crowned Sparrow and Bewick's Wren were the most abundant species in the study region with densities that ranged from 0.74-0.80 territories/ha. In comparison, other species that are also associated with oak woodland such as Bridled Titmouse, Hepatic Tanager, and Hutton's Vireo were moderately abundant (0.28-0.42 territories/ha), whereas Arizona Woodpecker, Acorn Woodpecker, Mexican Jay, and especially Elegant Trogon were much less abundant (0.12-0.061 territories/ha; Table 5). Among species associated with vegetation communities typically found at higher elevations, Painted Redstart, Broad-tailed Hummingbird, Red-faced Warbler, and Yellow-eyed Junco were among the most abundant species (0.22-0.43 territories/ha), whereas Magnificent Hummingbird, Steller's Jay, Grace's Warbler, and Plumbeous Vireo were moderately abundant (0.094-0.14territories/ha). In contrast, Band-tailed Pigeon, Greater Pewee, Northern Flicker, and Hairy Woodpecker were relatively rare (0.032-0.035 territories/ha). Densities of species typically found in high-elevation forest such as Mountain Trogon, Townsend's Solitaire, and Eastern Bluebird (0.0063-0.011), those often restricted to riparian areas such as Sulphur-bellied Flycatcher, Thick-billed Kingbird, and Summer Tanager (0.015-0.029), and those that have larger body sizes or home ranges such as Wild Turkey, Red-tailed Hawk, and Greater Roadrunner (0.0038-0.0062) were often low.

Estimates of abundance of several species of management or conservation concern in areas I covered were notably large after accounting for detection probability. For example, I estimate that 233 ± 52 (± SE) individuals, pairs, or groups of Wild Turkey were present in areas I covered along point transects across the region based on 59 encounters (n) and an average estimated detection probability ($\hat{p}$) of 0.25 ± 0.048. For Thick-billed Parrot, I estimate that 165 ± 38 individuals, pairs, or flocks were present in areas I covered ($n = 34$, $\hat{p} = 0.21 \pm 0.035$), whereas for Band-tailed Pigeon I estimate that 415 ± 78 were present ($n = 109$, $\hat{p} = 0.25 \pm 0.041$). For somewhat more abundant species such as Elegant Trogon, I estimate that 2,976 ± 316 individuals or pairs were present in covered areas ($n = 406$, $\hat{p} = 0.13 \pm 0.013$), whereas for Bewick's Wren, which was encountered more than any other species, I estimate that 5,303 ± 246 individuals or pairs were present ($n = 1{,}268$, $\hat{p} = 0.24 \pm 0.0093$). For Arizona Woodpecker, Buff-breasted Flycatcher, Olive Warbler, and Grace's Warbler, which are species of conservation concern in the Sierra Madre Occidental Bird Conservation Region (USFWS 2008), I estimate 2,369 ± 253 ($n = 312$, $\hat{p} = 0.13 \pm 0.012$), 172 ± 25 ($n = 62$, $\hat{p} = 0.36 \pm 0.036$), 296 ± 37 ($n = 109$, $\hat{p} = 0.36 \pm 0.034$), and 894 ± 120 ($n = 214$, $\hat{p} = 0.24 \pm 0.028$) individuals or pairs were present in areas I covered, respectively.

Table 5: Abundance of 72 species of breeding birds with ≥30 total encounters during 1,851 point counts at 1,562 stations across the Sky Islands and adjacent Sierra Madre Occidental of Sonora and Chihuahua, Mexico 2009-2012. All density (no./ha.) estimates and associated standard errors (SE) and coefficients of variation (CV) are based on distance-sampling methods. An average of 5% of encounters was omitted for each species when fitting detection functions when truncated extreme values or missing covariates. Relative abundance equals number of encounters divided by total counts and frequency of occurrence equals number of presence points divided by total points. Estimates of density for these species at the scale of each mountain range is provided in Appendix C.

Species	Encounters	Present Points	Density	SE_D	CV_D	Relative Abundance	Frequency of Occurrence
Montezuma Quail	64	52	0.044	0.023	0.53	0.040	0.033
Wild Turkey	59	52	0.0044	0.0010	0.22	0.037	0.033
Red-tailed Hawk	39	37	0.0038	0.0010	0.25	0.025	0.024
Band-tailed Pigeon	109	94	0.035	0.007	0.21	0.069	0.060
White-winged Dove	291	157	0.080	0.010	0.12	0.18	0.10
Mourning Dove	114	96	0.053	0.012	0.23	0.072	0.061
Thick-billed Parrot	34	24	0.0039	0.0017	0.44	0.022	0.015
Greater Roadrunner	69	59	0.0062	0.0012	0.19	0.044	0.038
White-throated Swift	31	31	0.010	0.007	0.71	0.020	0.020
Broad-billed Hummingbird	79	73	0.98	0.26	0.26	0.050	0.047
Magnificent Hummingbird	28	28	0.14	0.03	0.22	0.018	0.018
Broad-tailed Hummingbird	74	72	0.40	0.11	0.28	0.047	0.046
Elegant Trogon	406	298	0.061	0.007	0.11	0.26	0.19
Mountain Trogon	41	30	0.011	0.008	0.68	0.026	0.019
Acorn Woodpecker	337	256	0.10	0.01	0.11	0.21	0.16
Hairy Woodpecker	48	38	0.032	0.007	0.23	0.030	0.024
Arizona Woodpecker	312	257	0.12	0.02	0.13	0.20	0.16
Northern Flicker	156	130	0.033	0.005	0.16	0.099	0.083
Greater Pewee	221	175	0.035	0.005	0.15	0.14	0.11
Western Wood-Pewee	289	219	0.21	0.03	0.15	0.18	0.14
Cordilleran Flycatcher	82	76	0.073	0.013	0.18	0.052	0.049
Buff-breasted Flycatcher	62	54	0.032	0.006	0.18	0.039	0.035
Dusky-capped Flycatcher	1010	727	0.27	0.02	0.06	0.64	0.47
Ash-throated Flycatcher	380	282	0.15	0.02	0.12	0.24	0.18
Brown-crested Flycatcher	138	110	0.065	0.014	0.22	0.087	0.070
Sulphur-bellied Flycatcher	82	72	0.024	0.004	0.18	0.052	0.046
Cassin's Kingbird	136	104	0.035	0.007	0.20	0.086	0.067
Thick-billed Kingbird	35	27	0.015	0.006	0.40	0.022	0.017
Plumbeous Vireo	200	179	0.094	0.011	0.11	0.13	0.11
Hutton's Vireo	400	348	0.28	0.03	0.12	0.25	0.22
Steller's Jay	380	279	0.14	0.03	0.19	0.24	0.18
Mexican Jay	542	472	0.099	0.007	0.07	0.34	0.30
Common Raven	32	28	0.0022	0.0006	0.29	0.020	0.018
Mexican Chickadee	104	78	0.19	0.04	0.20	0.066	0.050
Bridled Titmouse	449	363	0.42	0.04	0.09	0.28	0.23
Bushtit	168	151	0.24	0.03	0.12	0.11	0.10
White-breasted Nuthatch	371	295	0.15	0.02	0.11	0.23	0.19
Brown Creeper	245	202	0.29	0.03	0.10	0.15	0.13
Cactus Wren	58	50	0.042	0.009	0.22	0.037	0.032
Rock Wren	45	41	0.018	0.005	0.29	0.028	0.026

Canyon Wren	275	239	0.083	0.021	0.25	0.17	0.15
Bewick's Wren	1268	765	0.74	0.04	0.05	0.80	0.49
House Wren	139	89	0.17	0.04	0.20	0.088	0.057
Blue-gray Gnatcatcher	198	177	0.21	0.03	0.13	0.13	0.11
Eastern Bluebird	33	30	0.0088	0.0019	0.21	0.021	0.019
Townsend's Solitaire	29	27	0.011	0.003	0.30	0.018	0.017
Brown-backed Solitaire	39	33	0.0063	0.0022	0.35	0.025	0.021
American Robin	363	269	0.18	0.02	0.11	0.23	0.17
Northern Mockingbird	103	81	0.050	0.015	0.30	0.065	0.052
Phainopepla	51	35	0.052	0.012	0.24	0.032	0.022
Olive Warbler	109	85	0.064	0.014	0.21	0.069	0.054
Crescent-chested Warbler	48	37	0.088	0.018	0.21	0.030	0.024
Grace's Warbler	214	176	0.11	0.02	0.16	0.14	0.11
Black-throated Gray Warbler	111	90	0.11	0.03	0.24	0.070	0.058
Rufous-capped Warbler	31	27	0.020	0.006	0.28	0.020	0.017
Red-faced Warbler	121	87	0.25	0.08	0.30	0.077	0.056
Painted Redstart	697	505	0.43	0.04	0.08	0.44	0.32
Slate-throated Redstart	50	35	0.073	0.017	0.23	0.032	0.022
Spotted Towhee	878	519	0.28	0.02	0.08	0.56	0.33
Rufous-crowned Sparrow	694	486	0.80	0.15	0.18	0.44	0.31
Canyon Towhee	81	75	0.16	0.04	0.24	0.051	0.048
Yellow-eyed Junco	287	180	0.22	0.03	0.13	0.18	0.12
Hepatic Tanager	674	510	0.36	0.03	0.07	0.43	0.33
Summer Tanager	43	36	0.029	0.008	0.26	0.027	0.023
Black-headed Grosbeak	818	571	0.41	0.04	0.09	0.52	0.37
Blue Grosbeak	90	67	0.042	0.007	0.18	0.057	0.043
Varied Bunting	51	44	0.067	0.019	0.28	0.032	0.028
Brown-headed Cowbird	112	100	0.085	0.013	0.15	0.071	0.064
Hooded Oriole	57	32	0.040	0.011	0.28	0.036	0.020
Scott's Oriole	280	238	0.065	0.010	0.15	0.18	0.15
House Finch	74	61	0.13	0.02	0.19	0.047	0.039
Lesser Goldfinch	53	42	0.060	0.018	0.30	0.034	0.027

Spatial Variation in Abundance.—Densities varied widely both among species and mountain ranges (see estimates in Appendix C). Densities varied across elevation for 66 of the 72 species (92%) for which densities were estimated (Table 6). Densities of 24 species that are associated with habitat features found at high elevations increased with elevation. Densities of Yellow-eyed Junco, Steller’s Jay, Red-faced Warbler, and Grace’s Warbler, for example, increased by an average of 1.5 ± 0.3 to 4.9 ± 0.4% (± SE) with each 100-m increase in elevation ($P < 0.01$; Table 6, Fig. 6). In contrast, densities of 35 species, including those associated with oak woodland (e.g., Bridled Titmouse), low-elevation riparian areas (e.g., Hooded Oriole), grassy areas within woodland (e.g., Rufous-crowned Sparrow), and desertscrub (e.g., Cactus Wren), decreased with elevation. Densities of Bewick’s Wren, Dusky-capped Flycatcher, and Black-headed Grosbeak, which are largely associated with oak woodland for example, decreased by an average of 1.5 ± 0.5 to 3.3 ± 0.6% with each 100-m increase in elevation ($P < 0.01$; Table 6, Fig. 6). Densities of seven species were greatest at moderate elevations. These species included those associated with tall oak woodland or pine-oak woodland (e.g., Arizona Woodpecker, Mexican Jay, Painted Redstart, Hepatic Tanager) and with deep canyons with tall trees (e.g., Brown-backed Solitaire). Densities of six species such as Wild Turkey, Bushtit, and Black-throated Gray Warbler, did not vary with elevation ($P \geq 0.30$) and were similar across a wide range of vegetation types (Fig. 6).

Densities typically also varied with latitude (71% of species) and longitude (65% of species), and these patterns were correlated with those for elevation. Densities of species associated with coniferous forest often increased with increasing proximity to the Sierra Madre, and thus with decreasing latitude (e.g., densities highest in south) and increasing longitude (e.g., densities highest in east; Table 6). Moreover, larger effects of latitude on densities were negatively correlated with larger effects of elevation (r = -0.58, $P < 0.001$), larger effects of longitude on densities were positively correlated with that for elevation (r = 0.78, $P < 0.001$), and the effects of latitude and longitude were highly negatively correlated (r = -0.86, $P < 0.001$), which reflected strong northwest-southeast gradients in densities among species across the region. Densities of seven species were greatest at moderate latitudes and/or longitudes; these species tended to be those also found at higher densities at moderate elevations and in the most structurally developed oak or pine-oak woodlands.

Bird-Habitat Relationships.—Densities of the majority of species varied among major vegetation communities. Evidence of this variation was convincing ($P \leq 0.01$) for 51% of species (n = 37 of 72), moderate (P = 0.01-0.05) for 14%, suggestive (P = 0.051-0.10) for 6%, but lacking ($P \geq$ 0.13) for the remaining 29% of species (Table 6). Among species that showed at least moderate evidence of variation in densities among vegetation communities, densities of 30% (n = 14 of 47) were highest in mixed-conifer forest. This pattern was especially prominent for Thick-billed Parrot, Mountain Trogon, Northern Flicker, Cordilleran Flycatcher, Mexican Chickadee, House Wren, Crescent- chested Warbler, Red-faced Warbler, and Slate-throated Redstart, which had densities that averaged >2-times greater in mixed-conifer forest than in other communities (Fig. 6). In contrast, although densities of Broad-tailed Hummingbird, Greater Pewee, Steller's Jay, Brown Creeper, and Olive Warbler were also highest on average in mixed-conifer forest, they were similar in neighboring pine forest and pine-oak woodland (Fig. 6). Densities of 26% of species were highest in montane riparian areas. These species included Acorn Woodpecker, Western Wood-Pewee, Ash-throated Flycatcher, Brown-crested Flycatcher, Sulphur-bellied Flycatcher, Cassin's Kingbird, Brown-backed Solitaire, Summer Tanager, and Hooded Oriole, which had densities that averaged >2-times greater in riparian vs. upland vegetation communities. In contrast, although densities of Dusky-capped Flycatcher, Bridled Titmouse and Painted Redstart were also highest in riparian areas, they were similar in other communities dominated by oaks and pines (Fig. 6). Although densities of 15% of species peaked in pine forest (e.g., Band-tailed Pigeon, Hairy Woodpecker, Plumbeous Vireo, Townsend's Solitaire, American Robin, Grace's Warbler, and Yellow-eyed Junco), they were often similar in adjacent pine-oak woodland or mixed-conifer forest. Densities of Blue-gray Gnatcatcher were highest in oak-pine woodland but similar in mountain scrub. Moreover, although densities of Buff-breasted Flycatcher and Black-throated Gray Warbler were highest in pine-oak woodland, they were also similar in pine and mixed-conifer forest or in oak woodland and mixed-conifer forest, respectively. Densities of 13% species were highest in mountain scrub (e.g., Bushtit, Bewick's Wren, Northern Mockingbird, Spotted Towhee, and Scott's Oriole) but with the exception of Spotted Towhee, were also similar in oak savannah, oak woodland, or oak-pine woodland.

Densities of somewhat fewer species (9%) were highest in oak savannah and adjacent lowland vegetation types including Cactus Wren, Rock Wren, Rufous-crowned Sparrow, and Canyon Towhee. Notably, densities of only one species, the Mexican Jay, were highest in oak woodland and were also similar in adjacent oak-pine woodland (Fig. 6).

Species for which densities did not vary significantly among major vegetation communities typically used a broad range of communities or were rare and thus precision of estimates was low. Elegant Trogon for example, occurred at similar densities in all vegetation communities in which oaks were dominant but densities averaged much lower in pine forest (Fig. 6). Densities of Arizona Woodpecker followed a similar pattern but were lower in mountain scrub and mixed-conifer forest (Fig. 6). Densities of Magnificent Hummingbird, which was rare, were similar in montane riparian areas and pine-oak woodland (0.38-0.42 ± 0.11-0.19 individuals/ha; ± SE), averaged somewhat lower in pine forest and oak-pine woodland (0.24-0.25 ± 0.14 territories/ha), and were very low or zero in other vegetation communities. Densities of Hepatic Tanager seemed somewhat higher in pine-oak and oak-pine woodland than in other communities in which densities were similar ($F_{7, 1349} = 1.76$, $P = 0.081$; Fig. 6). Likewise, densities of Hutton Vireo seemed somewhat higher in oak-pine woodland and montane riparian areas than in other communities, especially pine forest and oak savannah where densities were low ($F_{7, 1349} = 1.806$, $P = 0.072$; Fig. 6). Densities of Rufous-capped Warbler seemed higher in montane riparian areas (0.16 ± 0.053 territories/ha) than in mountain scrub, oak savannah, oak woodland, or oak-pine woodland (0.013-0.032 ± 0.009-0.019 territories/ha), and were not encountered in other communities ($F_{7, 1349} = 1.76$, $P = 0.081$). Densities of Black-headed Grosbeak varied very little among communities with similar patterns for White-breasted Nuthatch, which occurred at somewhat higher densities in pine and mixed-conifer forest (Fig. 6).

I developed models that identified and quantified the effects of important environmental factors on densities of 30 bird species at the scale of transects occupied by each species (Table 7). These species were present along an average of 108.5 ± 7.2 transects (range = 52-181) within 24.9 ± 0.7 mountain ranges (range = 17-24) and thus typically had fairly broad distributions in the study region. With regard to the random effects, variation in densities among transects within mountain ranges was higher than that among mountain ranges for 97% of species, and residual standard deviations for density averaged 63.5 ± 7.6% greater than that for intercepts (Table 7). Seventeen of 18 potential explanatory factors that I considered (see Table 1) were included in models for at least one species, and conifer cover (10 species), a principal component representing increasing tall-tree cover and decreasing shrub cover (9 species), and broadleaf deciduous cover (7 species) were included in the largest number of models. Broadleaf deciduous cover, fire intensity, tree density, and three other factors that were in fewer models had only positive effects on densities (Table 7). Densities of American Robin, Grace’s Warbler, Spotted Towhee, and Yellow-eyed Junco all increased with fire intensity ($P \leq 0.026$) and there was suggestive evidence ($P = 0.11$) of a similar effect on densities of Northern Flicker after considering other important factors. Similarly, densities of Western Wood-Pewee, Dusky-capped Flycatcher, Hutton’s Vireo, Steller’s Jay, Canyon Wren, Yellow-eyed Junco, and Black-headed Grosbeak all increased with increasing broadleaf deciduous cover ($P \leq 0.058$) after considering other important factors.

Table 6: Spatial variation in density (log no./ha.) of 72 species of breeding birds across the Sky Islands and adjacent Sierra Madre Occidental of Sonora and Chihuahua, Mexico, 2009-2012. Estimates are slope parameters and SE for linear or quadratic effects from linear mixed-effects models with island and transect fit as nested random effects. Where linear terms fit best based on *p*-values, trends note direction of effects (+ or -) and estimates quantify the percent change in density with each 100-m increase in elevation or 10-km increase in latitude or longitude. Were quadratic terms fit best, densities were highest at intermediate values of covariates (∩) and estimates are for quadratic terms. No effect (na) indicates *p*-values >0.10 for both linear and quadratic terms. Variation in densities among vegetation communities was assessed with mixed-effects ANOVA. Density was estimated based on distance-sampling methods for species with ≥30 total encounters.

	Elevation (100 m)			Latitude (10 km)			Longitude (10 km)			Vegetation Community	
Species	Est.	SE	Trend	Est.	SE	Trend	Est.	SE	Trend	*F*	*P*
Montezuma Quail	-0.27	0.13	-*	0.15	0.13	na	-0.13	0.09	na	1.04	0.40
Wild Turkey	0.025	0.034	na	-0.008	0.005	∩**	0.01	0.02	na	1.25	0.27
Red-tailed Hawk	-0.041	0.022	-**	0.018	0.012	na	-0.01	0.01	na	1.36	0.21
Band-tailed Pigeon	0.45	0.12	+	0.005	0.078	na	0.10	0.05	+	3.03	0.002
White-winged Dove	-0.99	0.17	-	0.63	0.24	+	-0.64	0.14	-	1.37	0.20
Mourning Dove	-0.58	0.14	-	0.42	0.17	+*	-0.20	0.12	-	1.32	0.23
Thick-billed Parrot	0.018	0.017	na	-0.084	0.038	-	0.05	0.03	+	4.82	<0.001
Greater Roadrunner	-0.097	0.032	-	0.038	0.018	+*	-0.02	0.01	na	1.52	0.14
White-throated Swift	0.026	0.045	na	0.011	0.027	na	-0.004	0.002	∩**	1.05	0.39
Broad-billed Hummingbird	-2.31	0.58	-	-0.33	0.55	na	-0.63	0.38	na	1.16	0.32
Magnificent Hummingbird	0.74	0.32	+*	-0.65	0.18	-	0.30	0.15	+	1.06	0.39
Broad-tailed Hummingbird	1.30	0.51	+*	-0.76	0.36	-*	0.64	0.24	+	2.95	0.003
Elegant Trogon	-1.06	0.16	-	-0.24	0.12	-*	0.04	0.09	na	1.19	0.30
Mountain Trogon	0.11	0.057	+*	-0.32	0.083	-	0.18	0.06	+	1.95	0.050
Acorn Woodpecker	-1.41	0.23	-	-0.23	0.18	na	0.10	0.13	na	5.20	<0.001
Hairy Woodpecker	0.64	0.10	+	-0.31	0.11	-	0.16	0.08	+	11.53	<0.001
Arizona Woodpecker	-0.27	0.062	∩	-0.061	0.030	∩*	-0.26	0.11	-	1.57	0.13
Northern Flicker	0.55	0.11	+	-0.21	0.091	-*	0.19	0.06	+	6.75	<0.001
Greater Pewee	0.80	0.13	+	-0.45	0.10	-	0.26	0.07	+	5.34	<0.001
Western Wood-Pewee	-1.81	0.42	-	0.053	0.30	na	-0.20	0.21	na	2.19	0.026
Cordilleran Flycatcher	1.09	0.24	+	-0.65	0.19	-	0.44	0.13	+	5.26	<0.001
Buff-breasted Flycatcher	0.38	0.15	+*	-0.22	0.13	-**	0.18	0.09	+	4.07	<0.001
Dusky-capped Flycatcher	-2.20	0.35	-	-0.18	0.057	∩	-0.048	0.026	∩**	8.01	<0.001
Ash-throated Flycatcher	-1.41	0.23	-	-0.23	0.18	na	0.10	0.13	na	5.23	<0.001
Brown-crested Flycatcher	-1.71	0.21	-	-0.37	0.16	-*	-0.01	0.12	na	2.49	0.011
Sulphur-bellied Flycatcher	-0.71	0.12	-	-0.14	0.080	-**	0.07	0.06	na	5.02	<0.001
Cassin's Kingbird	-0.62	0.15	-	0.15	0.093	na	-0.07	0.07	na	2.10	0.033
Thick-billed Kingbird	-0.61	0.12	-	-0.078	0.081	na	-0.05	0.06	na	0.72	0.67
Plumbeous Vireo	1.27	0.27	+	-0.54	0.20	-	0.39	0.14	+	4.95	<0.001
Hutton's Vireo	-0.29	0.11	∩	0.31	0.29	na	-0.043	0.020	∩*	1.80	0.072
Steller's Jay	2.36	0.26	+	-0.94	0.34	-	0.59	0.24	+	9.61	<0.001
Mexican Jay	-0.29	0.044	∩	-0.073	0.025	∩	-0.027	0.011	∩*	4.92	<0.001
Common Raven	-0.062	0.018	-	0.024	0.010	+*	-0.01	0.01	-	1.53	0.14
Mexican Chickadee	1.86	0.30	+	-1.70	0.36	-	1.18	0.24	+	7.10	<0.001
Bridled Titmouse	-3.51	0.46	-	0.38	0.50	na	-0.89	0.31	-	7.80	<0.001
Bushtit	0.16	0.38	na	0.21	0.25	na	-0.03	0.18	na	2.26	0.021
White-breasted Nuthatch	0.54	0.23	+*	-0.74	0.27	-	0.20	0.21	na	1.17	0.31

Brown Creeper	2.92	0.53	+	-2.04	0.40	-	1.15	0.31	+	4.26	<0.001
Cactus Wren	-0.24	0.061	-	0.26	0.20	na	-0.02	0.15	na	2.36	0.016
Rock Wren	-0.23	0.071	-	0.13	0.054	+*	-0.08	0.04	-	3.45	<0.001
Canyon Wren	-0.79	0.20	-	-0.051	0.027	∩*	-0.11	0.11	na	0.85	0.56
Bewick's Wren	-3.34	0.59	-	2.27	0.75	+	-1.70	0.50	-	7.35	<0.001
House Wren	1.91	0.34	+	-1.40	0.32	-	0.85	0.23	+	10.06	<0.001
Blue-gray Gnatcatcher	-0.43	0.099	∩	-0.14	0.051	∩	0.43	0.19	+	2.78	0.005
Eastern Bluebird	0.026	0.080	na	-0.13	0.045	-	0.06	0.04	+	0.46	0.88
Townsend's Solitaire	0.18	0.043	+	-0.11	0.029	-	0.08	0.02	+	2.15	0.029
Brown-backed Solitaire	-0.045	0.015	∩	-0.088	0.052	-**	0.07	0.04	+	2.99	0.003
American Robin	2.36	0.36	+	-0.94	0.30	-	0.74	0.20	+	8.77	<0.001
Northern Mockingbird	-0.19	0.11	-**	0.53	0.21	+*	-0.16	0.16	na	2.87	0.004
Phainopepla	-0.51	0.20	-	0.48	0.24	+*	-0.51	0.15	-	1.28	0.25
Olive Warbler	1.18	0.15	+	-0.61	0.14	-	0.39	0.10	+	12.93	<0.001
Crescent-chested Warbler	0.90	0.29	+	-1.08	0.24	-	0.64	0.18	+	2.17	0.027
Grace's Warbler	1.47	0.28	+	-0.62	0.21	-	0.38	0.16	+	11.36	<0.001
Black-throated Gray Warbler	-0.24	0.29	na	0.68	0.28	+*	0.20	0.21	na	2.05	0.038
Rufous-capped Warbler	-0.73	0.19	-	-0.27	0.11	-*	-0.04	0.09	na	1.76	0.081
Red-faced Warbler	2.01	0.41	+	-1.75	0.40	-	1.19	0.27	+	8.63	<0.001
Painted Redstart	-1.16	0.16	∩	-1.49	0.47	-	-0.078	0.037	∩*	3.50	<0.001
Slate-throated Redstart	0.36	0.19	+**	-0.98	0.27	-	0.57	0.20	+	7.20	<0.001
Spotted Towhee	4.08	0.47	+	1.07	0.50	+*	-0.069	0.039	∩**	3.43	<0.001
Rufous-crowned Sparrow	-3.31	0.53	-	2.00	0.59	+	-1.75	0.34	-	16.34	<0.001
Canyon Towhee	-1.37	0.23	-	0.68	0.27	+*	-0.33	0.17	-	13.09	<0.001
Yellow-eyed Junco	4.93	0.39	+	-1.10	0.42	-	0.67	0.29	+	31.32	<0.001
Hepatic Tanager	-0.45	0.13	∩	-0.15	0.057	∩	-0.080	0.024	∩	1.76	0.081
Summer Tanager	-0.86	0.14	-	0.017	0.090	na	-0.08	0.06	na	5.26	<0.001
Black-headed Grosbeak	-1.53	0.49	-	0.23	0.36	na	-0.73	0.22	-	0.89	0.52
Blue Grosbeak	-0.96	0.15	-	-0.11	0.11	na	-0.13	0.08	na	1.56	0.13
Varied Bunting	-1.40	0.20	-	-0.12	0.15	na	-0.27	0.10	-	1.88	0.060
Brown-headed Cowbird	-1.38	0.21	-	0.33	0.16	+*	-0.17	0.11	na	2.20	0.025
Hooded Oriole	-0.86	0.22	-	0.071	0.14	na	-0.06	0.10	na	4.08	<0.001
Scott's Oriole	-0.49	0.14	-	0.18	0.18	na	-0.25	0.12	-	3.47	<0.001
House Finch	-0.79	0.20	-	1.10	0.35	+	-0.39	0.27	na	1.03	0.41
Lesser Goldfinch	-0.82	0.20	-	-0.14	0.12	na	-0.16	0.09	-	0.47	0.88

*P = 0.01-0.05
**P = 0.051-0.10

Habitat models often included factors thought to be important in explaining densities given the natural history of each species, but also identified factors with unanticipated effects. With regard to vegetation physiognomy, densities of Elegant Trogon, Acorn Woodpecker, and Scott's Oriole, which are often associated with oaks, decreased with increasing cover of conifers, whereas densities of Dusky-capped Flycatcher, Bridled Titmouse, and Painted Redstart, which are also associated with oaks or pine-oak woodland, increased with increasing cover of oaks (Table 7). In contrast, densities of Greater Pewee, Steller's Jay, Grace's Warbler, and especially Yellow-eyed Junco, which occurred at maximum densities in pine or mixed-conifer forest (Fig. 6), all

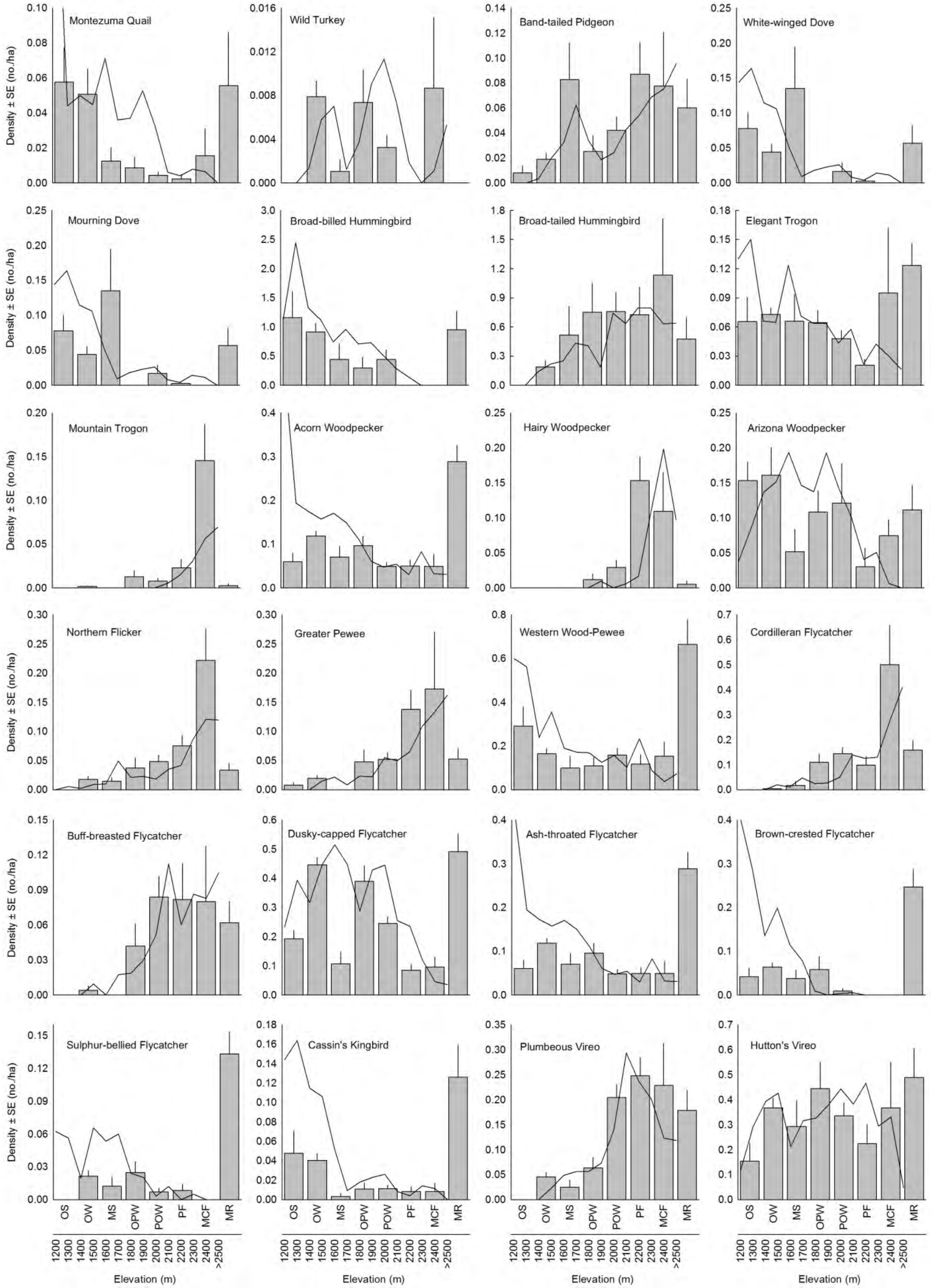


Figure 6: Variation in bird density (no. individuals, pairs, or flocks/ha) across vegetation (bars) and elevation (lines) gradients in the Sky Islands and adjacent Sierra Madre Occidental, Mexico 2009-2012. Vegetation communities (oak savannah and scrub-OS, oak woodland-OW, mountain scrub-MS, oak-pine woodland-OPW, pine-oak (con't)…

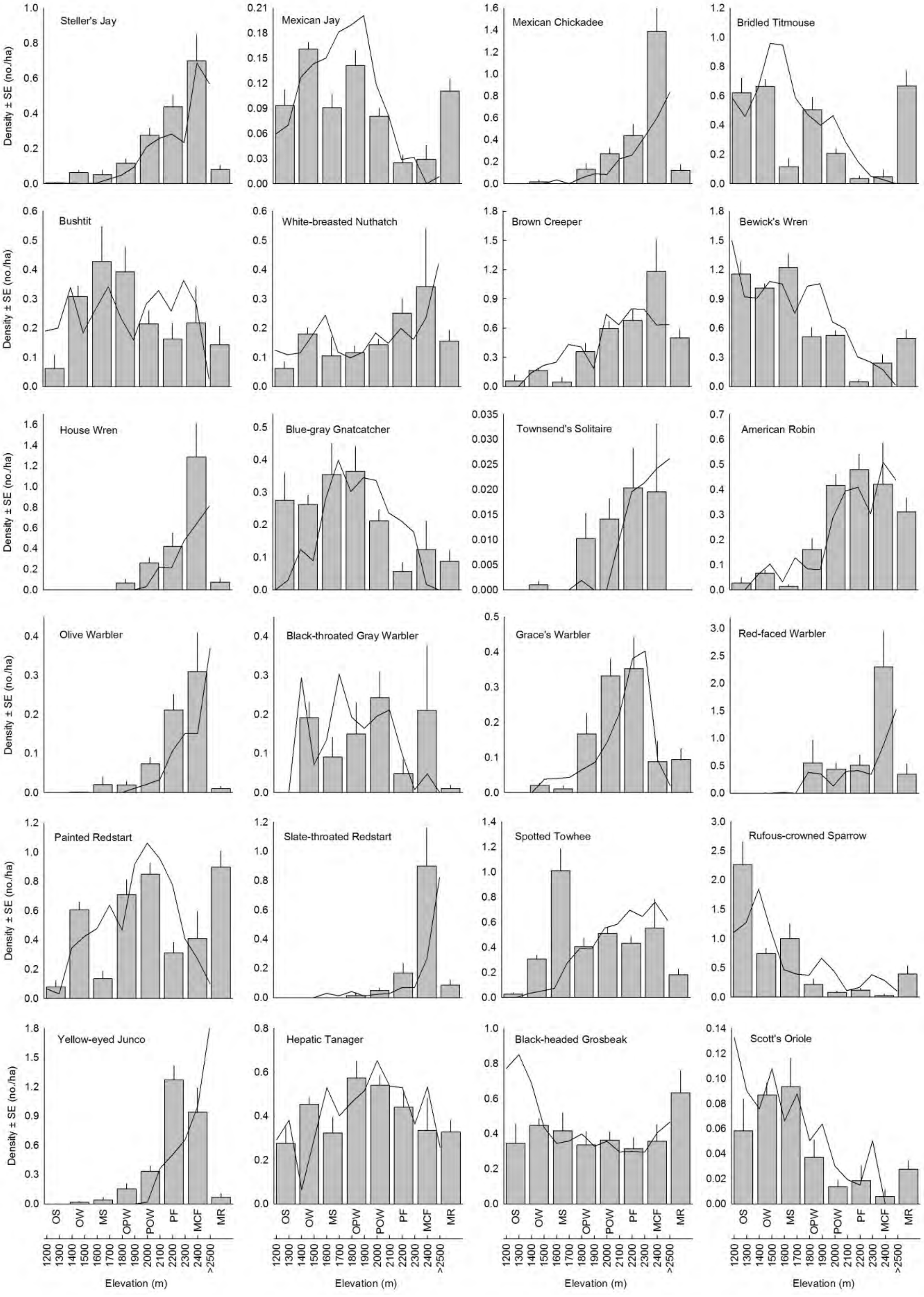


Figure 6 continued: woodland-POW, pine forest-PF, mixed conifer forest-MCF, montane riparian-MR) were the dominant communities within 100 m of point-count stations and are listed in order of mean elevation except for montane riparian, which spanned the entire gradient. Elevational distributions of communities are wider than bars. Elevation lines connect mean density in 100 m intervals; the >2500 m band includes points between 2450 and 2750 m.

increased with increasing cover of conifers (Table 7). Interestingly, densities of Hepatic Tanager, which were similar across a broad range of vegetation communities (Fig. 6), increased with increasing cover of both conifers and oaks, and at a greater rate with cover of oaks. Densities of Acorn Woodpecker and White-breasted Nuthatch, which nest in cavities, increased with increasing dominance (e.g., density weighted by size; Table 1) of snags, whereas densities of Elegant Trogon and Bridled Titmouse, which also nest in cavities, increased as snags become older and more decayed (Table 7). Densities of Northern Flicker, Dusky-capped Flycatcher, and Bridled Titmouse decreased, whereas densities of Plumbeous Vireo and Scott's Oriole increased with increasing proximity of drainage channels, suggesting associations with upland or riparian environments. Moreover, densities of Plumbeous Vireo and especially American Robin increased with increasing proximity of surface water. Not surprisingly, densities of Canyon Wren increased markedly with increasing dominance of cliff faces, with positive but much smaller and less intuitive effects for Plumbeous Vireo and Grace's Warbler. With regard to gross vegetation structure, densities of Northern Flicker, Dusky-capped Flycatcher, Canyon Wren, Grace's Warbler, and Hepatic Tanager all increased as densities of canopy trees increased, whereas densities of Band-tailed Pigeon increased and Brown-headed Cowbird decreased with increasing dominance of canopy trees.

The effects of vegetation cover and the vertical position of that cover were often complex and explained variation in densities of 37% species often in combination with other factors. A principal component (PC1) representing increasing tall-tree cover (e.g., >6 m above ground) and decreasing shrub cover (e.g., <3 m above ground) has positive effects on densities of three species and negative effects on densities of six species after adjusting for the effects of other factors (Table 7). In contrast, a principal component (PC2) representing increasing short-tree cover (3-6 m above ground) has positive effects on densities of two species and negative effects on densities of four species. More specifically, increasing values of PC1 had positive effects on densities of Plumbeous Vireo, after adjusting for distance to water, drainages, and other factors, Painted Redstart, after adjusting for the positive effects of oak cover, and was the only factor that explained variation in densities of Brown Creeper, suggesting strong positive effects of tall-tree cover (Table 7). In contrast, increasing values of PC1 had negative effects on densities of Blue-grey Gnatcatcher, after adjusting for distance to drainage, and on densities of Spotted Towhee, after adjusting for fire intensity, grass-forb cover, and grazing intensity, which indicated positive effects of increasing shrub cover. Not surprisingly, increasing PC1 had strong negative effects and increasing PC2 had strong positive effects on densities of Mexican Jay, indicating the importance of short-tree vs. tall-tree cover. Notably, increases in both PC1 and PC2 had strong negative effects on densities of Bewick's Wren and Rufous-crowned Sparrow, indicating the importance of shrub vs. tree cover. Moreover, once the positive effects of conifer and broadleaf deciduous cover, and fire and grazing intensity were considered, densities of Yellow-eyed Junco decreased with both PC1 and PC2, which suggests the importance of shrub cover and open mid-story and tall tree cover. Densities of Hutton's Vireo increased with increasing values of PC2, whereas densities of White-breasted Nuthatch decreased with increasing values of PC2, which indicated positive or negative effects of short-tree cover, respectively.

I did not evaluate the effects of tree species composition on bird densities because estimates of composition and physiognomy were often highly correlated. Nonetheless, composition of dominant tree species varied widely across the study region (Appendix D) and contributed to

Table 7: Factors that explained variation in density (log no./ha) of individuals, pairs, or flocks of 30 breeding bird species along point transects occupied by each species in the Sky Islands and adjacent Sierra Madre Occidental of Sonora and Chihuahua, Mexico, 2009-2012. Estimates are based on linear mixed-effects models in which mountain range (island) was fit as a random effect and quantify the percent change in density with each one-unit change in explanatory factors. Stepwise variable selection based on Bayesian information criterion (BIC) was used to select fixed effects for all species except those noted. Random effect estimates are standard deviations for intercepts (between-island variation) and residuals (within-island variation). See Table 1 for definitions and units of variables.

Species	Sample Size		Random Effects		Fixed Effects			
Variable (transformation)	Islands	Transects	Intercept	Residual	Estimate	SE	*t*	*p*
Band-tailed Pigeon								
Tree dominance	21	55	0.049	0.077	0.0014	0.0005	2.68	0.012
Elegant Trogon*								
Snag decay class	25	98	0.012	0.087	0.028	0.015	1.85	0.069
Conifer cover					-0.11	0.061	-1.73	0.087
Acorn Woodpecker								
Conifer cover	27	105	0.020	0.12	-0.26	0.083	-3.11	0.003
Tree species diversity					0.018	0.0079	2.24	0.028
Arizona Woodpecker								
Snag dominance	27	126	0.059	0.12	0.0094	0.0034	2.75	0.007
Northern Flicker*								
Distance to drainage (ln)	22	65	0.013	0.073	-0.028	0.013	-2.13	0.040
Fire intensity					0.032	0.020	1.62	0.11
Tree density (ln)					0.031	0.014	2.27	0.028
Greater Pewee								
Conifer cover	20	65	0.066	0.090	0.22	0.077	2.83	0.007
Western Wood-Pewee								
Broadleaf deciduous cover	22	78	0.11	0.24	0.70	0.24	2.96	0.005
Dusky-capped Flycatcher								
Distance to drainage (ln)	29	181	0.073	0.15	-0.055	0.018	-3.02	0.003
Broadleaf deciduous cover					0.36	0.14	2.47	0.015
Oak cover					0.40	0.085	4.69	<0.001
Tree density (ln)					0.058	0.020	2.85	0.005
Ash-throated Flycatcher								
Conifer cover	27	105	0.022	0.12	-0.26	0.083	-3.12	0.003
Tree species diversity					0.018	0.0079	2.22	0.029
Plumbeous Vireo								
Snag decay class	19	68	8.7E-06	0.14	-0.10	0.036	-2.83	0.007
Cliff dominance (ln)					0.11	0.043	2.45	0.018
Distance to drainage (ln)					0.094	0.028	3.39	0.002
Distance to water					0.034	0.016	2.15	0.038
PC1: tall tree vs. shrub cover					0.069	0.016	4.23	<0.001
Hutton's Vireo								
Broadleaf deciduous cover	29	150	7.5E-06	0.23	0.36	0.18	2.07	0.047
PC2: short tree cover					0.042	0.023	1.82	0.072
Steller's Jay								
Conifer cover	22	93	0.11	0.16	0.43	0.12	3.70	<0.001
Broadleaf deciduous cover					0.45	0.20	2.23	0.029
Mexican Jay								
PC1: tall tree vs. shrub cover	29	151	0.029	0.069	-0.023	0.0052	-4.38	<0.001
PC2: short tree cover					0.024	0.0078	3.12	0.002

Species	Sample Size		Random Effects		Fixed Effects			
Variable (transformation)	Islands	Transects	Intercept	Residual	Estimate	SE	*t*	*p*
Bridled Titmouse								
Distance to drainage (ln)	28	146	0.059	0.23	-0.081	0.024	-3.36	0.001
Grass-forb cover					0.94	0.21	4.49	<0.001
Oak cover					0.47	0.14	3.40	<0.001
Snag decay class					0.12	0.041	2.85	0.005
Bushtit*								
Conifer cover	28	91	6.2E-06	0.19	0.24	0.12	1.95	0.056
Broadleaf evergreen cover					0.56	0.30	1.86	0.067
White-breasted Nuthatch								
PC2: short tree cover	25	123	0.097	0.12	-0.054	0.018	-2.95	0.004
Snag dominance					0.013	0.0042	3.07	0.003
Brown Creeper								
PC1: tall tree vs. shrub cover	22	75	0.15	0.27	0.11	0.029	3.74	<0.001
Canyon Wren								
Cliff dominance (ln)	26	97	2.8E-06	0.17	0.12	0.039	3.13	0.0026
Broadleaf deciduous cover					0.47	0.16	2.98	0.004
Tree density (ln)					0.057	0.024	2.35	0.021
Bewick's Wren								
Broadleaf evergreen cover	30	161	0.23	0.23	1.08	0.45	2.42	0.017
PC1: tall tree vs. shrub cover					-0.066	0.025	-2.60	0.011
PC2: short tree cover					-0.067	0.029	-2.30	0.023
Blue-gray Gnatcatcher*								
PC1: tall tree vs. shrub cover	23	90	0.041	0.18	-0.045	0.020	-2.29	0.026
Distance to drainage (ln)					0.047	0.027	1.73	0.088
American Robin								
Distance to water	22	91	1.0E-05	0.21	0.073	0.017	4.30	<0.001
Fire intensity					0.14	0.045	3.01	0.004
Grace's Warbler								
Cliff dominance (ln)	17	64	3.3E-06	0.17	0.22	0.057	3.88	<0.001
Fire intensity					0.16	0.049	3.29	0.002
Conifer cover					0.31	0.14	2.21	0.032
Tree density (ln)					0.069	0.030	2.32	0.025
Painted Redstart								
PC1: tall tree vs. shrub cover	25	143	0.071	0.27	0.14	0.021	6.56	<0.001
Oak cover					0.58	0.15	3.81	<0.001
Spotted Towhee								
Grass-forb cover	27	134	0.072	0.24	-0.65	0.27	-2.44	0.016
Fire intensity					0.14	0.054	2.54	0.013
Grazing intensity (ln)					-0.37	0.084	-4.43	<0.001
PC1: tall tree vs. shrub cover					-0.096	0.021	-4.54	<0.001
Rufous-crowned Sparrow								
Broadleaf evergreen cover	29	148	0.077	0.35	-1.59	0.58	-2.74	0.007
PC1: tall tree vs. shrub cover					-0.12	0.039	-3.04	0.003
PC2: short tree cover					-0.14	0.042	-3.45	<0.001
Tree species diversity					-0.055	0.023	-2.38	0.019
Yellow-eyed Junco								
Broadleaf deciduous cover	17	52	4.4E-06	0.25	2.11	0.51	4.12	<0.001
Conifer cover					1.11	0.30	3.66	0.001

Species	Sample Size		Random Effects		Fixed Effects			
Variable (transformation)	Islands	Transects	Intercept	Residual	Estimate	SE	*t*	*p*
Fire intensity					0.23	0.097	2.35	0.026
Grazing intensity (ln)					0.78	0.18	4.32	<0.001
PC1: tall tree vs. shrub cover					-0.12	0.048	-2.56	0.016
PC2: short tree cover					-0.22	0.058	-3.71	<0.001
Hepatic Tanager								
Conifer cover	29	172	0.031	0.20	0.32	0.130	2.55	0.0120
Oak cover					0.53	0.13	4.02	<0.001
Tree density (ln)					0.062	0.025	2.53	0.013
Black-headed Grosbeak*								
Broadleaf deciduous cover	32	172	0.092	0.26	0.40	0.21	1.91	0.058
Brown-headed Cowbird								
Tree dominance	22	58	0.098	0.11	-0.0023	0.0008	-2.96	0.006
Scott's Oriole								
Conifer cover	26	98	0.082	0.061	-0.15	0.067	-2.19	0.032
Distance to drainage (ln)					0.028	0.0093	2.99	0.004
Snag dominance					-0.0054	0.0023	-2.36	0.021

*Models based on stepwise selection with BIC included no fixed effects so Akaike information criterion used.

major differences in the structure and general appearance of habitats occupied by many bird species. Trees such as *Quercus sideroxyla* and *Tilia americana* were restricted to the Sierra Madre whereas others such as *Pinus yecorensis*, *Quercus mcvaughii*, *Quercus durifolia*, and *Arbutus xalapensis* occurred in very few Sky Islands, including some where they had not been documented in the past. Others tree species such as *Pinus engelmannii*, *Quercus arizonica*, and *Quercus hypoleucoides* occurred across much of the region and contributed to a high degree of uniformity in the structure and appearance of vegetation across space. Although the effects of species composition were not assessed, densities of some species varied with diversity of dominant tree species. Densities of Acorn Woodpecker and Ash-throated Flycatcher for example, increased with increasing tree species diversity whereas densities of Rufous-crowned Sparrow decreased after adjusting for other factors (Table 7).

DISCUSSION

I described the distribution, abundance, diversity, and habitat relationships of breeding birds in the Madrean Sky Islands of Sonora and Chihuahua, Mexico and adjacent portions of the Sierra Madre Occidental. I also evaluated biogeographical relationships among breeding bird communities in montane vegetation across nearly the entire Sky Islands region based on data I gathered in Mexico with recent data from mountain ranges in the U.S. My efforts represent the first systematic study of bird communities and bird-habitat relationships in montane vegetation communities in this region of Mexico since the early 1950s. Between 1951 and 1955, Joe Marshall Jr. (1957) surveyed portions of 15 mountain ranges and areas in the adjacent Sierra Madre and provided detailed accounts of avifauna and vegetation that helped establish the ecological significance and uniqueness of the Sky Islands region. In Mexico, Marshall (1957) considered nine mountain ranges (Pinito, Azul, Aconchi, Cananea, Ajos, Tigre, San Luis, Púlpito, Oposura) and five areas in the adjacent Sierra Madre Occidental: the Sierra Huachinera, Sierra Nácori (Pinos Altos), upper Rio Gavilán, and areas on the western (lower Rio Gavilán, Mesa Tres Rios) and eastern slopes (la Tinaja). Including effort in six other ranges in the U.S., his work focused along 65 km of survey routes in pine-oak woodland and adjacent riparian areas that he often surveyed multiple times in different seasons (mainly April-September). In comparison, my efforts focused in portions of 26 Sky Island mountain ranges and six areas in the adjacent Sierra Madre in Mexico, and spanned 289 km of point transects in all major montane vegetation communities in the region, which I typically surveyed once when most species were breeding (May-July). Thus, although levels of effort were similar in the Sierra Madre, my coverage in the Sky Islands of Mexico was much broader and included several mountain ranges in which observations of birds have not been reported since the late 1800s (e.g., Sierra San José and Cíbuta) or possibly ever (e.g., Madera, Juriquipa, Carboneras, Ceniza, Bacadéhuachi, Mariquita, Pan Duro; Van Rossem 1945, Marshall 1957, Russell and Monson 1998, Flesch 2008a).

Given the value of baseline data gathered by Marshall (1957) and the breadth of his insights into questions I addressed, I have attempted to compare our results and those from other more recent efforts in the region. These comparisons focus on evaluating spatiotemporal variation in the status and distribution of breeding birds, on factors that drive those patterns, and on refining our understanding of bird-habitat relationships. Despite the importance of these comparisons, they are complicated by differences in the intensity, location, and timing of survey effort, a lack of data on changes in land use and vegetation structure, and by varying methodologies. As I describe in subsequent sections, one of my main findings is that montane forests and woodlands of pines, which Marshall visited shortly after or while they were being commercially logged, have matured to varying extents over the last six decades and that the extensive network of logging roads present in Marshall's time is now largely in disrepair. Thus, many Sky Islands in Mexico are much less accessible today and subjected to much lower levels of exploitation by humans. As a result, populations of many species that depend on pines such as Northern Goshawk, Plumbeous Vireo, and Grace's Warbler, and those that are the focus of hunting by humans such as Wild Turkey seem to be more abundant and broadly distributed today than during the 1950s. Despite these auspicious trends, local extinctions of some small and isolated populations due to habitat degradation associated with past logging, stochastic processes, climate change, or a combination of these and other factors seem to have driven the extirpation of other populations that were present in the past. Moreover, changes in the status and distribution of other species, many of which have strong Madrean affinities, such as Brown-backed Solitaire and Crescent-chested Warbler, are likely due to northward range expansion that began after Marshall's efforts and seem to be continuing today (Phillips 1968, Johnson 1994, Flesch 2008a, Rosenberg et al. 2011). Below, I describe evidence of these patterns with reference to specific species and localities and discuss my findings on diversity, distribution, biogeography, and habitat relationships and implications for management and conservation.

Diversity and Status.—Estimates of breeding bird diversity in the northern Sierra Madre and Sky Islands range from as high as 295 species, which includes adjacent lowland species (Felger and Wilson 1995) to as low as 103 species, which includes only landbirds in Mexico (Escalante et al. 1993). More broadly, the entire Sierra Madre Occidental, including both montane and lowland vegetation, is thought to support 478 bird species or ~45% of the Mexican avifauna (Kobelkowsky-Vidrio et al. 2014), although these estimates are based mainly on large-scale distribution maps rather than field work. During extensive field surveys, I detected 199 species of birds including 165 species of landbirds that were at least presumably breeding, and an additional seven species of possible breeders. In comparison, in both the U.S. and Mexico, Marshall (1957) observed 163 species including 127 species of landbirds that were presumably breeding, 93 of which he found in pine-oak woodland and adjacent riparian areas. Similarly, in a region that included portions of 14 Sky Islands and adjacent lowlands in the borderlands of Sonora, Flesch (2008a) observed 161 species of landbirds that were presumably breeding and found that presence of oak or pine-oak woodland and pine forest had large positive effects on regional diversity of breeding birds. Including 10 species that have bred recently only in Sky Islands in the U.S. (Gray Flycatcher, American Dipper, Juniper Titmouse, Mountain Chickadee, Golden-crowned Kinglet, Ruby-crowned Kinglet, Orange-crowned Warbler, Macgillivray's Warbler, Lazuli Bunting, Evening Grosbeak; Corman and Wise-Gervais 2005) and 3 species not detected during the study that were observed by Marshall (1957) and that have been observed recently (Prairie Falcon, Purple Martin, Striped Sparrow), I estimate 185 species of landbirds breed in montane vegetation in the Sky Islands and adjacent portions of the Sierra Madre in Mexico. Other species not detected during the study that have occurred near the region and that may one day be found breeding include Gray-collared Becard (*Pachyramphus major*), Aztec Thrush (*Ridgwayia pinicola*), Gray Silky-Flycatcher (*Ptilogonys cinereus*), and Elegant Euphonia (*Euphonia elegantissima*).

Although I did not assess factors that explained diversity in a quantitative sense, diversity was often higher in larger mountain ranges such as the Sierra el Tigre and those in the south and east such as the Aconchi, Bacadéhuachi, and Púlpito, patterns that are likely due to a range of processes. Larger Sky Islands, for example, often support more habitat and thus larger populations that are less vulnerable to stochastic extinctions and provide larger targets for dispersing individuals, which augments colonization rates and dampens extinction risks (Lomolino et al. 2006). Those processes along with the effects of current and past isolation likely explain variation in bird diversity among ranges (e.g., Watson 2003) just as they explain diversity of small mammals and pines in this and other regions (Lomolino et al. 1989, Hanski and Gaggiotti 2004, Lomolino et al. 2006, Ferguson et al. 2013). Increasing proximity to the Sierra Madre likely also bolsters diversity, perhaps independent of island size, by enhancing colonization rates of Madrean species (e.g., Ferguson et al. 2013). Presence of White-striped Woodcreeper, Slate-throated Redstart, and other species rarely found away from the Sierra Madre in the Bacadéhuachi for example, is likely due to its proximity to source populations in the nearby Sierra Madre despite relatively small size. Moreover, diversity likely also increases from north to south across the Sky Islands region despite the fact that the southern Sky Islands typically attain lower elevations and thus support fewer montane vegetation communities. This is because diversity tends to increase at lower latitudes and because thornscrub and subtropical habitat elements likely promote occupancy by more tropical species (Brown 1982, Rosenzweig 1995).

In the Sky Islands, I observed 152 species at least presumably breeding, eight other species of possible breeders, and estimate 169 breeding species were present with a likely range as high as 180. Breeding species that may have been present but were either undetected or evidence was insufficient to presume breeding, include those I classified as possible breeders, others that may breed locally or irregularly in the region, and some species found only by Marshall (1957), which include Prairie Falcon (*Falco mexicanus*), Purple Martin, and Juniper Titmouse (*Baeolophus ridgwayi*). Some of these species depend on habitats or resources that are rare in space or available only sporadically in time, which could explain their apparent absence during the study. Species associated with Great Basin conifer (pinyon-juniper) woodland, for example, which is restricted largely to the extreme northeastern portion of the study area, may breed locally in the study area. They include Gray Flycatcher, Juniper Titmouse, and Gray Vireo. Gray Flycatcher breeds as far south as the Chiricahua Mountains in Arizona (Corman and Wise-Gervais 2005) and was observed in potential breeding habitat at times when migrants may still have been moving through the region. Juniper Titmouse breeds in extreme southeastern Arizona (Phillips et al. 1964, Corman and Wise-Gervais 2005) and was observed by Marshall (1957) and others (Russell and Monson 1998, Gomez de Silva 2005) at the northern end of the Sierra San Luis. Gray Vireo breeds in adjacent portions of Arizona and New Mexico (Corman and Wise-Gervais 2005, DeLong and Williams. 2006) and was possibly breeding in the San Luis during the study. Red Crossbill may breed sporadically in the Mexican Sky Islands at times when conifer seeds are abundant, although breeding in Sonora has not been documented (Russell and Monson 1998, Flesch 2008a). Although I did not observe Prairie Falcon, recent observations of a nest with young in the western foothills of the Sierra Esmeralda and a pair around a likely nest in the foothills of the Sierra el Humo (*unpubl. data*) indicate recent presence in the region.

Other species often restricted to the Sierra Madre could breed locally or sporadically in the Sky Islands. Tufted Flycatcher was collected in the Oposura by C. J. Cahoon in June 1887 and has not been observed there subsequently (Marshall 1957) but presence in potential breeding habitat in the Aconchi suggests it may breed locally in the Sky Islands. In Mexico, Eared Quetzal has been found nesting as far north as Mesa de las Guacamayas, which is the northernmost peak in the Sierra Madre Occidental (Lammertink et al. 1996), and also breeds locally and sporadically in some of the larger Sky Islands in southern Arizona (Corman and Wise-Gervais 2005). Although Sky Islands in Mexico are lower in elevation and thus less mesic than those in the U.S., additional survey effort may one day reveal a small breeding population. Northern Parula has been observed in potential breeding habitat during the breeding season in the Ajos where Marshall and Phillips collected a male and female in breeding condition in 1952 (Marshall 1957, Russell and Monson 1998). This species and possibly Hooded Warbler, which has also been observed in potential breeding habitat during the breeding season in the Ajos (Russell and Monson 1998, *unpubl. data*) could breed locally and sporadically in the region as suggested by observations of singing males in June in riparian forest in the Cebadilla. Although Marshall (1957) observed Striped Sparrow (*Oriturus superciliosus*) in the Sierra Madre, my failure to detect it in the Sierra Madre was likely due to a lack of effort in appropriate habitat, which is not present in the Sky Islands. Failure to observe other species such as Thick-billed Parrot and Pygmy Nuthatch are likely due regional extirpation (see below)

*Spatiotemporal Variation in Status.—*I observed a large number of new species that had not been documented previously in the region but failed to detect others that occurred historically, which suggested important changes in status of some species. Species I presumed or confirmed breeding that were either not observed or presumed to breed by Marshall (1957) in the study region include Short-tailed Hawk, Mountain Trogon, Tufted Flycatcher, Pine Flycatcher, Yellow-green Vireo, Red-breasted Nuthatch, Hermit Thrush, Orange-billed Nightingale-Thrush, Russet Nightingale-Thrush, Brown-backed Solitaire, Hooded Warbler, Virginia’s Warbler, Crescent-chested Warbler, Slate-throated Redstart, Black-chinned Sparrow, Western Tanager, and Flame-colored Tanager. Moreover, in the Sky Islands, I observed 13 species that were at least presumably breeding for the first time (Berylline Hummingbird, White-striped Woodcreeper, Warbling Vireo, Yellow-green Vireo, Hermit Thrush, Townsend Solitaire, Brown-backed Solitaire, Virginia's Warbler, Crescent-chested Warbler, Slate-throated Redstart, Black-chinned Sparrow, Western Tanager, and Flame-colored Tanager), and three others that were possibly breeding (Northern Saw-whet Owl, Audubon's Warbler, and Chipping Sparrow). Additionally, I also observed Short-tailed Hawk in 12 of 17 Sky Islands that supported pines, indicating major changes in status that have only recently been described based in part, on field work conducted during this effort (Flesch et al. 2008a, Snyder et al. 2010). Importantly, of species observed for the first time, all except Short-tailed Hawk in the Sky Islands, and Mountain Trogon, Tufted Flycatcher, Crescent-chested Warbler, and Slate-throated Redstart in the Sierra Madre were rare or distributed locally. These patterns are likely attributable to natural range expansion, limitations in past survey effort especially in remote regions and rare vegetation communities, and to changes in vegetation structure.

Species for which observed changes in status are likely attributable to recent range expansion are mainly those with strong Madrean affinities, which as a group include many species that have expanded northward in recent decades (Monson and Phillips 1981, Johnson 1994, Flesch 2008a, Rosenberg et al. 2011). Presence of Brown-backed Solitaire and Crescent-chested Warbler in three Sky Islands in Mexico, for example, including some that are close to the U.S., together with recent observations in Sky Islands in southern Arizona (Rosenberg et al. 2011) suggest range expansion. These species were not observed by Marshall (1957) anywhere in the Sky Islands region or adjacent Sierra Madre and all localities noted by Russell and Monson (1998) in Sonora were >180 km south in the Yécora region. Those patterns together with observations of Brown-backed Solitaire in the Huachinera in summer 2006 (*unpubl. data*) at sites visited multiple times by Marshall, immediately to the east in the Sierra Tabaco in summer 1995 (Lammertink et al. 1996), and of large numbers of wintering individuals along the Áros-Yaqui river corridor on the Northern Jaguar Reserve (Flesch et al. 2015), strongly suggest range expansion. Similarly, Slate-throated Redstart, which I found throughout the northern Sierra Madre and very locally in the Bacadéhuachi, may also have recently expanded its range northward across the northern Sierra Madre Occidental, thus matching similar trends in the northern Sierra Madre Oriental in northeast Mexico (McCormack et al. 2005). This warbler, which prefers mesic slopes and draws with lush groundcover in montane forest, was not reported anywhere in the region by Marshall (1957) or documented north of the Yécora region by Russell and Monson (1998). Nonetheless, recent reports from southeastern Arizona (Rosenberg et al. 2011), Mesa de las Guacamayas in Chihuahua in 1995 and 2005 (Lammertink et al. 1996, Gomez de Silva 2005), and regular occurrence in winter along the Áros-Yaqui river corridor on the Northern Jaguar Reserve (Flesch et al. 2015) strongly suggest recent range expansion, which may continue in the future. Flame-colored Tanager has likely also expanded its range in recent years as evidenced by observations in three of the taller Sky Islands immediately north of Mexico (Corman and Wise-Gervais 2005) and an absence of records in potential breeding habitat in northern Sonora before this study (Russell and Monson 1998, Flesch 2008a). Regardless, this species was extremely rare the region and observed only in tall montane riparian forest or mixed-conifer forest on the mesic east side of the Sierra los Ajos and in riparian forest and nearby uplands in the Sierra Cebadilla where it was uncommon (e.g., eight singing males or pairs), which are the highest elevation and likely most mesic areas of Sonora. Mountain Trogon may also be expanding its range across the northern Sierra Madre. Although this species was not detected in the Sky Islands and has not yet been observed in the U.S., I found it in four of six areas I surveyed in the Sierra Madre including some where it was fairly common. Those areas are all well north of the high mesas and canyons of the Yécora region, which were the northernmost localities noted by Russell and Monson (1998). Other evidence of range expansion by Mountain Trogon includes observations in extreme western Chihuahua near El Gavilán in summer 1995 (Lammertink et al. 1996) where Marshall failed to observe it in 1951, 1952 and 1955, and recent observations on Mesa de las Guacamayas (Javier Cruz Nieto, *pers. comm.*). Although not a Madrean species *per se*, Short-tailed Hawk has expanded its range >1,500 km across much of western Mexico into the Sky Islands region since the 1940s; in Marshall's time this small *Buteo* had only recently colonized the state of Colima (Schaldach 1963, Williams et al. 2007).

Observed changes in status of some species are likely due to variation in survey effort. White-striped Woodcreeper and Yellow-green Vireo, for example, have likely occurred in the Sierra Bacadéhuachi for some time as suggested by historical and recent records in nearby lowlands (Arroyo el Riíto), a lack of past surveys in this range, and little evidence of recent range expansion (Van Rossem 1945, Marshall 1957, Russell and Monson 1998, Flesch 2008b, *unpubl. data*). Similarly, presence of Berylline Hummingbird was likely due its rarity and limited past effort in the southern and eastern portions of the region where it is most likely to occur. Limited previous efforts at the highest elevations in the Sky Islands likely also explain why several species with strong Nearctic affinities had not been documented historically. Although Marshall (1957) considered the Sky Islands of Mexico too low in elevation and not sufficiently montane to support birds associated with high-elevation forest types that are found in nearby Arizona, I documented some of these species in Mexico. Marshall, for example, attributed absence of Virginia's Warbler to a lack of dense deciduous brush associated with montane forest and noted a lack of fir forest explained absences of Hermit Thrush, Western Tanager, and the gap in the range of Cordilleran Flycatcher between the higher Sky Islands in Arizona and the Sierra Madre. Nonetheless, I observed Virginia's Warbler in dense deciduous brush associated with montane forest in two of the taller Sky Islands in Sonora that are immediately south of Arizona (e.g., Mariquita and Ajos), Hermit Thrush and Western Tanager in fir and adjacent pine forest at high elevations in at least one Sky Island, and Cordilleran Flycatcher in many of the taller Sky Islands in Mexico where I specifically targeted high elevations for surveys. All of these species, however, were distributed locally and often occurred at very low densities, suggesting limitations in past effort, Marshall's focus on pine-oak woodland at moderate elevations, and the remote and rugged nature of the study area, explain a lack of past observations. Hermit Thrush, for example, was observed singing, paired, and carrying food in mixed-conifer forest on the remote east side of the Sierra los Ajos in and around the only stands of forest dominated by white fir (*Abies concolor*) in Sonora, within which they commonly nest (Martin and Roper 1988). Together with records in early August 1995 (Lammertink et al 1996) and a nest in summer 2005 (Gomez de Silva 2005) on Mesa de las Guacamayas in Chihuahua, these may be the only breeding populations of Hermit Thrush in mainland Mexico. Moreover, Western Tanager was detected in many of those same areas in the Ajos where it was singing, paired, and carrying food at times when migrants have not been found in Sonora (Russell and Monson 1998, *unpubl. data*). Moreover, this species was also observed in pine forest and adjacent pine-oak woodland in the

Púrica and Azul where evidence of breeding was less convincing. Thus, although Marshall (1957) noted Western Tanager was erroneously considered a breeding bird in Sonora based on historical observations (Van Rossem 1931, 1945, Miller et al. 1957, Howell and Webb 1995, S. Howell, *pers. comm.*), it almost certainly breeds in fir forest in the Ajos and perhaps locally at high elevations in other ranges. Together with observations of singing Western Tanager and a male attending a nest occupied by a female Flame-colored Tanager on Mesa de las Guacamayas (Gomez de Silva 2005), these may be the only breeding localities in mainland Mexico. Thus, observed changes in the status of Hermit Thrush, Virginia's Warbler, and Western Tanager are likely due to a lack of past effort at high elevations rather than true changes. Although Marshall's contention regarding the absence of high-elevation forest types and associated bird species in Mexico was largely correct, some of these habitats and species do exist but are rare and distributed locally. Regardless, a lack of spruce-fir forest explains continued absences of breeding Red-breasted Nuthatch, Golden-crowned Kinglet (*Regulus satrapa*), and Ruby-crowned Kinglet (*Regulus calendula*), which occur in at the highest elevations in some Sky Islands in Arizona (Corman and Wise-Gervais 2005).

Whereas the true status of some species associated with high-elevation forests in the Mexican Sky Islands may not have changed, at least for the time being, observed changes in the status of other associated species may be real and due to vegetation change. A small breeding population of Townsend Solitaire I documented for the first time, for example, may be due to the recovery of pines following the cessation of commercial logging (see below) or to natural range expansion. The recovery of pines together with increased survey effort, likely also explains changes in the status of Cordilleran Flycatcher. I found this species singing and nesting at low densities in many Sky Islands that reach elevations >2,000 m where dense stands of large conifers occur along rocky draws that provide small cliff faces for nesting. Although observations of Northern Saw-whet Owl and Audubon's Warbler in potential breeding habitat during the breeding season also suggest changes in status, they were observed in areas that may be too low in elevation and not sufficiently montane for breeding, as suggested by characteristics of areas where they breed in adjacent Arizona (Corman and Wise-Gervais 2005).

Despite the addition of several new species to the breeding avifauna of the Mexican Sky Islands of Mexico, other species have likely been extirpated. Thick-billed Parrot, for example, was observed by Marshall (1957) among pines in the Oposura in 1953, reported to be common by Sheffler (1931) in the Tigre in the early 1900's (based on photo evidence and reports by residents), which are the only records of this species in the Mexican Sky Islands. Nonetheless, widespread declines in the Sierra Madre due to habitat loss linked to commercial logging (Lanning and Shiflett 1981, 1983, Lammertink et al. 1996, Snyder et al. 1999) and the possibly it was only an erratic visitant (vs. a regular breeding species) likely explains its absence in the Sky Islands today. Although, Pygmy Nuthatch may still breed in some Sky Islands in Mexico despite no detections in five ranges where it occurred in the past (Van Rossem 1945, Marshall 1957), this noisy nuthatch may also be locally extinct.

Distribution.—Patterns of animal distribution are driven by the area, connectivity, and fitness potential or quality of habitat, and the effects of interspecific interactions and historical factors (Hanski and Gaggiotti 2004, Lomolino et al. 2006, Hodgson et al. 2009). Patterns of bird distribution in the Sky Islands seemed to largely match the presence and apparent quality of habitat for various species with important exceptions. In general, species associated with oak woodland, which is the dominant montane vegetation community in the region, were distributed much more broadly than those associated with pines, which cover less area, are often found in smaller patches, and occur in fewer Sky Islands. Moreover, species associated with high-elevation forest and especially broadleaf deciduous elements within forest had the most restricted distributions. Despite these general patterns, some species were not observed in patches of apparently suitable habitat, which were often small in area, isolated from other similar patches, or of low apparent quality. Although these patterns could be due to imperfect detection of species that were actually present, or to incorrect evaluations of habitat quality, a number of more mechanistic processes discussed below likely drove them.

Species associated with oak woodland were typically observed only as far west as the Sierra las Avispas-Cíbuta complex or the Sierra San Juan. This last range supports a relatively small patch of oak woodland (ca. 19 km^2) isolated from the Avispas-Cíbuta complex by broad lowland valleys. Some oak woodland species, however, also occurred further west to the Sierra el Humo. This range supports the westernmost oak woodland in the Sky Islands and thus defines the western distributional limits of Arizona Woodpecker, Mexican Jay, Bridled Titmouse and other species with strong affinities to the Sierra Madre (Flesch and Hahn 2005). Nonetheless, oak woodland in the Humo is isolated, of limited spatial extent (ca. 11 km^2), short in stature, and largely restricted to sheltered north- and east-facing slopes and draws at the highest elevations. Thus, population sizes of breeding bird species that depend on oaks are likely small and habitat quality for those that require large trees or complex vegetation structure is likely low. These factors could explain absences of Whiskered Screech-Owl, Western Wood-Pewee, Hepatic Tanager, and other species that occur to the east in the larger and less isolated Sierra San Juan where oak woodland is also better developed (Flesch and Hahn 2005, Flesch 2008a). Absence of Whiskered Screech-Owl in the Humo may reflect the distribution and connectivity of oak woodland during recent glacial maxima. This is because it is non-migratory, thought to be extremely sedentary, has not been observed away from oaks (Marshall 1957, Phillips et al. 1964, Monson and Phillips 1981), and thus may not disperse across large expanses of lowland vegetation. Because lowlands between the Humo and San Juan are somewhat lower in elevation and dominated largely by desertscrub (vs. those between the San Juan and Avispas-Cíbuta that are higher and dominated by grassland), they may not have provided woodland connections between ranges during the Pleistocene. Nonetheless, presence of Arizona Woodpecker and Mexican Jay in the Humo, which are also non-migratory but occasionally found away from breeding habitat (Marshall 1957, Phillips et al. 1964, Monson and Phillips 1981), suggests extinction risks posed by small population size or low habitat quality may have also driven these patterns. Alternatively, the possibility Whiskered Screech-Owl was present but undetected is unlikely given its highly territorial nature and efforts to locate it with recorded territorial calls in the best potential habitat in 2004, 2006 (*unpubl. data*), and during this study. Failure to detect some species, however, may explain other apparent absences. For example, Montezuma Quail was observed only as far west as the San Juan but was likely present in the Humo; this often secretive quail has been described by local residents (Enrique Zepeda, *pers. comm.*) and was collected somewhere west of Sasabe near the Humo in 1961 (Russell and Monson 1998).

Low habitat quality or small habitat patch size likely explains distribution patterns of other species associated with oak woodlands. Band-tailed Pigeon, Northern Pygmy-owl, Elegant

Trogon, White-breasted Nuthatch, and Brown Creeper, for example, were distributed only as far west as the Sierra las Avispas-Cíbuta complex or the nearby Sierra Esmeralda. These species likely require larger patches of woodland with greater structural complexity than exists in the Humo or San Juan where there is no evidence they have bred. Nonetheless, Elegant Trogon was observed in the San Juan in November (Flesch and Hahn 2005) where breeding habitat may occur very locally. Acorn Woodpecker was observed in the Humo in 2010 and possibly in 1975 when S. Russell observed a likely individual from a great distance (*pers. comm.*) and has been observed outside breeding season in the San Juan (Flesch and Hahn 2005). Nonetheless, this species is a common straggler away from its breeding range even in summer and likely breeds only as far west as the more extensive and taller oak woodland of the Avispas-Cíbuta complex, except perhaps in exceptional mast years. Although Band-tailed Pigeon has bred as far west as the southwestern foothills of the las Avispas (at la Arizona in June 1929; Van Rossem 1931), oaks may now be too sparse to support breeding there today.

The distributional limits of species associated with pines largely matched the distribution of pine-oak woodland, but in some cases extended into smaller stands of pines at the limits of their range. Most species associated with pines occurred only as far west as the Sierra el Pinito, which is a large range that supports extensive pine-oak woodland and some pine forest on the highest north-facing slopes. Nonetheless, Short-tailed Hawk, Cordilleran Flycatcher, and Steller’s Jay, which are largely obligated to areas with tall conifers in the region, occurred to the south in the neighboring Sierra la Madera where pines cover much less area and pine-oak woodland is restricted to few patches at the highest elevations. Short-tailed Hawk and Steller’s Jay, which nest in pines in the region, as well as American Robin, which is often found in areas with pines, occurred further west around the summit of the Sierra Cíbuta. This range includes a small peak that reaches an elevation of 2,060 m and supports the westernmost pines in mainland Mexico. Pines in the Cíbuta, however, are fairly sparse, virtually never more dominant than oaks, and many adults had recently died and were in poor condition. Thus, low habitat quality or insufficient habitat patch size may explain absences of Greater Pewee, Plumbeous Vireo, Olive Warbler, Grace's Warbler, Yellow-eyed Junco, and other species that depend on pines south and west of the Pinito. Nonetheless, some bird species often found among pines or other tall conifers such as Spotted Owl, Mexican Whip-poor-will, and Brown Creeper occurred in all three of these ranges, and in the remarkable case of the whip-poor-will, nearly 100 km west on the north side of the highest peak in the Humo. Despite presence of these species at the western distributional limits of pines, they were virtually all rare with the exception of Greater Pewee, Plumbeous Vireo, Steller’s Jay, Grace's Warbler, and Yellow-eyed Junco in the Pinito.

Highly restricted distributions of species associated with high-elevation coniferous forest, and especially broadleaf deciduous elements within forest, was due to the rarity of those environments. These species rarely occurred west of the Sierra los Ajos and were often absent from small patches of potentially suitable habitat. Breeding habitat for Red-faced Warbler, for example, which occurs in forest with brushy deciduous growth, was largely absent west of the Ajos where it was rare except locally in riparian forest at high elevations on the mesic east side of the range. Habitat for Virginia’s Warbler was distributed even more locally and occurred west to the Sierra Mariquita where there are dense stands of New Mexican locust. Although House Wren occurred in areas with large pines and low brush in the Elenita and Mariquita, it was not observed in pine forest in the Azul or in mixed-conifer forest in the Tigre, which may be too arid to provide suitable forest structure. Similarly, although Hairy Woodpecker was found as far west as the small patch of pine forest around the summit of the Sierra Azul and at the highest elevations in the Elenita and Mariquita, it was not observed in the Tigre where breeding habitat seemed to be present but surveys in late June may have been too late to detect it. Importantly, Northern Goshawk, which require cool shady conditions and tall trees that provide sufficient space for maneuvering below the canopy, occurred as far west as the Pinito, and in the Elenita and Ajos.

Why organisms are absent from patches of suitable habitat is a question that has perplexed biologists for generations. The Madrean Sky Islands feature many examples of this pattern that have not been investigated rigorously and quantitatively. The distribution pattern of Mexican Chickadee provides an excellent example. This small songbird occurs only in a narrow band of Sky Islands immediately north and west of the Sierra Madre (Marshall 1957, Phillips et al. 1964) but not in what appears to be suitable habitat in mountains of somewhat similar area to the west (e.g., Ajos, Púrica, Elenita) where it has never been observed (Russell and Monson 1998, Flesch 2008a). Notably, interspecific competition likely does not explain this pattern because island vacancies are not filled by ecologically similar congeners such as Mountain Chickadee (*Poecile gambeli*) or arranged in the characteristic "checkerboard" (*sensu* Diamond 1973) pattern that often results from competition. Although areas where populations have not been observed may not in fact provide suitable habitat, this pattern is more likely a result of limited propensity for dispersal, tendency to not leave breeding habitat, and to the absence of woodland connections across lowlands that connected montane habitat islands during past glacial maxima. The historical distribution of movement corridors during the last glacial maximum has been found to affect genetic variation and divergence times in populations of Mexican Jay (McCormack et al. 2008) and snakes (Holycross and Douglas 2007) that do not disperse across lowland vegetation in the region. Historical connectivity among mountain ranges may be important in explaining the current distribution of chickadees, Whiskered Screech-Owl, and other sedentary species of resident birds that are obligated to montane vegetation.

In addition to levels of historical connectivity, other processes such as higher extinction risks of small and isolated populations may also explain absences of some species from habitat islands. Yellow-eyed Junco, for example, was detected only in Sky Islands in the northern and eastern portions of the study area that supported large stands of pines and not in the Aconchi where it occurred in the 1950s or in the Oposura where it has never been observed (Russell and Monson 1998). Although numerous lowland records and its ability to winter in oak woodland below preferred breeding habitat in pine forest (Phillips et al. 1964, Monson and Phillips 1981) suggest it is less sedentary than Mexican Chickadee, dispersing Yellow-eyed Junco likely rarely reach small and distant patches of habitat in those ranges. Moreover, Steller's Jay, which is also resident but found in lowlands in some years, was not detected in the Aconchi where it occurred in 1954 (Marshall 1957) despite ample survey effort. Thus, lower immigration rates, higher extinction risks posed by small population size, and perhaps low habitat quality or habitat degradation due to past logging may explain apparent absences of these species. More rigorous assessments of factors that drive distribution patterns and of minimum thresholds in habitat area and isolation needed to promote occupancy among species with varying dispersal abilities will be possible in the future using data I assembled during this effort on the area, current and historical isolation, and local habitat quality.

Spatiotemporal Variation in Distribution.—I documented numerous populations in Sky Islands where they had not been described in the past but failed to observe others that had been described. Importantly, these patterns were not limited to rare species and included those that were fairly common and readily detectable during the breeding season. Collectively, these patterns and similar traits among species that exemplified them suggested important distributional and environmental changes in the region many of which had not been described. Processes that likely drove these patterns include local colonization and extinction events driven by stochastic processes linked to variation in island size and isolation, changes in vegetation structure or management that have affected the quantity and quality of habitat, and to differences in the location, timing, and intensity of survey effort.

Changes in vegetation structure and composition have likely been pervasive in many portions of the study area. Marshall (1957), for example, noted the effects of commercial logging on the cover and dominance of pines in many Sky Islands in Mexico. In the early 1950s, he noted the loss of much pine due to logging in the Azul, Pinto, Aconchi, Tigre, Cananea, and in the central Ajos, and that local hand sawing had removed some of the larger pines in the southern Oposura. Only in the Púlpito, where he worked on the high northern mesa where pines are naturally sparse, and in the San Luis, where he worked in canyons that supported few pines, did he note the absence of logging. In the Sierra el Tigre, these changes likely occurred over the span of a single decade. In 1941, S. White (1948) described the presence of old growth pine forest in the Tigre, which may have provided breeding habitat for the population of Thick-billed Parrot noted by Sheffler (1931) and that according to Marshall (1957) may have supported Eared Quetzal and Imperial Woodpecker (*Campephilus imperialis*). By the time Marshall reached the Tigre in 1953, however, most of the old pines had been logged and reduced to what he described as dense charred second growth. Although the once pristine groves of old pines are largely gone from ranges where Marshall lamented the effects of logging, I found that signs of recent logging were absent in the Sky Islands and even signs of small-scale woodcutting were sparse. For example, I observed moderate to high levels of recent cutting at only 3% of survey stations most of which were in the adjacent Sierra Madre where commercial logging remains widespread. I found that Sky Islands logged roughly 65 to 90 years ago supported large stands of pines of typically small to moderate sizes on slopes and occasionally much larger sizes in draws, and that pine-oak woodland and pine forest had matured at rapid rates. Today, these areas provide important habitat for birds and other wildlife, and their ecological and economic values are likely to increase at accelerating rates in future decades as they mature. Moreover, the extensive network of logging roads I found in ranges where Marshall noted logging, were largely in disrepair. Thus, these montane forests and woodlands were much less accessible, which greatly enhances their value as wilderness. Only in the Oposura, Púlpito, and San Luis where Marshall (1957) and I observed little to no signs of past logging, and in the Juriquipa, San José , and Pan Duro, were roads into the high country absent or very sparse.

The cessation of logging and subsequent recovery of pines has undoubtedly affected the distribution and quality of habitats for birds that depend on them. These changes together with variation in the location and intensity of past effort likely explain many distributional changes I documented. In general, I found breeding populations of montane bird species that depend on pines to be much more broadly distributed than suggested by past efforts, and importantly, these patterns are not based only on ranges not visited by Marshall (1957) or others (Van Rossem 1945, Russell and Monson 1998) in the past. Sharp-shinned Hawk and Northern Goshawk, for example, were found in several ranges where they had not been observed in the past. Although higher effort could explain these patterns, especially for such species that occur at low densities, dependences on mature forest conditions that afford space to maneuver below the canopy that was likely rare following logging, also explains these trends. Moreover, presence of Hairy Woodpecker, Greater Pewee, Plumbeous Vireo, Grace's Warbler, Olive Warbler, and perhaps Buff-breasted Flycatcher and Cordilleran Flycatcher, in pine forest and pine-oak woodland in many Sky Islands where they had not been documented in the past (Table 4) was likely due to recolonization of new habitats created by the cessation of logging and recovery of pines. This is especially likely in places where Marshall (1957) described extensive logging (e.g., Elenita, Azul, Pinito, Tigre) where I visited many of the same areas he worked. Possible exceptions include the Sierra el Pinto where I worked at somewhat higher elevations in the central portion of the range that Marshall (1957) who worked to the south at El Oso (and at el Pinito where I worked but is too low to support many of those species). In the Elenita, Marshall noted working at lower elevations and may not have visited areas near the summit that support higher densities of those species but where logging was likely to have been most intense. Regardless, in contrast to patterns for species associated with pines, distributions of species associated with oaks have been largely stable across time, which further implicates the recovery of pines in driving these changes in distribution. Although separating the effects of changing vegetation structure from variation in survey coverage is complex, there is little doubt the cessation of logging has had marked affects on the presence and quality of resources for many bird species.

Logging activities and the human populations they introduce can increase hunting and other stressors on wildlife. Marshall (1957) attributed the rarity of Wild Turkey in the Sky Islands of Mexico and nearby Sierra Madre to the effects of hunting, and A. S. Leopold (1949) found Wild Turkey to be much more common in the Sierra Madre near El Gavilán only a decade earlier. During my efforts, however, most logging roads were in disrepair and most mountain ranges were largely devoid of permanent settlements and bore few signs of recent human activity. Thus, with the exception of the growth of towns and cities near the bases of the Pinito, Madera, Elenita, Oposura and other nearby ranges, human activities other than cattle ranching (limited except at lower elevations) and in some cases mining (restricted to few areas), seemed much more limited than in past decades. Much broader distributions of Wild Turkey are emblematic of these changes. I found Wild Turkey, for example, in 16 Sky Islands including 13 where it had not been documented in the past, which provides strong evidence it much more broadly distributed than during Marshall's and perhaps Russell and Monson's (1998) efforts. Although Wild Turkey was uncommon, these changes are likely a result of lower accessibility, reduced hunting pressure, and improved management by local landowners. The apparent recovery of this and others populations of birds in the Sky Islands in combination with recent creation of wildlife management units and a tendency for rural residents to move to urban areas (Cartron et al. 2005, Sisk et al. 2007) offers auspicious prospects for conservation.

Despite these auspicious trends, absences of some species in areas where they had been observed in the past were also conspicuous and suggest distributions of some species have also contracted. Thick-billed Parrot was not detected in two Sky Islands or in the Sierra Huachinera where it was observed before 1960, or in the Sierra Madre at Cebadilla and El Macho where it was observed more recently (Van Rossem 1945, Marshall 1957, Cirett Galán and Rogero Diaz 1993, Lammertink et al. 1996). Additionally, Flammulated Owl, Violet-green Swallow, and Pygmy Nuthatch were not observed in Sky Islands where they occurred in the past, Purple Martin was not observed in the Sky Islands or Sierra Madre where there were breeding records from earlier decades, and Eared Quetzal was not observed in areas of Sierra Madre were it occurred historically (Van Rossem 1945, Marshall 1957, Phillips 1986, Cirett Galán and Rogero Diaz 1993, Lammertink et al. 1996, Russell and Monson 1998). Although many of these species were likely rare or uncommon before the age of commercial logging, and in some cases are at or near the limits of their ecological tolerances in the region, evidence suggests they were more broadly distributed in the past. Importantly, all of these species require mature montane forest and large trees with cavities for breeding that often occur in the largest pine and Douglas fir trees and snags (Lanning and Shiflett 1983, Lammertink et al. 1996, Monterrubio Rico and Enkerlin Hoeflich 2004, González-Rojas et al. 2008). These legacies of old forests are often among the last habitat features to regenerate following logging (Franklin et al. 2000) and were often sparse in Sky Islands I visited, which likely explains these patterns. Widespread declines of species dependent on old forests and large snags due to past logging have been described across coniferous forests of the western U.S. (Brawn and Balda 1988, Raphael et al. 1988, Hejl 1994) and likely explain the unfortunate fate of the Imperial Woodpecker (Lammertink et al. 1996). Thus, although pines seems to have largely recovered in many Sky Islands following the cessation of logging, these areas will require more time and potentially active management before they support the habitat features and species found historically.

More local vegetation changes likely explain absences of other populations. Grace’s Warbler, for example, was not observed in the few small stands of live pines in the high Sierra Cíbuta despite historical records (Van Rossem 1945) and Grace’s Warbler, Greater Pewee, Pygmy Nuthatch, and Yellow-eyed Junco were not detected in small stands of pines restricted to the highest north faces in the San José despite specimens from the 1890s (Van Rossem 1945). Nonetheless, a likely breeding population of Black-chinned Sparrow documented for the first time, combined with extensive mountain scrub and Mearns’ (1907) descriptions of greater pine cover suggest intense wildfire has affected vegetation and bird communities in this small range. In the Cíbuta, poor condition and high mortality of adult pines suggest they are declining and that a few remaining populations of pine-dependent birds are threatened, which is likely due to recent drought that could be linked to climate change.

Biogeographical Relationships.—Quantitative biogeographical regionalizations can provide important insights into the ecological and evolutionary forces that shape regional biotas and offer a useful framework to identify unique species assemblages with high conservation value (Kreft and Jetz 2010). Moreover, such efforts can also help delimit biogeographical boundaries and transition zones among them, which have fascinated zoogeographers for generations but have traditionally been based on qualitative methods (Sclater 1858, Darlington 1957, Morrone 2009). Biogeographical relationships among faunal communities in the Sky Islands region and the historical processes that have shaped them have been contemplated for some time (e.g., Marshall 1957, Findley 1969, Hubbard 1974, Lowe 1992, Findley 1996). Nonetheless, to my knowledge, biogeographical regionalizations across the entire Sky Islands region have never been assessed quantitatively based on detailed distributional data. Moreover, insights on the boundary between the Sky Islands and adjacent Sierra Madre Occidental (and in most cases the Mogollon Plateau) have been based largely on vegetative, topographical, and physiographical criteria (e.g., Marshall 1957, Ferguson et al. 2013, Brusca and Moore 2013), less often on plant (e.g., McLaughlin 1992, 1995) and animal (e.g., Flesch and Hahn 2005) distribution, and rarely on quantitative estimates of dissimilarities among community assemblages (Kobelkowsky-Vidrio et al. 2014). These gaps of knowledge are due likely to a dearth of distributional data from the region, which were especially limited in Mexico. Regardless, answers to these questions are important given the ecological, biogeographical, and conservation significance of the Sky Islands region and more broadly for understanding the biogeography of a vast transition zone between the Nearctic and Neotropical faunal realms known as the Mexican Transition Zone, which at its northern end is dominated by the Madrean Sky Islands and adjacent Sierra Madre (Halffter 1987, Kobelkowsky-Vidrio et al. 2014). Here, I addressed these questions using data on breeding bird communities gathered during exhaustive field work in nearly all Sky Island ranges in Mexico, with recent data from southern Arizona, and the most appropriate analytical tools (Kreft and Jetz 2010).

Results of regionalizations from across the Sky Islands and adjacent Sierra Madre were largely biogeographically and spatially coherent, and also produced some novel insights. I confirmed an important and largely discrete biogeographical transition between the Sierra Madre and adjacent Sky Islands. Despite the prominence of this discontinuity, it was characterized by only moderate levels of turnover driven largely by eight species that occurred exclusively in the Sierra Madre and by many others that occurred in few Sky Islands. In comparison to magnitudes of dissimilarity between communities of volant mammals between the Nearctic and Neotropical faunal realms, which occurs at a higher level of biogeographical organization, differences between breeding bird communities between the Sierra Madre and Sky Islands were only half as great (e.g., β_{sim} values of 0.8 vs. 0.4) based on identical methods, and somewhat greater for non-volant mammals (Kreft and Jetz 2010). Regardless, results of both ordination and hierarchical cluster analyses indicated a clear biogeographical division between the Sky Islands and Sierra Madre. Moreover, my results also confirmed that the boundary between the Sky Islands and Sierra Madre based strictly on biogeographical criteria (e.g., differences in community assemblages of breeding birds), conforms largely with that based on topographical and physiographical criteria, and to a lesser extent, on contemporary levels of connectivity among oak woodlands (Marshall 1957, McLaughlin 1995, Brusca and Moore 2013, Ferguson et al. 2013). Based on floristic criteria, McLaughlin (1995) found that the boundary between the Sky Islands and Sierra Madre was somewhat equivocal. Moreover, Brusca and Moore (2013) considered the boundary to be west of the Tigre and Bacadéhuachi and north of the Púlpito based on what they thought to be sufficient levels of connectivity of oak woodlands between these ranges and the Sierra Madre. In contrast, results based strictly on biogeographical criteria suggest the boundary between these regions is much more discrete and that all three of these mountain ranges with the possible exception of the Sierra Bacadéhuachi should be considered Sky Islands. Although the Bacadéhuachi was clustered with the Sierra Madre due likely to shared occurrences of many Madrean species, including some not found in other Sky Islands, community composition in ordination space was more similar to that in nearby Sky Islands that also supported thornscrub at lower elevations and pines at higher elevations. In a biogeographical sense, the boundary between the Sierra Madre and Sky Islands should be based on the composition of plant and animal communities and thus conform to historical levels of topographic, physiographic, and vegetative connectivity, which have traditionally been used to define this boundary. Data on taxa other than birds are needed to corroborate these patterns.

The Sky Islands region has been described as a biogeographical transition zone where species of Madrean, Petran, Chihuahuan-Great Plains, Sonoran, and Sinaloan (e.g., lowland Neotropical) affinities mix (Findley 1969, McLaughlin 1995, Warshall 1995). By revealing a clear discontinuity in community composition between the Sky Islands and Sierra Madre, and fairly continuous changes in turnover across the region, my results largely confirm this suggestion. Not surprisingly, changes in turnover were more highly correlated with the latitudinal vs. longitudinal position of mountain ranges. This is likely because the principal source pools of species that contribute to communities in these montane islands are mainly of Madrean and Petran origins and reside principally to the north or south. In contrast, contributions to these communities of Chihuahuan, Sonoran, and Sinaloan origins, which occur more along east-west gradients, are smaller and largely affect communities at lower elevations near the bases of the Sky Islands. Nonetheless, because I considered data on breeding birds only from what has traditionally been considered the Sky Islands region and areas in the nearby Sierra Madre, my inferences do not extend beyond those areas and address regional boundaries at larger scales.

On floristic grounds, the Sky Islands region was described as being roughly coincident with the Apachian sub-province of the Madrean floristic province (McLaughlin 1989, 1992, 1995). That regionalization was based on an ordination technique (PCA) similar to that used here (NMDS) and on floristic data from across the western U.S., which were available for few Sky Islands in the U.S. and none in Mexico. Thus, to my knowledge, the northern boundary of the Sky Islands region has been defined only on floristic grounds (e.g., McLaughlin 1992, 1995) and Marshall's (1957) qualitative, but nonetheless profound observations regarding changes in the relative association of pines and oaks north and south of the Santa Teresa mountains that has traditionally been considered the boundary (but see Brusca and Moore 2013, Moore et al. 2013). Although the western boundary of the Sky Islands region is well defined based on the distribution of oak woodland and associated animal species, the location of the southern boundary is vague (McLaughlin 1995, Flesch and Hahn 2005, Van Devender et al. 2013). Given the presence of some distinctively Madrean species north of the Santa Teresa mountains (e.g., Yellow-eyed Junco in the Pinal Mountains; Corman and Wise-Gervais 2005) and south of the Sierra Aconchi (e.g., White-striped Woodcreeper and Arizona Woodpecker in the Sierra Mazatán; Flesch and Hahn 2005), and a lack of quantitative regionalizations based on floral and faunal communities in the region, methods described here should be applied to assessing these regional boundaries more rigorously for more taxa.

Despite largely continuous gradients in turnover across the Sky Islands region, there were also significant but variable levels of regionalization among them. These patterns reflected high levels of biogeographical complexity in this region driven by its geographical position, steep but variable elevation gradients, Madrean and Petran influences at higher elevations, and to a lesser extent, Sonoran, Sinaloan, Chihuahuan, and Great Basin influences at lower elevations (Findley 1969, Hubbard 1974, McLaughlin 1995, Warshall 1995). With regard to regionalizations within the Sky Islands, I found evidence for three discrete groups of ranges with varying levels of internal regionalization. A group of southern Sky Islands that are all in Mexico, with two exceptions (Chiricahua and Huachuca Mountains) had stronger Madrean affinities and little internal regionalization. This group was distinguished from a much smaller group of western Sky Islands located at the edge of the Coastal Plain that have much stronger Sonoran and lowland

Neotropical affinities. Those two groups were distinguished from a larger group of northern Sky Islands that had much higher levels of internal regionalization and thus more complex biogeographical affinities. Fairly continuous variation in community composition across the southern group of Sky Islands is likely driven by consistently strong Madrean influences and fairly similar elevational profiles that promote similar vegetation communities at both high and low elevations. In the northern Sky Islands, however, Madrean influences are lower, Petran influences increase as mountains attain greater elevations, and longitudinal positions, elevation ranges, and vegetation communities are much more variable. Such conditions likely drive higher and less continuous levels of regionalization in the northern Sky Islands, which have more complex biogeographical affinities.

Quantitative regionalizations of the Sky Islands based on breeding bird communities conflict somewhat with qualitative insights on herpetofaunal communities. Lowe (1992) described what he considered to be a major biogeographical line across the Sky Islands region that was roughly coincident with U.S. Interstate Highway 10, which he compared to Wallace's Line in the Asian East Indies. Based on distributions of montane rattlesnakes (*Crotalus* spp.), he noted this line corresponded with the northern distributional limits of Madrean species and southern limits of Petran species, and also noted the line applied to birds (pg. 95) on which he provided no data. More recently, this purported biogeographical line was described to apply more generally to all herpetofauna despite the availability of few Petran species to test it (Swann et al. 2005, Flesch et al. 2010b). My results based on dissimilarities among communities of breeding birds in 48 mountain ranges across the Sky Islands region suggest the location of Lowe's line is equivocal at best, vastly less significant than Wallace's Line, and could be located further south. All 22 mountain ranges I considered in the U.S., except the Chiricahua and Huachuca Mountains, and some northern ranges in Mexico that support mainly oak woodland, were included in the northern group of Sky Islands that have lower Madrean affinities. This suggests that for birds, any line resembling a "Madrean line" may be located further south and east of Mexico Route 15. The presence and location of such a Madrean line or other discrete biogeographical transition should be based on a broader range of taxa and on objective quantitative tools such as those used here. Future biogeographical regionalizations in the Sky Islands region should also consider mountain ranges I failed to visit (e.g., Sierra el Carmen, Sierra Enmedio, Sierra el Pinito-Sombreretillo complex, Animas Mountains) and those outside of what has traditionally been considered the Sky Islands region.

*Bird-Habitat Relationships.—*Understanding how environmental attributes affect the abundance of wildlife populations is a fundamental aspect of applied ecology that is essential for guiding management. I assessed variation in densities of 72 species of breeding birds among eight major montane vegetation communities. Moreover, I identified and described the effects of important attributes of vegetation structure and physiognomy, disturbance, and other habitat features on densities of 30 bird species. These efforts produced many important inferences on bird-habitat relationships, only some of which are discussed here. Quantitative inferences on bird-habitat relationships in Madrean woodland and forest types are particularly important because studies in the Sky Islands region (e.g., Balda 1967, Ganey et al. 1996, Hall and Mannan 1999, Martin and Morrison 1999, Conway and Kirkpatrick 2007, Kirkpatrick and Conway 2010, Sanderlin et al. 2013) are still relatively rare compared to those elsewhere in North America including those in somewhat similar montane vegetation communities on the adjacent Mogollon Plateau (e.g., Brawn and Balda 1988, Block and Finch 1997, Rosenstock 1998, Jentsch et al. 2008). Moreover, because I considered the potentially confounding effects of variation in detection probabilities when assessing bird-habitat relationships, which has rarely been considered in the region (but see Kirkpatrick and Conway 2010, Sanderlin et al. 2013), inferences reported here are more reliable.

Densities of most bird species varied among vegetation communities suggesting some level of general habitat specialization. Importantly, much larger proportions of species occurred at peak densities in mixed-conifer forest and montane riparian areas, and many of these species were fairly restricted to these communities and thus found at dramatically higher densities within them. Nonetheless, because areas around most stations were dominated by >1 vegetation community and stations classified based on a single dominant community type, levels of habitat specialization are likely somewhat higher than reported here. Regardless, my results are nearly identical to those reported by Marshall (1957; pg. 65), similar to those found for occupancy probabilities of montane species in the Sky Islands of neighboring Arizona (Sanderlin et al. 2013), and suggest habitat breadths of species associated with mixed-conifer forest and montane riparian areas are fairly narrow in the region. I also found important effects of cover of coniferous and of broadleaf deciduous trees on densities of 57% of 30 species, which are habitat attributes associated with those vegetation communities. Thus, given the rarity of mixed-conifer forest and montane riparian areas in the Sky Islands region, these communities and species that depend on them are good foci for conservation efforts. Although a considerable proportion of species also occurred at peak densities in pine forest, with similar results for occupancy probabilities (Sanderlin et al. 2013), densities of these species were also often similar in adjacent pine-oak woodland or mixed-conifer forest, suggesting lower levels of habitat specialization. In contrast, fewer species occurred at peak densities and were relatively restricted to oak or pine-oak woodland, which conflicts somewhat with Marshall's (1957) results, but was likely driven by the fact that oaks and pines are dominant components of many vegetation communities I considered.

Marshall (1957) made major contributions to our understanding of bird-habitat relationships in Madrean forest and woodland types. Although he focused on pine-oak woodland, he also provided important insights based on impressions from adjacent vegetation communities he visited incidentally. In contrast to Marshall's approach, I differentiated between oak-pine and pine-oak woodland based on relative dominances of oaks vs. pines despite the continuous gradient between them. Moreover, I also differentiated between pine and mixed-conifer forest that Marshall considered together likely given his focus at lower elevations. These factors, more systematic effort across all major montane vegetation communities, and the more contemporary survey and modeling methods I used, likely explain some differences between our findings. Nonetheless, the vast majority of Marshall's largely qualitative inferences on bird-habitat relationships were remarkably consistent with those I derived based on detectability-corrected estimates of bird densities and detailed quantitative measurements of vegetation and other habitat attributes. For example, Marshall's accounts of habitat use by many species often implicated the same habitat attributes indentified by my modeling efforts. Below, I compare some of our inferences on bird-habitat relationships and those of other efforts and focus largely on instances where they varied.

Marshall (1957) noted 12 species that reached their greatest abundance in pine-oak woodland (Montezuma Quail, Whiskered Screech Owl, Mexican Whip-poor-will, White-eared Hummingbird, Acorn Woodpecker, Dusky-capped Flycatcher, Greater Pewee, Eastern Bluebird, Western Bluebird, Hutton Vireo, Painted Redstart, Hepatic Tanager) but found that very few of them (e.g., Painted Redstart) depended upon a combined life forms of both pines and oaks. Although I focused on the 72 most abundant diurnal species and thus did not consider owls or nightjars, some of our inferences varied. Marshall, for example, considered Montezuma Quail to be more abundant in pine-oak than in oak woodland, and in Mexico, Leopold and McCabe (1957) considered it an indicator species of pine-oak woodland. In contrast, I found Montezuma Quail to be vastly more abundant in oak savannah, oak woodland, and montane riparian areas, which are more likely to support dense grasses and forbs that seem to be the principal resources that drive habitat use (Stromberg 1990, 2000). Acorn Woodpecker was much more abundant in montane riparian vegetation than in oak and especially pine-oak woodland, and densities increased markedly with decreasing cover of conifers and increasing tree species diversity. Although riparian areas where Acorn Woodpecker occurred often supported large oaks and were immediately adjacent to oak or pine-oak woodland, presence of large trees for granaries and their tendency to roost in locations with good visibility may explain these patterns. Marshall noted associations between Dusky-capped Flycatcher and dense woodlands dominated by broadleaf trees, large trees, and both riparian and upland areas, and, although he noted their use of any woods considered them a species of pine-oak woodland. His verbal model was remarkably similar to my quantitative model, which indicated increasing densities with increasing cover of oaks and broadleaf deciduous trees, tree density, and areas near drainage channels. Nonetheless, Dusky-capped Flycatcher densities were considerably higher in oak woodland, oak-pine woodland and montane riparian areas than in pine-oak woodland, which suggests pines are less important than indicated by Marshall. Moreover, although Marshall considered Greater Pewee to be most abundant in pine-oak woodland, I found that densities were >2-times greater in pine and mixed-conifer forest and were explained only by conifer cover. Finally, although Marshall also thought abundance of Hepatic Tanager peaked in pine-oak woodland, despite their use of a variety of communities, I found that densities were very similar in oak woodland and pine forest and that oak cover had a much greater effect on densities than conifer cover.

Inferences on bird-habitat relationships for species thought to be associated with vegetation communities other than pine-oak woodland conformed with those of other studies to varying degrees. Marshall thought Buff-breasted Flycatcher densities peaked in riparian woodland but noted their use of a wide range of vegetation communities, and Martin and Morrison (1999) noted strong positive associations between occupancy and areas with low slopes and open canopies of large pines vs. oaks. I found that densities of Buff-breasted Flycatcher were very similar in all forest and woodland types dominated by tall conifers, similar but somewhat lower in riparian woodlands, and much lower in oak-pine woodland. Nonetheless, estimated densities in riparian areas would have been higher if only those riparian points located in areas dominated by pines were considered. Although, sample sizes were insufficient to assess associations between densities of Buff-breasted Flycatcher and specific habitat attributes, it seemed most abundant in open groves of large pines with little to no mid-story and understory cover, and in areas where signs of past wildfire were common, which conforms with recent observations from neighboring Arizona (Martin and Morrison 1999, Conway and Kirkpatrick 2007). Marshall considered Black-throated Gray Warbler to be most abundant in oak woodland and areas with junipers, but I found them at similar densities in oak, oak-pine, and pine-oak woodland, and especially in areas with dense cover of short oaks. Marshall considered Elegant Trogon to be most abundant in riparian woodland and secondarily pine-oak woodland and noted their use of oaks and broadleaved deciduous trees in the mid-story while foraging, and Hall and Mannan (1999) noted associations with both riparian and upland vegetation communities. Although I also found that densities of Elegant Trogon peaked in riparian woodlands, they were similar in all communities that supported oaks except pine-oak woodland where they were lower and were much lower in pine forest. Additionally, densities of Elegant Trogon also declined with increasing cover of conifers, which further suggested the importance of oaks. Marshall considered Spotted Owl to be obligated to forest conifers and in southern Arizona, Ganey and Balda (1989) noted their occurrence in steep canyons with oaks and riparian trees. Although my inferences were strictly qualitative, I found Spotted Owls in virtually all mountain ranges that supported large areas of pines (with exceptions due largely to windy survey conditions) and also in areas dominated by large riparian trees (e.g., Sierra las Avispas) and oaks in those ranges where tall conifers were absent (e.g., Cucurpe) or sparse (e.g., Cibuta, San Antonio, Juriquipa), which indicates fairly broad habitat breadth in the region. Although Marshall noted associations between Thick-billed Parrot and pine forest, I found densities were ~10-times greater in mixed-conifer than in pine forest, suggesting the importance of Douglas fir that is frequently used for nesting (Monterrubio Rico and Enkerlin Hoeflich 2004). Finally, Marshall noted the importance of open pine forest vs. pine-oak woodland for Yellow-eyed Junco, and Kirkpatrick and Conway (2010) found strong positive associations between nest-site selection and proximity to drainage channels and coverage of woody debris, low brush, forbs, and grasses, and negative associations with canopy cover. Those patterns conform generally to my findings that densities were much higher in forest than woodland, and increased as coverage of broadleaf deciduous and conifer trees, shrubs, and open conditions in the mid-story and canopy also increased.

Since Marshall's (1957, 1963) remarks on the effects of wildfire on bird communities in montane vegetation communities in the Sky Islands, the effects of fire on birds in Madrean forest and woodland types have been relatively little studied (e.g., Horton and Mannan 1988, Ganey et al. 1996, Short 2003, Bock and Block 2005, Kirkpatrick et al. 2006, Kirkpatrick and Conway 2010) vs. elsewhere in western North America (e.g., Hejl 1994, Hutto 1995, Saab and Powell 2005). Although existing studies provide important insights on the effects of fire on birds, broad generalizations are challenging because effects often vary in complex ways among species and with fire intensity, pre-fire conditions, and time-since-fire (Smucker et al. 2005, Hutto, *in prep.*). Nonetheless, some of my findings conform to those of past studies in the Sky Islands or other regions of western North America. After adjusting for the effects of important habitat attributes, I found that densities of 17% of bird species varied with an index of fire severity based on the degree of vegetation disturbance due to fire, and that fire effects were universally positive. Thus, the effects of fire conformed generally to that in Sky Islands of Arizona where occupancies of 17% of 65 species and relative abundances of 25% of 16 species varied with a similar index of fire severity, and where fire effects were positive for 73% of species (Kirkpatrick et al. 2006). With regard to specific species, I found that densities of Grace's Warbler and Spotted Towhee responded positively to fire severity, which conforms generally with results from Arizona (Kirkpatrick et al. 2006). Moreover, I found that densities of Northern Flicker, American Robin, and Yellow-eyed Junco also responded positively to fire, which conforms generally with results from elsewhere in western North America (Hejl 1994, Smucker et al. 2005, Dickson et al. 2009) but has not been found in Madrean forest and woodland types (Short 2003, Kirkpatrick et al. 2006). In the case of Spotted Towhee, these patterns were almost certainly driven by an abundance of epicormic oak sprouts that create a dense shrub layer in years shortly after fire. With regard to American Robin, Yellow-eyed Junco, and perhaps Grace's Warbler, these patterns could be driven by preferences for more open forest conditions. Marshall (1963), for example, attributed lower densities of American Robin, Yellow-eyed Junco, and other species in the Sky Islands of Arizona to much denser stand structure driven by fire suppression, and suggested higher densities in Mexico were due to more open forest conditions maintained by frequent low-severity fire. Although I did not assess differences in bird densities or stand structure between countries, cross-border differences in the presence and extent of fire sign seems to persist today. In vegetation communities dominated by pines in eight Sky Islands in Arizona, for example, Kirkpatrick et al. (2006) observed evidence of wildfire at 27% of 1,513 points, of which 73% showed signs of low-severity fire. In comparison, in a broader range of vegetation communities in Mexico, I observed evidence of wildfire at 42% of points, of which 84% showed signs of low-severity fire. Future studies of fire effects in Madrean forest and woodland types should consider more species and assess the effects of time-since-fire across a broad range of fire severities and pre-fire conditions at multiple spatial scales.

Conservation and Management.—The Sky Islands region is an important conservation priority of global recognition (Felger and Wilson 1995, Foreman et al. 2000, Mittermeier 2004). Nonetheless, threats to biodiversity in this region are high and are focused along the U.S.-Mexico border where development is rapid and ongoing (Cordova and Parra 2007, Flesch et al. 2010a) and in montane forests at high elevations where drought, insect outbreaks, and other stressors linked to global climate change are increasing and expected to accelerate in coming decades (Westerling et al. 2006, Seager et al. 2007). My observations suggest the effects of climate change on coniferous forests and woodlands at high elevation may already be occurring. I found that some pines in smaller and more arid mountain ranges (e.g., Cíbuta and San Antonio), for example, seemed to have already succumbed to the effects of recent drought as evidenced by high mortality rates, poor condition, and uneven age structures. Moreover, I also found that many adult white fir at the lower-elevation margins of its range in the Sierra los Ajos were showing signs of drought stress (e.g., yellowing leaves or dead individuals) that could be linked to climate change. These patterns foreshadow potential changes in the structure, composition, and distribution of coniferous forests and woodlands, which could have major effects on wildlife. These patterns are especially troublesome given the rarity of mixed-conifer forest in this region and the much narrower habitat breadths of breeding bird species that depend on them. Information reported here establishes important baselines for monitoring these and other changes in bird and vegetation communities in this region.

Despite some alarming patterns, I also found strong evidence that forests and woodlands of pines have recovered across vast areas of northern Sonora following the cessation of commercial logging in the early and mid-1900s. These changes combined with limited land use and low accessibility, have created areas of essentially *de facto* wilderness across large areas of the Sky Islands in Mexico. As a result, distributions and abundances of many breeding bird populations, and undoubtedly other wildlife, are likely much broader today than they were in past decades. Moreover, natural range expansion of species with strong Madrean affinities during recent decades has also augmented species diversity in the Sky Islands and could to some extent offset potential losses of montane species due to climate change. These changes offer excellent prospects for large-scale conservation efforts in the region and programs to assist landowners in managing and conserving wildlife populations and other natural resources on private lands. Whereas the ecological value of these forests should continue to grow as they mature, so too will their economic value and potentially renewed interest in logging in the region. In advance of these and other potential threats, conservation planners should develop high priority conservation targets based on rigorous, systematic, and scientific criteria. Although developing those targets was beyond the scope of my efforts, data reported here could be applied to those objectives in the future. Preliminarily, my results suggest that conservation efforts in the Sierra Aconchi, Bacadéhuachi, Tigre, Púrica, Púlpito, and other ranges may be especially productive. More broadly, my results and the diverse and wild character of the Sky Islands of northwest Mexico indicate high conservation value and the importance of preserving this unique region for future generations.

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APPENDICES

Appendix A: Common and scientific names and mnemonic codes of bird species noted in the text. Mnemonic codes denote species for which the status and distribution and mapped in Appendix B.

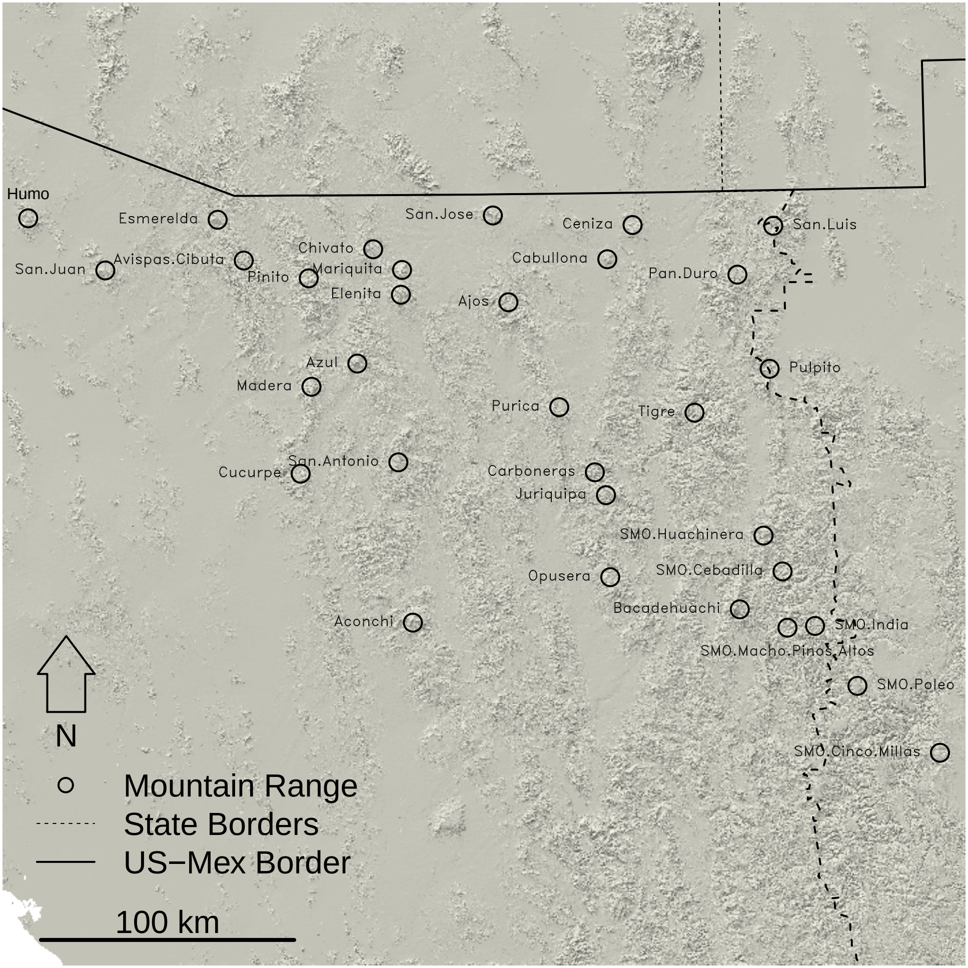
Common Name	Scientific Name	species
Scaled Quail	*Callipepla squamata*	SCQU
Elegant Quail	*Callipepla douglasii*	ELQU
Gambel's Quail	*Callipepla gambelii*	GAQU
Montezuma Quail	*Cyrtonyx montezumae*	MONQ
Wild Turkey	*Meleagris gallopavo*	WITU
Turkey Vulture	*Cathartes aura*	TUVU
Sharp-shinned Hawk	*Accipiter striatus*	SSHA
Cooper's Hawk	*Accipiter cooperii*	COHA
Northern Goshawk	*Accipiter gentilis*	NOGO
Common Black-Hawk	*Buteogallus anthracinus*	COBH
Gray Hawk	*Buteo nitidus*	GRHA
Short-tailed Hawk	*Buteo brachyurus*	STHA
Swainson's Hawk	*Buteo swainsoni*	SWHA
Zone-tailed Hawk	*Buteo albonotatus*	ZTHA
Red-tailed Hawk	*Buteo jamaicensis*	RTHA
Golden Eagle	*Aquila chrysaetos*	GOEA
American Kestrel	*Falco sparverius*	AMKE
Peregrine Falcon	*Falco peregrinus*	PEFA
Band-tailed Pigeon	*Patagioenas fasciata*	BTPI
Eurasian Collared-Dove	*Streptopelia decaocto*	EUCD
White-winged Dove	*Zenaida asiatica*	WWDO
Mourning Dove	*Zenaida macroura*	MODO
Inca Dove	*Columbina inca*	INDO
Common Ground-Dove	*Columbina passerina*	COGD
White-tipped Dove	*Leptotila verreauxi*	WTDO
Thick-billed Parrot	*Rhynchopsitta pachyrhyncha*	TBPA
Yellow-billed Cuckoo	*Coccyzus americanus*	YBCU
Greater Roadrunner	*Geococcyx californianus*	GRRO
Flammulated Owl	*Otus flammeolus*	FLOW
Western Screech-Owl	*Megascops kennicottii*	WESO
Whiskered Screech-Owl	*Megascops trichopsis*	WHSO
Great Horned Owl	*Bubo virginianus*	GHOW
Northern Pygmy-Owl	*Glaucidium gnoma*	NOPO
Elf Owl	*Micrathene whitneyi*	ELOW
Spotted Owl	*Strix occidentalis*	SPOW
Northern Saw-whet Owl	*Aegolius acadicus*	NSWO
Lesser Nighthawk	*Chordeiles acutipennis*	LENI
Common Nighthawk	*Chordeiles minor*	CONI
Common Poorwill	*Phalaenoptilus nuttallii*	COPO
Buff-collared Nightjar	*Caprimulgus ridgwayi*	BCNI
Mexican Whip-poor-will	*Caprimulgus arizonae*	MWPW
White-throated Swift	*Aeronautes saxatalis*	WTSW
Broad-billed Hummingbird	*Cynanthus latirostris*	BBIH
White-eared Hummingbird	*Hylocharis leucotis*	WEHU
Berylline Hummingbird	*Amazilia beryllina*	BEHU

Violet-crowned Hummingbird	*Amazilia violiceps*	VCHU
Blue-throated Hummingbird	*Lampornis clemenciae*	BTHH
Magnificent Hummingbird	*Eugenes fulgens*	MAHU
Plain-capped Starthroat	*Heliomaster constantii*	PCST
Lucifer Hummingbird	*Calothorax lucifer*	LUHU
Black-chinned Hummingbird	*Archilochus alexandri*	BCHU
Anna's Hummingbird	*Calypte anna*	ANHU
Costa's Hummingbird	*Calypte costae*	COHU
Broad-tailed Hummingbird	*Selasphorus platycercus*	BTAH
Elegant Trogon	*Trogon elegans*	ELTR
Mountain Trogon	*Trogon mexicanus*	MOTR
Eared Quetzal	*Euptilotis neoxenus*	EAQU
Acorn Woodpecker	*Melanerpes formicivorus*	ACWO
Gila Woodpecker	*Melanerpes uropygialis*	GIWO
Ladder-backed Woodpecker	*Picoides scalaris*	LBWO
Hairy Woodpecker	*Picoides villosus*	HAWO
Arizona Woodpecker	*Picoides arizonae*	ARWO
Northern Flicker	*Colaptes auratus*	NOFL
Gilded Flicker	*Colaptes chrysoides*	GIFL
White-striped Woodcreeper	*Lepidocolaptes leucogaster*	WSWO
Northern Beardless-Tyrannulet	*Camptostoma imberbe*	NOBT
Tufted Flycatcher	*Mitrephanes phaeocercus*	TUFL
Greater Pewee	*Contopus pertinax*	GRPE
Western Wood-Pewee	*Contopus sordidulus*	WEWP
Pine Flycatcher	*Empidonax affinis*	PINF
Cordilleran Flycatcher	*Empidonax occidentalis*	COFL
Buff-breasted Flycatcher	*Empidonax fulvifrons*	BBFL
Black Phoebe	*Sayornis nigricans*	BLPH
Say's Phoebe	*Sayornis saya*	SAPH
Vermilion Flycatcher	*Pyrocephalus rubinus*	VEFL
Dusky-capped Flycatcher	*Myiarchus tuberculifer*	DCFL
Ash-throated Flycatcher	*Myiarchus cinerascens*	ATFL
Brown-crested Flycatcher	*Myiarchus tyrannulus*	BCFL
Sulphur-bellied Flycatcher	*Myiodynastes luteiventris*	SBFL
Cassin's Kingbird	*Tyrannus vociferans*	CAKI
Thick-billed Kingbird	*Tyrannus crassirostris*	TBKI
Western Kingbird	*Tyrannus verticalis*	WEKI
Rose-throated Becard	*Pachyramphus aglaiae*	RTBE
Loggerhead Shrike	*Lanius ludovicianus*	LOSH
Bell's Vireo	*Vireo bellii*	BEVI
Gray Vireo	*Vireo vicinior*	GRVI
Plumbeous Vireo	*Vireo plumbeus*	PLVI
Hutton's Vireo	*Vireo huttoni*	HUVI
Warbling Vireo	*Vireo gilvus*	WAVI
Yellow-green Vireo	*Vireo flavoviridis*	YGVI
Steller's Jay	*Cyanocitta stelleri*	STJA
Western Scrub-Jay	*Aphelocoma californica*	WESJ
Mexican Jay	*Aphelocoma wollweberi*	MEJA
Common Raven	*Corvus corax*	CORA
Violet-green Swallow	*Tachycineta thalassina*	VGSW

Barn Swallow	*Hirundo rustica*	BARS
Mexican Chickadee	*Poecile sclateri*	MECH
Bridled Titmouse	*Baeolophus wollweberi*	BRTI
Verdin	*Auriparus flaviceps*	VERD
Bushtit	*Psaltriparus minimus*	BUSH
Red-breasted Nuthatch	*Sitta canadensis*	RBNU
White-breasted Nuthatch	*Sitta carolinensis*	WBNU
Pygmy Nuthatch	*Sitta pygmaea*	PYNU
Brown Creeper	*Certhia americana*	BRCR
Cactus Wren	*Campylorhynchus brunneicapillus*	CACW
Rock Wren	*Salpinctes obsoletus*	ROWR
Canyon Wren	*Catherpes mexicanus*	CANW
Sinaloa Wren	*Thryothorus sinaloa*	SIWR
Bewick's Wren	*Thryomanes bewickii*	BEWR
House Wren	*Troglodytes aedon*	HOWR
Blue-gray Gnatcatcher	*Polioptila caerulea*	BGGN
Black-tailed Gnatcatcher	*Polioptila melanura*	BTGN
Black-capped Gnatcatcher	*Polioptila nigriceps*	BCGN
Eastern Bluebird	*Sialia sialis*	EABL
Western Bluebird	*Sialia mexicana*	WEBL
Townsend's Solitaire	*Myadestes townsendi*	TOSO
Brown-backed Solitaire	*Myadestes occidentalis*	BBSO
Orange-billed Nightingale-Thrush	*Catharus aurantiirostris*	OBNT
Russet Nightingale-Thrush	*Catharus occidentalis*	RUNT
Hermit Thrush	*Catharus guttatus*	HETH
American Robin	*Turdus migratorius*	AMRO
Northern Mockingbird	*Mimus polyglottos*	NOMO
Curve-billed Thrasher	*Toxostoma curvirostre*	CBTH
Crissal Thrasher	*Toxostoma crissale*	CRTH
Phainopepla	*Phainopepla nitens*	PHAI
Olive Warbler	*Peucedramus taeniatus*	OLWA
Crescent-chested Warbler	*Oreothlypis superciliosa*	CCWA
Lucy's Warbler	*Oreothlypis luciae*	LUWA
Virginia's Warbler	*Oreothlypis virginiae*	VIWA
Hooded Warbler	*Setophaga citrina*	HOWA
Northern Parula	*Setophaga americana*	NOPA
Audubon's Warbler	*Setophaga coronata auduboni*	AUWA
Grace's Warbler	*Setophaga graciae*	GRWA
Black-throated Gray Warbler	*Setophaga nigrescens*	BTYW
Fan-tailed Warbler	*Basileuterus lachrymosus*	FTWA
Rufous-capped Warbler	*Basileuterus rufifrons*	RCWA
Red-faced Warbler	*Cardellina rubrifrons*	RFWA
Painted Redstart	*Myioborus pictus*	PARE
Slate-throated Redstart	*Myioborus miniatus*	STRE
Yellow-breasted Chat	*Icteria virens*	YBCH
Spotted Towhee	*Pipilo maculatus*	SPTO
Rusty Sparrow	*Aimophila rufescens*	RUSP
Rufous-crowned Sparrow	*Aimophila ruficeps*	RCSP
Canyon Towhee	*Melozone fusca*	CANT
Rufous-winged Sparrow	*Peucaea carpalis*	RWSP

Botteri's Sparrow	*Peucaea botterii*	BOSP
Chipping Sparrow	*Spizella passerina*	CHSP
Black-chinned Sparrow	*Spizella atrogularis*	BCSP
Lark Sparrow	*Chondestes grammacus*	LASP
Five-striped Sparrow	*Amphispiza quinquestriata*	FSSP
Black-throated Sparrow	*Amphispiza bilineata*	BTSP
Yellow-eyed Junco	*Junco phaeonotus*	YEJU
Hepatic Tanager	*Piranga flava*	HETA
Summer Tanager	*Piranga rubra*	SUTA
Western Tanager	*Piranga ludoviciana*	WETA
Flame-colored Tanager	*Piranga bidentata*	FCTA
Northern Cardinal	*Cardinalis cardinalis*	NOCA
Pyrrhuloxia	*Cardinalis sinuatus*	PYRR
Black-headed Grosbeak	*Pheucticus melanocephalus*	BHGR
Blue Grosbeak	*Passerina caerulea*	BLGR
Indigo Bunting	*Passerina cyanea*	INBU
Varied Bunting	*Passerina versicolor*	VABU
Bronzed Cowbird	*Molothrus aeneus*	BROC
Brown-headed Cowbird	*Molothrus ater*	BHCO
Black-vented Oriole	*Icterus wagleri*	BVOR
Hooded Oriole	*Icterus cucullatus*	HOOR
Scott's Oriole	*Icterus parisorum*	SCOR
House Finch	*Carpodacus mexicanus*	HOFI
Red Crossbill	*Loxia curvirostra*	RECR
Pine Siskin	*Spinus pinus*	PISI
Black-headed Siskin	*Spinus notatus*	BHSI
Lesser Goldfinch	*Spinus psaltria*	LEGO

Appendix B: Maps summarizing the status and distribution of birds in the Sky Islands and adjacent Sierra Madre Occidental in northwest Mexico, May-July, 2009-2012. A higher resolution version of this Appendix can be downloaded at the following link and should be viewed in a pdf viewer (vs. browser) to ensure accurate projection.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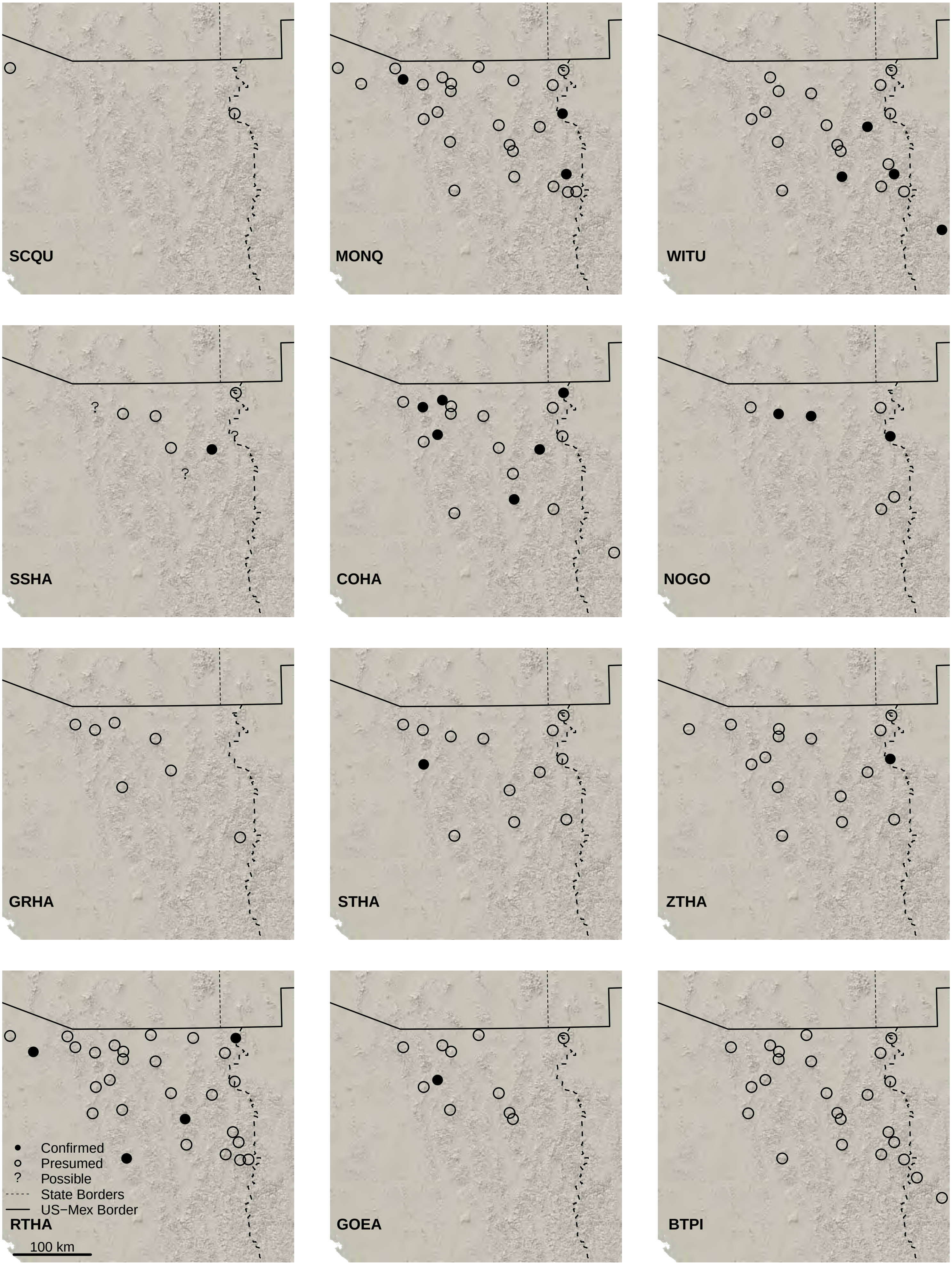
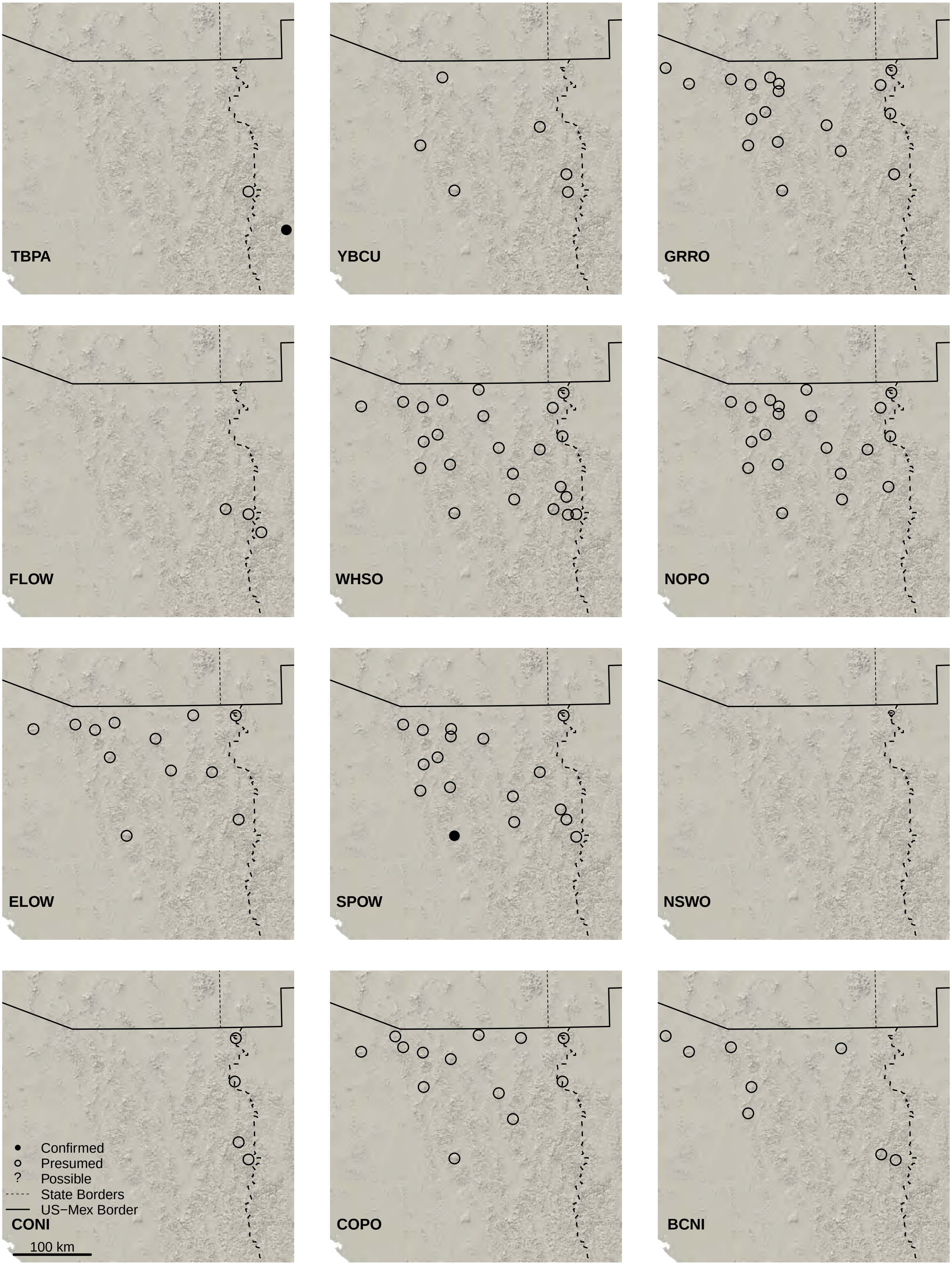
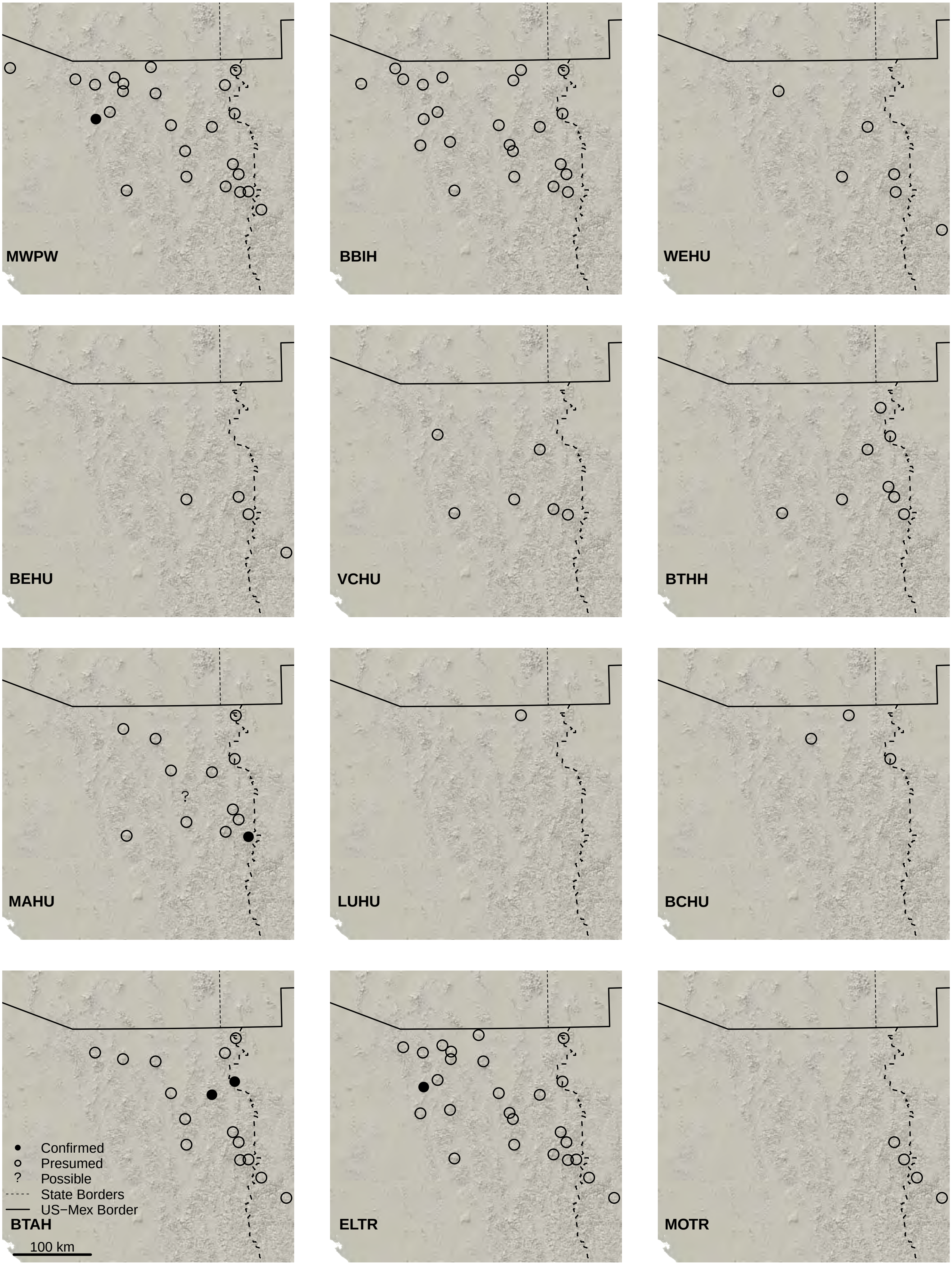
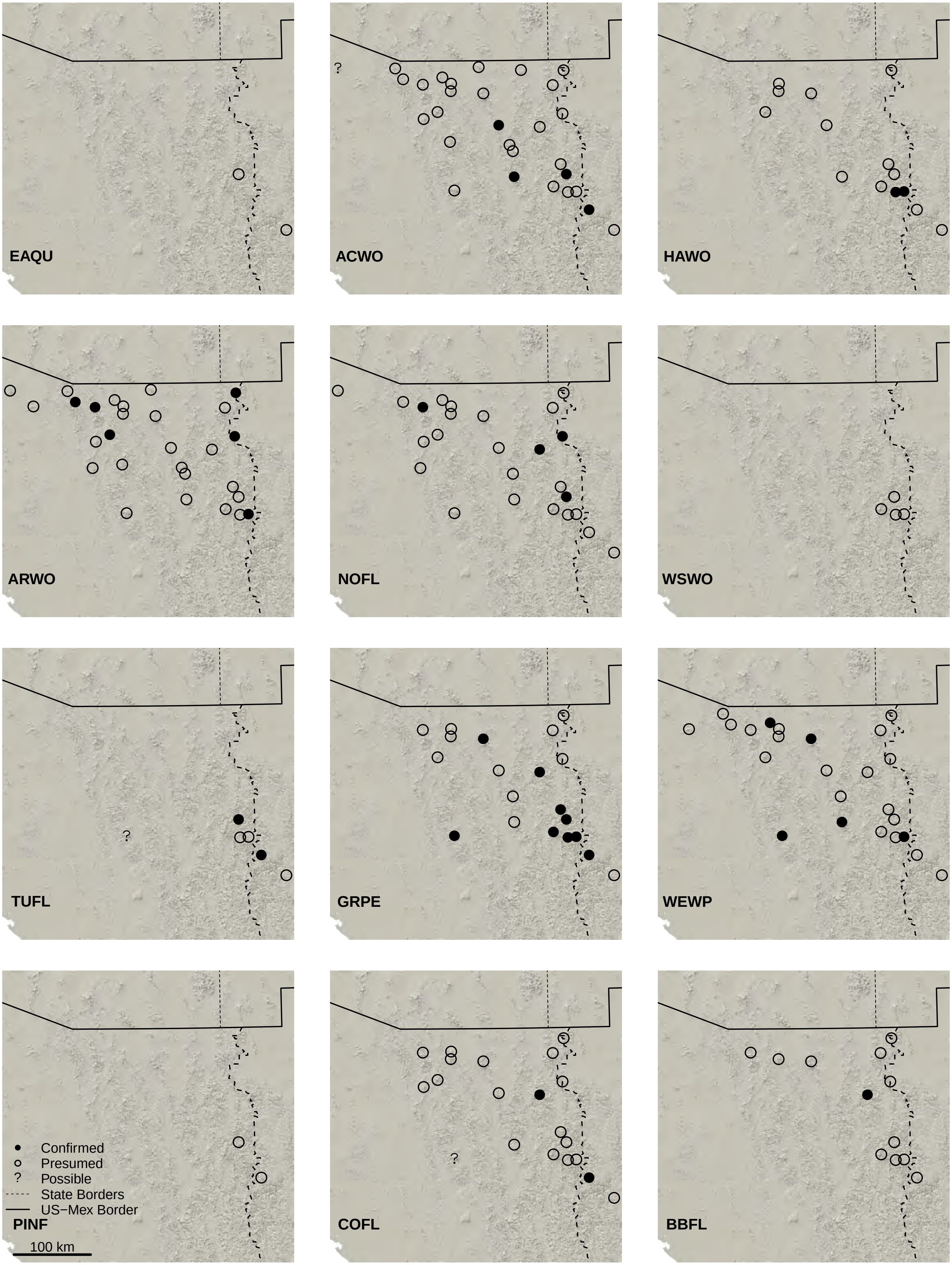
San.Jose
Ceniza
San.Luis
Chivato
Avispas.Cibuta
Mariquita
Cabullona
San.Juan
Pinito
Pan.Duro
Elenita
Ajos
Azul
Pulpito
Madera
Purica
Tigre
San.Antonio
Cucurpe
Carboneras
Juriquipa
SMO.Huachinera
SMO.Cebadilla
Opusera
Bacadehuachi
Aconchi
SMO.India
SMO.Macho.Pinos.Altos
SMO.Poleo
SMO.Cinco.Millas
N
Mountain Range
State Borders
US−Mex Border
100 km


SCQU
MONQ
WITU
SSHA
?
?
?
COHA
NOGO
GRHA
STHA
ZTHA
RTHA
GOEA
BTPI
● Confirmed
○ Presumed
? Possible
State Borders
US−Mex Border
100 km


TBPA
YBCU
GRRO
FLOW
WHSO
NOPO
ELOW
SPOW
NSWO
CONI
COPO
BCNI
● Confirmed
○ Presumed
? Possible
State Borders
US−Mex Border
100 km


MWPW
BBIH
WEHU
BEHU
VCHU
BTHH
MAHU
?
LUHU
BCHU
BTAH
ELTR
MOTR
● Confirmed
○ Presumed
? Possible
State Borders
US−Mex Border
100 km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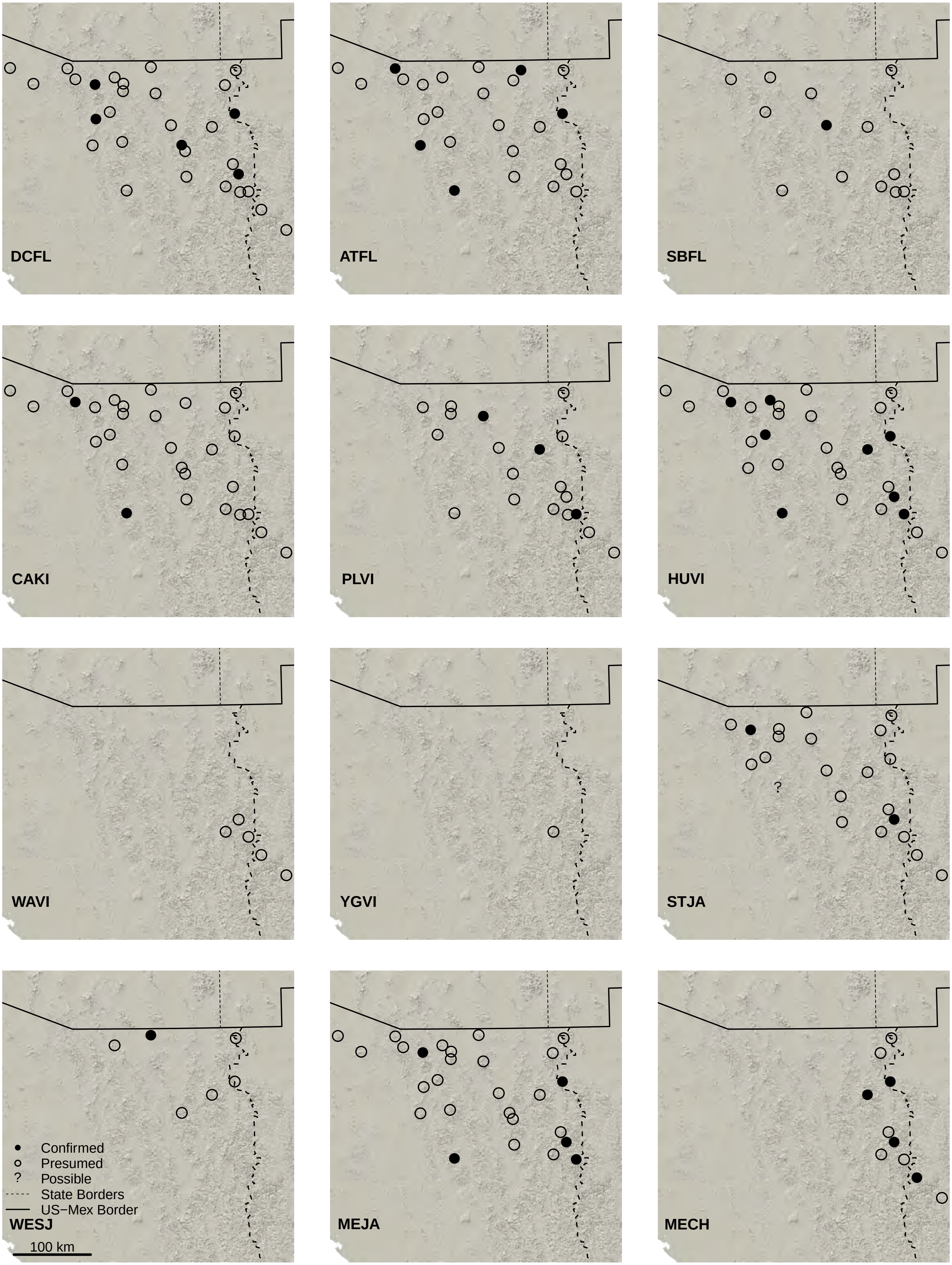
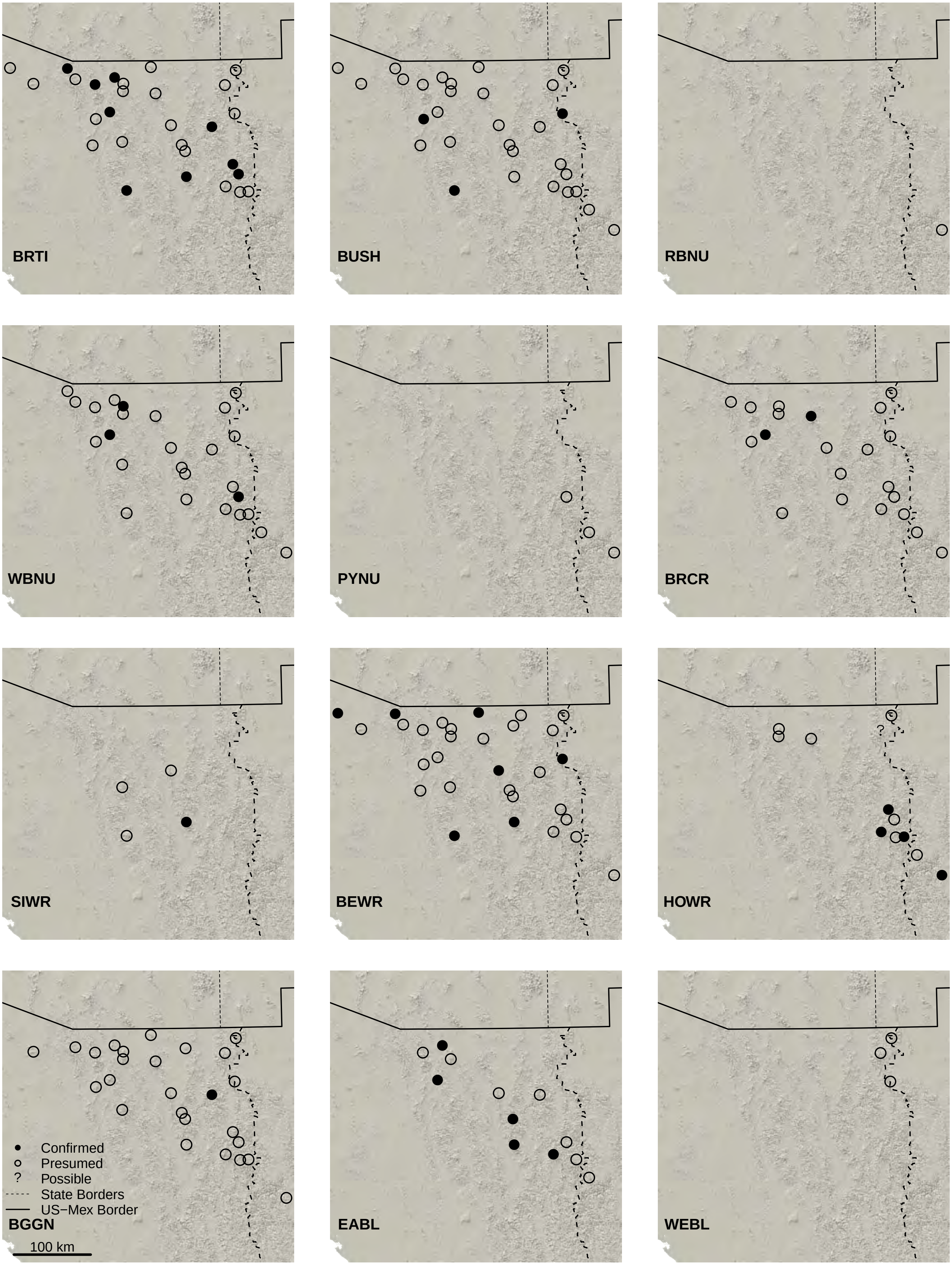
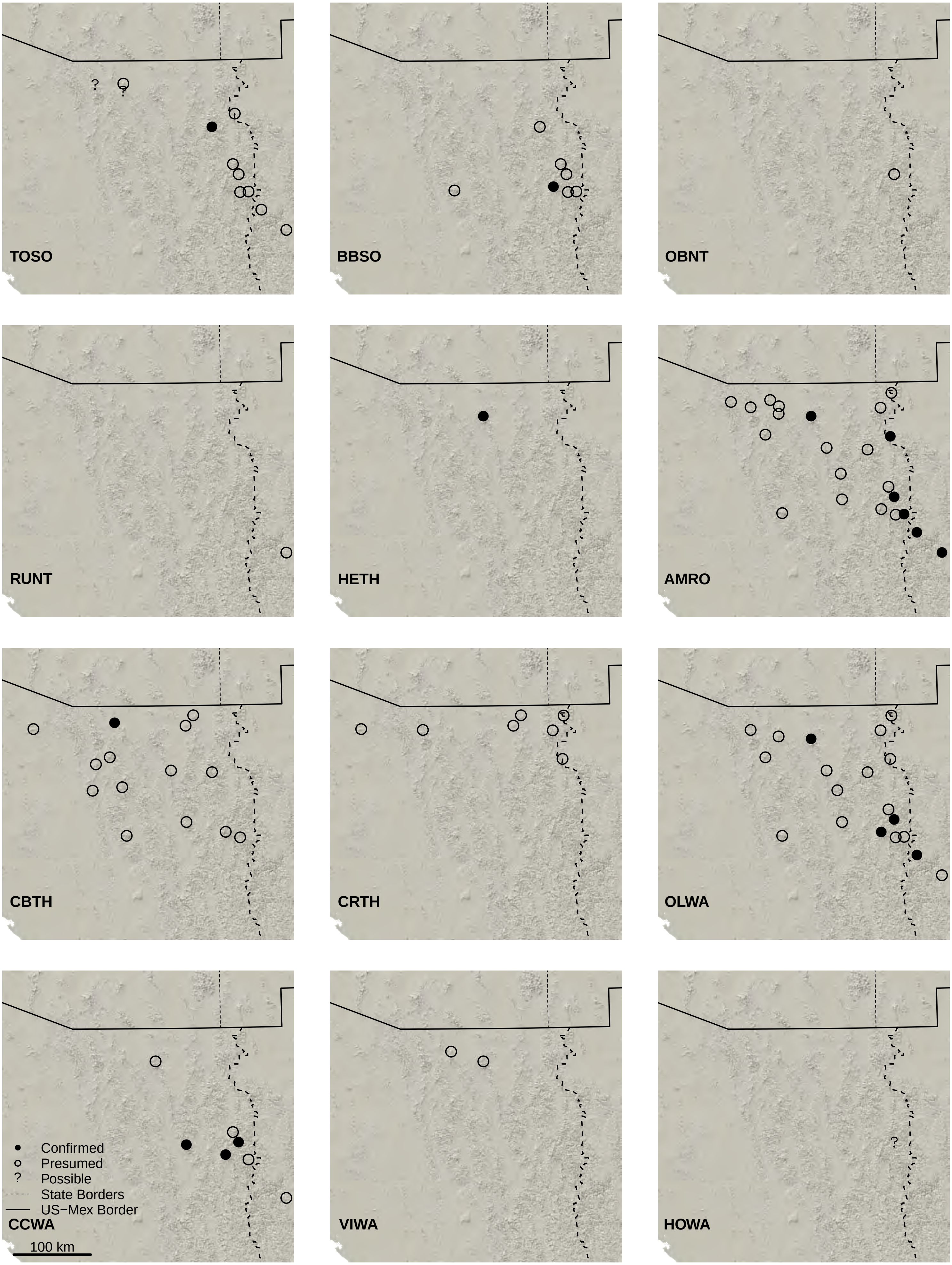
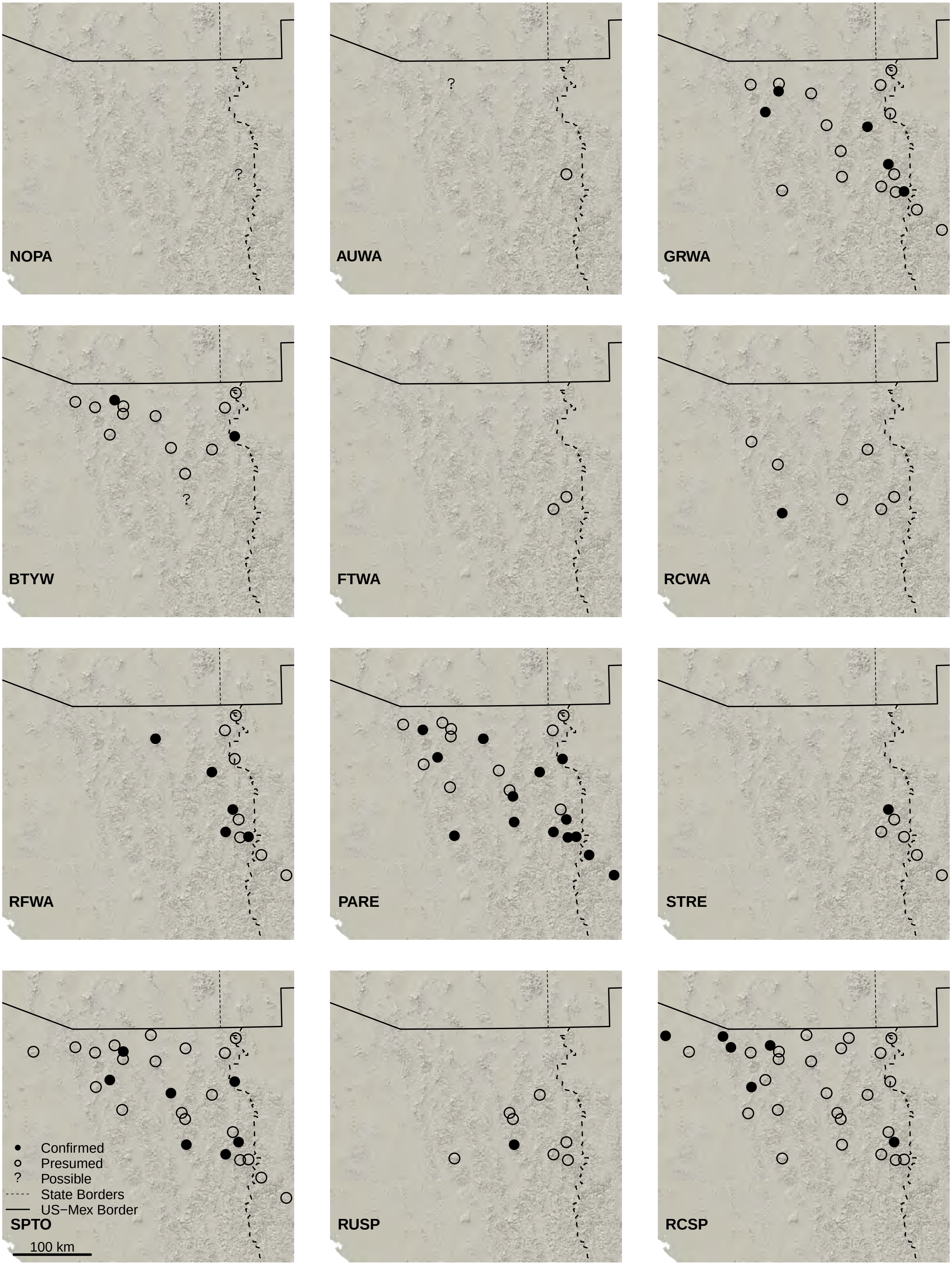
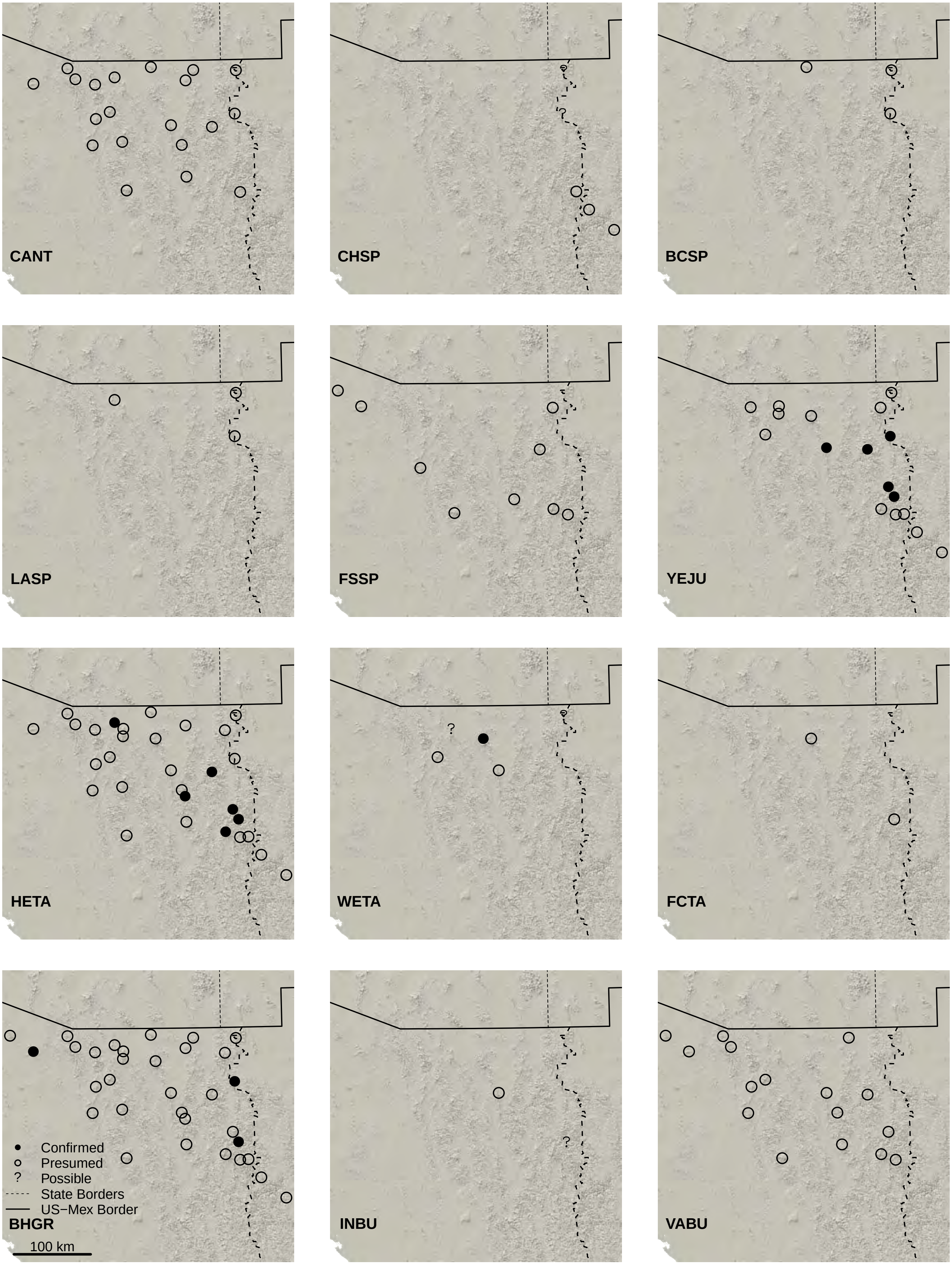
ACWO
?
HAWO
ARWO
NOFL
WSWO
TUFL
?
GRPE
WEWP
● Confirmed
○ Presumed
? Possible
State Borders
US−Mex Border
PINF
100 km
COFL
?
BBFL

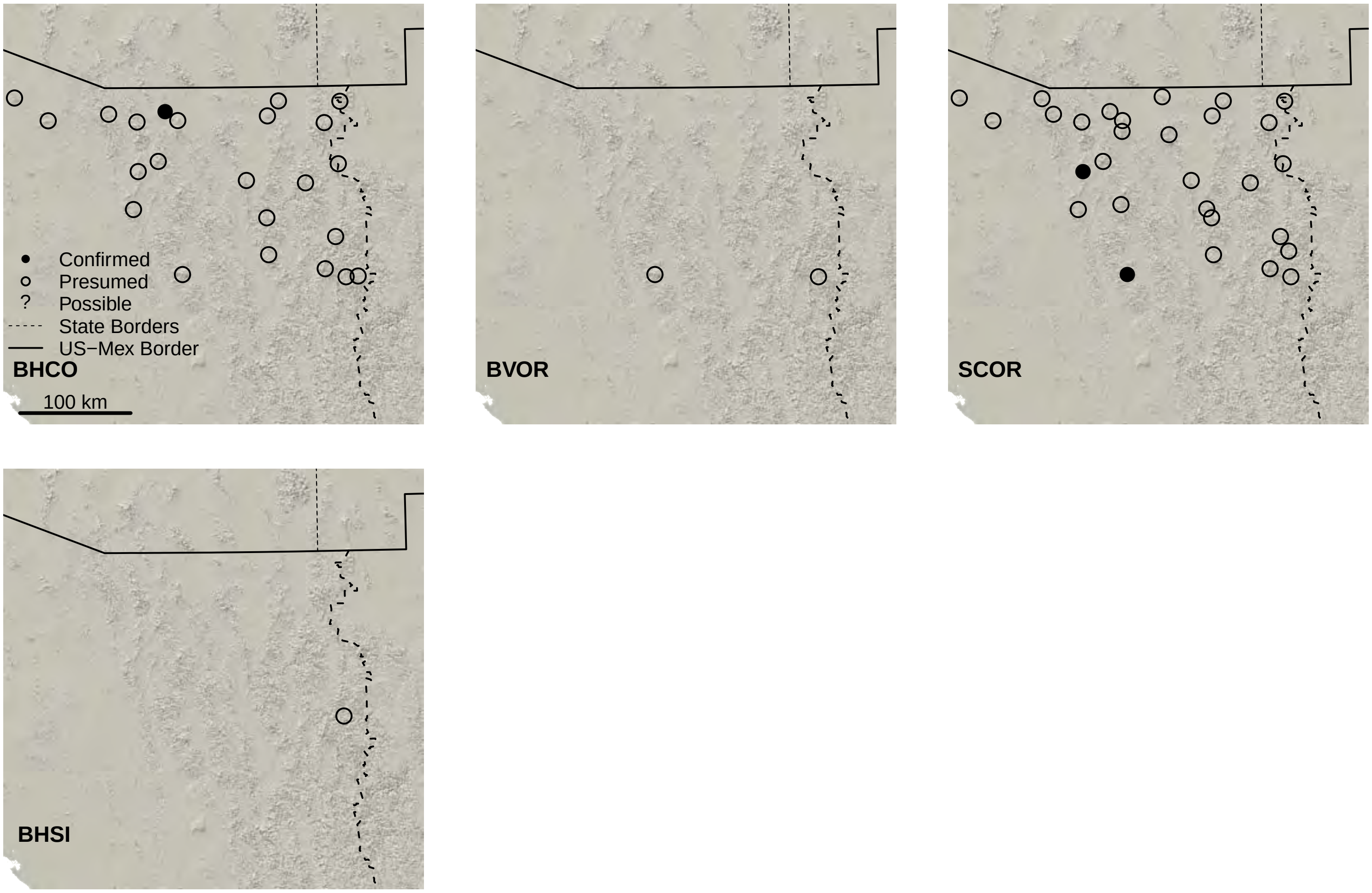

DCFL
ATFL
SBFL
CAKI
PLVI
HUVI
WAVI
YGVI
STJA
?
WESJ
MEJA
MECH
● Confirmed
○ Presumed
? Possible
State Borders
US−Mex Border
100 km


BRTI
BUSH
RBNU
WBNU
PYNU
BRCR
SIWR
BEWR
HOWR
BGGN
EABL
WEBL
Confirmed
Presumed
?
Possible
State Borders
US−Mex Border
100 km


TOSO
BBSO
OBNT
RUNT
HETH
AMRO
CBTH
CRTH
OLWA
CCWA
VIWA
HOWA
● Confirmed
○ Presumed
? Possible
State Borders
US−Mex Border
100 km


NOPA
AUWA
GRWA
BTYW
FTWA
RCWA
RFWA
PARE
STRE
SPTO
RUSP
RCSP
● Confirmed
○ Presumed
? Possible
State Borders
US−Mex Border
100 km


CANT
CHSP
BCSP
LASP
FSSP
YEJU
HETA
WETA
FCTA
BHGR
INBU
VABU
?
● Confirmed
○ Presumed
? Possible
State Borders
US−Mex Border
100 km


● Confirmed
○ Presumed
? Possible
State Borders
US−Mex Border
BHCO
100 km
BVOR
SCOR
BHSI

Appendix C: Densities of 72 species of breeding birds with ≥30 total encounters during 1,851 point counts at 1,562 stations across the Sky Islands and adjacent Sierra Madre Occidental of Sonora and western Chihuahua, Mexico 2009-2012. All density estimates and associated standard errors (SE) are based on distance-sampling methods. Parenthetical numbers are numbers of stations in each range or region of the Sierra Madre. Relative abundance equals number of encounters / total counts.

	Humo (20)				San Juan (30)				Esmerelda (14)				Avispas-Cibuta (52)				Pinito (97)				Madera (30)				Chivato (33)			
Species	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA
Montezuma Quail					2	0.02	0.02	0.07					12	0.24	0.19	0.23					11	0.55	0.42	0.37	8	0.12	0.06	0.24
Wild Turkey																					1	0.00	0.00	0.03				
Red-tailed Hawk					4	0.02	0.01	0.13					4	0.01	0.01	0.08	3	0.01	0.00	0.03					1	0.01	0.01	0.03
Band-tailed Pigeon													16	0.10	0.04	0.31									4	0.07	0.05	0.12
White-winged Dove	27	0.39	0.11	1.35	35	0.4	0.1	1.17	4	0.05	0.03	0.29	70	0.29	0.09	1.35					21	0.24	0.11	0.70				
Mourning Dove	19	0.59	0.27	0.95									9	0.07	0.03	0.17	11	0.11	0.07	0.11	2	0.03	0.02	0.07	11	0.17	0.05	0.33
Thick-billed Parrot																												
Greater Roadrunner	4	0.01	0.00	0.20									9	0.03	0.01	0.17	4	0.01	0.00	0.04	2	0.01	0.01	0.07	5	0.02	0.01	0.15
White-throated Swift																	2	0.01	0.01	0.02								
Broad-billed Hummingbird					1	0.57	0.64	0.03	1	1.85	1.98	0.07	8	1.40	0.77	0.15	4	0.45	0.29	0.04					2	0.92	0.76	0.06
Magnificent Hummingbird																												
Broad-tailed Hummingbird																	7	0.63	0.32	0.07								
Elegant Trogon													48	0.22	0.06	0.92	9	0.03	0.01	0.09	17	0.17	0.06	0.57	14	0.10	0.03	0.42
Mountain Trogon																												
Acorn Woodpecker	1	0.04	0.04	0.05					1	0.03	0.03	0.07	56	0.45	0.14	1.08	16	0.09	0.03	0.16	13	0.23	0.07	0.43	17	0.27	0.08	0.52
Hairy Woodpecker																												
Arizona Woodpecker	1	0.02	0.02	0.05	8	0.38	0.23	0.27	3	0.10	0.05	0.21	35	0.27	0.07	0.67	28	0.18	0.04	0.29	20	0.40	0.11	0.67	8	0.13	0.05	0.24
Northern Flicker													5	0.02	0.01	0.10	4	0.02	0.01	0.04	2	0.05	0.05	0.07				
Greater Pewee																	7	0.02	0.01	0.07								
Western Wood-Pewee					8	0.86	0.34	0.27	3	0.20	0.12	0.21	35	0.97	0.47	0.67	1	0.01	0.01	0.01					20	0.54	0.15	0.61
Cordilleran Flycatcher																					1	0.05	0.05	0.03				
Buff-breasted Flycatcher																												
Dusky-capped Flycatcher					11	0.23	0.11	0.37	6	0.23	0.07	0.43	84	0.48	0.07	1.62	77	0.40	0.07	0.79	30	0.46	0.08	1.00	23	0.33	0.06	0.70
Ash-throated Flycatcher	12	0.42	0.16	0.60	20	0.4	0.12	0.67	21	0.59	0.1	1.5	29	0.20	0.07	0.56	46	0.19	0.04	0.47	13	0.21	0.08	0.43	25	0.32	0.07	0.76
Brown-crested Flycatcher	3	0.09	0.06	0.15									20	0.16	0.08	0.38	1	0.01	0.01	0.01					13	0.35	0.12	0.39
Sulphur-bellied Flycatcher													6	0.05	0.03	0.12									4	0.06	0.03	0.12
Cassin's Kingbird									1	0.02	0.02	0.07	16	0.19	0.09	0.31	8	0.02	0.01	0.08	3	0.05	0.03	0.10	13	0.14	0.05	0.39
Thick-billed Kingbird													16	0.14	0.07	0.31												
Plumbeous Vireo																	15	0.13	0.03	0.15								
Hutton's Vireo	2	0.27	0.20	0.10	2	0.21	0.19	0.07	3	0.21	0.11	0.21	29	0.40	0.10	0.56	28	0.37	0.09	0.29	17	0.51	0.13	0.57	25	0.97	0.25	0.76
Steller's Jay																	24	0.09	0.03	0.24	9	0.11	0.05	0.30				
Mexican Jay					2	0.02	0.02	0.07	5	0.09	0.03	0.36	38	0.18	0.04	0.73	43	0.17	0.03	0.44	20	0.20	0.04	0.67	27	0.22	0.04	0.82
Common Raven	1	0.01	0.01	0.05	2	0.01	0.01	0.07					10	0.02	0.01	0.19					1	0.00	0.00	0.03	1	0.00	0.00	0.03
Mexican Chickadee																												
Bridled Titmouse					12	0.6	0.16	0.4	8	0.85	0.26	0.57	37	0.78	0.16	0.71	41	0.54	0.09	0.42	18	0.96	0.23	0.60	25	1.19	0.24	0.76

	Humo (20)				San Juan (30)				Esmerelda (14)				Avispas-Cibuta (52)				Pinito (97)				Madera (30)				Chivato (33)			
Species	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA
Bushtit					1	0.12	0.12	0.03	1	0.14	0.14	0.07	10	0.34	0.22	0.19	7	0.25	0.11	0.07	10	0.79	0.22	0.33	8	0.50	0.22	0.24
White-breasted Nuthatch													25	0.21	0.06	0.48	21	0.09	0.02	0.21	15	0.26	0.07	0.50	26	0.89	0.29	0.79
Brown Creeper													2	0.07	0.07	0.04	2	0.04	0.03	0.02	2	0.16	0.16	0.07				
Cactus Wren					4	0.05	0.03	0.13																	4	0.05	0.02	0.12
Rock Wren	1	0.02	0.02	0.05	5	0.07	0.03	0.17	6	0.18	0.07	0.43	4	0.02	0.02	0.08					2	0.03	0.02	0.07	1	0.01	0.01	0.03
Canyon Wren					1	0.01	0.01	0.03	5	0.12	0.07	0.36	15	0.07	0.02	0.29	4	0.01	0.01	0.04	15	0.56	0.42	0.50				
Bewick's Wren	25	0.83	0.27	1.25	41	1.04	0.21	1.37	20	1.84	0.39	1.43	102	1.61	0.33	1.96	88	0.70	0.10	0.90	60	2.08	0.23	2.00	48	1.39	0.18	1.45
House Wren																												
Blue-gray Gnatcatcher					2	0.14	0.1	0.07					6	0.15	0.08	0.12	14	0.26	0.07	0.14	5	0.32	0.18	0.17				
Eastern Bluebird																	2	0.01	0.01	0.02								
Townsend's Solitaire																												
Brown-backed Solitaire																												
American Robin													2	0.03	0.02	0.04	24	0.14	0.04	0.24					3	0.03	0.02	0.09
Northern Mockingbird	17	0.26	0.12	0.85	7	0.04	0.02	0.23					2	0.01	0.01	0.04									20	0.20	0.08	0.61
Phainopepla	11	0.39	0.17	0.55	26	0.58	0.15	0.87					6	0.08	0.05	0.12									8	0.57	0.29	0.24
Olive Warbler																	2	0.01	0.01	0.02								
Crescent-chested Warbler																												
Grace's Warbler																	24	0.19	0.07	0.24								
Black-throated Gray Warbler													2	0.02	0.02	0.04	7	0.09	0.05	0.07					1	0.12	0.12	0.03
Rufous-capped Warbler																					4	0.21	0.10	0.13				
Red-faced Warbler																												
Painted Redstart													21	0.48	0.29	0.40	48	0.70	0.14	0.49	14	0.36	0.10	0.47	4	0.39	0.26	0.12
Slate-throated Redstart																												
Spotted Towhee					2	0.04	0.03	0.07					46	0.35	0.10	0.88	66	0.44	0.09	0.67	19	0.41	0.15	0.63	6	0.10	0.06	0.18
Rufous-crowned Sparrow	23	1.26	0.59	1.15	35	2.81	0.91	1.17	33	3.45	1.3	2.36	66	1.34	0.45	1.27	50	0.49	0.15	0.51	37	1.24	0.40	1.23	21	0.77	0.39	0.64
Canyon Towhee					3	0.21	0.12	0.1	5	0.27	0.11	0.36	11	0.36	0.15	0.21	5	0.07	0.03	0.05					5	0.33	0.18	0.15
Yellow-eyed Junco																	11	0.16	0.07	0.11								
Hepatic Tanager					4	0.16	0.08	0.13	3	0.1	0.06	0.21	35	0.48	0.13	0.67	35	0.39	0.08	0.36	20	0.76	0.19	0.67	17	0.66	0.19	0.52
Summer Tanager									1	0.09	0.09	0.07	12	0.21	0.09	0.23									6	0.22	0.09	0.18
Black-headed Grosbeak	6	0.23	0.14	0.30	13	0.74	0.33	0.43	2	0.05	0.03	0.14	86	0.79	0.17	1.65	39	0.36	0.09	0.40	35	0.63	0.10	1.17	25	0.51	0.13	0.76
Blue Grosbeak									4	0.24	0.11	0.29	13	0.07	0.03	0.25					2	0.03	0.03	0.07	6	0.12	0.06	0.18
Varied Bunting	1	0.05	0.05	0.05	1	0.12	0.13	0.03	2	0.26	0.22	0.14	8	0.16	0.08	0.15					2	0.06	0.05	0.07				
Brown-headed Cowbird	3	0.12	0.07	0.15	4	0.11	0.06	0.13					9	0.18	0.08	0.17	6	0.08	0.03	0.06	4	0.20	0.10	0.13	11	0.51	0.16	0.33
Hooded Oriole													21	0.36	0.17	0.40	1	0.01	0.01	0.01					2	0.07	0.05	0.06
Scott's Oriole	5	0.07	0.03	0.25					4	0.06	0.03	0.29	4	0.03	0.03	0.08	11	0.05	0.02	0.11	39	0.40	0.11	1.30	19	0.18	0.07	0.58
House Finch	5	0.31	0.16	0.25	3	0.12	0.07	0.1	6	0.53	0.23	0.43	15	0.27	0.11	0.29	1	0.01	0.01	0.01	7	0.29	0.12	0.23	5	0.19	0.08	0.15
Lesser Goldfinch	13	0.57	0.27	0.65	1	0.02	0.02	0.03	3	0.35	0.26	0.21	1	0.02	0.02	0.02	1	0.01	0.01	0.01								

Appendix C: Densities of 72 species of breeding birds with ≥30 total encounters during 1,851 point counts at 1,562 stations across the Sky Islands and adjacent Sierra Madre Occidental of Sonora and western Chihuahua, Mexico 2009-2012. All density estimates and associated standard errors (SE) are based on distance-sampling methods. Parenthetical numbers are numbers of stations in each range or region of the Sierra Madre. Relative abundance equals number of encounters / total counts.

	Azul (53)				Cucurpe (20)				Mariquita (48)				Elenita (36)				San Antonio (22)				San.Jose (34)				Ajos (90)			
Species	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA
Montezuma Quail	1	0.06	0.07	0.02					2	0.02	0.01	0.04																
Wild Turkey													1	0	0	0.03												
Red-tailed Hawk	1	0.00	0.00	0.02	1	0.01	0.01	0.05	1	0	0	0.02									1	0	0.01	0.03	1	0	0	0.01
Band-tailed Pigeon	2	0.01	0.01	0.04					13	0.12	0.04	0.25	1	0.01	0.01	0.03					4	0.04	0.02	0.12	8	0.04	0.02	0.09
White-winged Dove					40	0.37	0.06	2.00									2	0.02	0.02	0.07	31	0.2	0.05	0.91				
Mourning Dove																												
Thick-billed Parrot																												
Greater Roadrunner	1	0.00	0.00	0.02	5	0.03	0.01	0.25	3	0.01	0	0.06	1	0	0	0.03	4	0.03	0.02	0.14								
White-throated Swift	3	0.02	0.02	0.06	2	0.04	0.03	0.10	2	0.01	0.01	0.04	3	0.03	0.03	0.08	1	0.01	0.02	0.04	4	0.04	0.03	0.12				
Broad-billed Hummingbird	1	0.71	0.76	0.02	7	11.0	5.66	0.35									2	1.39	1.1	0.07								
Magnificent Hummingbird																									3	0.38	0.22	0.03
Broad-tailed Hummingbird													3	0.95	0.67	0.08									1	0.24	0.26	0.01
Elegant Trogon	6	0.03	0.01	0.11	8	0.09	0.03	0.40	21	0.08	0.02	0.4	1	0.04	0.04	0.03					1	0.03	0.03	0.03	15	0.03	0.01	0.17
Mountain Trogon																												
Acorn Woodpecker									5	0.06	0.04	0.1	4	0.06	0.03	0.11	4	0.07	0.04	0.14	2	0.03	0.02	0.06	6	0.03	0.01	0.07
Hairy Woodpecker	8	0.12	0.06	0.15					2	0.03	0.02	0.04	6	0.13	0.06	0.17									1	0.01	0.01	0.01
Arizona Woodpecker	14	0.13	0.04	0.26	3	0.07	0.04	0.15	1	0.01	0.01	0.02	2	0.03	0.02	0.06	8	0.2	0.08	0.29	3	0.04	0.02	0.09	13	0.07	0.02	0.14
Northern Flicker	2	0.03	0.03	0.04					17	0.09	0.02	0.33	2	0.04	0.04	0.06									9	0.04	0.02	0.1
Greater Pewee	8	0.02	0.01	0.15					2	0.04	0.03	0.04	2	0.01	0	0.06									7	0.01	0.01	0.08
Western Wood-Pewee									13	0.38	0.13	0.25	4	0.27	0.17	0.11									30	0.24	0.07	0.33
Cordilleran Flycatcher	2	0.05	0.04	0.04					1	0.03	0.03	0.02	2	0.08	0.08	0.06									16	0.24	0.07	0.18
Buff-breasted Flycatcher													6	0.2	0.08	0.17									7	0.05	0.02	0.08
Dusky-capped Flycatcher	40	0.29	0.04	0.75	15	0.31	0.06	0.75	11	0.16	0.08	0.21	7	0.07	0.03	0.19	10	0.13	0.05	0.36					68	0.29	0.03	0.76
Ash-throated Flycatcher	30	0.25	0.06	0.57	7	0.20	0.07	0.35									9	0.12	0.04	0.32	5	0.08	0.04	0.15	3	0.02	0.01	0.03
Brown-crested Flycatcher	1	0.01	0.01	0.02	2	0.04	0.03	0.10																				
Sulphur-bellied Flycatcher	8	0.08	0.04	0.15																					11	0.06	0.02	0.12
Cassin's Kingbird	10	0.05	0.02	0.19					3	0.03	0.02	0.06					8	0.07	0.03	0.29					2	0.01	0.01	0.02
Thick-billed Kingbird																												
Plumbeous Vireo	5	0.07	0.04	0.09					3	0.07	0.04	0.06	10	0.24	0.1	0.28									26	0.25	0.06	0.29
Hutton's Vireo	23	0.56	0.16	0.43	3	0.13	0.07	0.15	21	0.54	0.19	0.4	8	0.2	0.06	0.22	4	0.13	0.06	0.14	8	0.21	0.07	0.24	32	0.37	0.09	0.36
Steller's Jay	21	0.12	0.03	0.40					51	0.65	0.16	0.98	6	0.08	0.06	0.17	1	0.06	0.06	0.04	4	0.05	0.03	0.12	28	0.18	0.05	0.31
Mexican Jay	18	0.12	0.03	0.34	4	0.05	0.02	0.20	1	0.01	0.01	0.02	1	0.01	0.01	0.03	9	0.13	0.04	0.32	13	0.1	0.02	0.38	31	0.11	0.02	0.34
Common Raven													4	0.01	0.01	0.11												
Mexican Chickadee																												
Bridled Titmouse	12	0.21	0.07	0.23	3	0.22	0.12	0.15	6	0.16	0.06	0.12	1	0.04	0.04	0.03	22	1.39	0.45	0.79	6	0.24	0.09	0.18	22	0.34	0.07	0.24

	Azul (53)				Cucurpe (20)				Mariquita (48)				Elenita (36)				San Antonio (22)				San.Jose (34)				Ajos (90)			
Species	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA
Bushtit	8	0.41	0.16	0.15					14	0.61	0.16	0.27	1	0.09	0.09	0.03	3	0.36	0.21	0.11	7	0.42	0.17	0.21	7	0.18	0.07	0.08
White-breasted Nuthatch	11	0.10	0.03	0.21					18	0.24	0.08	0.35	4	0.1	0.07	0.11	2	0.03	0.02	0.07					12	0.1	0.04	0.13
Brown Creeper	4	0.18	0.11	0.08					14	0.68	0.22	0.27	1	0.04	0.04	0.03									9	0.2	0.07	0.1
Cactus Wren	1	0.01	0.01	0.02	11	0.22	0.06	0.55									6	0.09	0.04	0.21								
Rock Wren																					2	0.03	0.03	0.06				
Canyon Wren	10	0.05	0.02	0.19	22	0.35	0.07	1.10	8	0.05	0.02	0.15	2	0.03	0.03	0.06	6	0.05	0.02	0.21	8	0.09	0.03	0.24	3	0.01	0.01	0.03
Bewick's Wren	31	0.36	0.09	0.58	10	0.62	0.24	0.50	22	0.47	0.14	0.42	4	0.07	0.04	0.11	41	1.46	0.2	1.46	56	1.16	0.22	1.65	24	0.22	0.1	0.27
House Wren									10	0.36	0.22	0.19	6	0.34	0.24	0.17									12	0.19	0.09	0.13
Blue-gray Gnatcatcher	3	0.10	0.06	0.06					2	0.1	0.1	0.04					5	0.35	0.15	0.18	2	0.14	0.1	0.06	4	0.09	0.05	0.04
Eastern Bluebird													1	0.01	0.01	0.03												
Townsend's Solitaire																												
Brown-backed Solitaire																												
American Robin	23	0.25	0.07	0.43					35	0.45	0.09	0.67	3	0.05	0.03	0.08									24	0.25	0.07	0.27
Northern Mockingbird					2	0.03	0.02	0.10													21	0.2	0.07	0.62				
Phainopepla																												
Olive Warbler	1	0.01	0.01	0.02									3	0.05	0.03	0.08									3	0.05	0.04	0.03
Crescent-chested Warbler																									1	0.03	0.03	0.01
Grace's Warbler	16	0.14	0.04	0.30									13	0.33	0.13	0.36									22	0.15	0.04	0.24
Black-throated Gray Warbler									6	0.09	0.05	0.12	16	0.64	0.29	0.44									10	0.08	0.03	0.11
Rufous-capped Warbler																												
Red-faced Warbler																									4	0.07	0.04	0.04
Painted Redstart	28	0.49	0.13	0.53					19	0.32	0.1	0.37	8	0.35	0.16	0.22	6	0.57	0.27	0.21					72	0.78	0.11	0.8
Slate-throated Redstart																												
Spotted Towhee	42	0.48	0.09	0.79					92	1.2	0.21	1.77	22	0.33	0.09	0.61	2	0.06	0.06	0.07	34	0.58	0.2	1	64	0.52	0.11	0.71
Rufous-crowned Sparrow	39	0.49	0.09	0.74	16	0.87	0.47	0.80	22	0.49	0.23	0.42					12	0.32	0.12	0.43	23	0.53	0.2	0.68	16	0.11	0.03	0.18
Canyon Towhee	2	0.08	0.07	0.04	7	0.48	0.22	0.35									7	0.43	0.2	0.25	3	0.11	0.07	0.09				
Yellow-eyed Junco	11	0.16	0.06	0.21					62	0.79	0.14	1.19	20	0.79	0.23	0.56									12	0.17	0.07	0.13
Hepatic Tanager	24	0.31	0.09	0.45					14	0.31	0.1	0.27	13	0.34	0.11	0.36	12	0.44	0.12	0.43	8	0.32	0.13	0.24	37	0.31	0.06	0.41
Summer Tanager																												
Black-headed Grosbeak	41	0.45	0.09	0.77	26	1.09	0.36	1.30	39	0.54	0.12	0.75	8	0.34	0.15	0.22	7	0.26	0.13	0.25	21	0.53	0.14	0.62	29	0.29	0.1	0.32
Blue Grosbeak	6	0.03	0.02	0.11	5	0.24	0.10	0.25													2	0.04	0.03	0.06				
Varied Bunting	6	0.11	0.05	0.11	6	0.51	0.25	0.30																				
Brown-headed Cowbird	4	0.12	0.07	0.08	1	0.06	0.07	0.05	2	0.06	0.04	0.04																
Hooded Oriole																	2	0.08	0.09	0.07								
Scott's Oriole	11	0.05	0.02	0.21	17	0.38	0.12	0.85	4	0.03	0.02	0.08	3	0.08	0.06	0.08	7	0.09	0.05	0.25	6	0.05	0.02	0.18	4	0.01	0	0.04
House Finch	1	0.02	0.02	0.02					1	0.02	0.02	0.02					4	0.18	0.09	0.14	1	0.04	0.04	0.03	1	0.01	0.01	0.01
Lesser Goldfinch																												

Appendix C: Densities of 72 species of breeding birds with ≥30 total encounters during 1,851 point counts at 1,562 stations across the Sky Islands and adjacent Sierra Madre Occidental of Sonora and western Chihuahua, Mexico 2009-2012. All density estimates and associated standard errors (SE) are based on distance-sampling methods. Parenthetical numbers are numbers of stations in each range or region of the Sierra Madre. Relative abundance equals number of encounters / total counts.

	Aconchi (95)				Purica (77)				Cabullona (4)				Ceniza (12)				Carboneras (16)				Juriquipa (64)				Opusera (100)			
Species	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA
Montezuma Quail					1	0	0	0.01									3	0.06	0.03	0.19					3	0.01	0.01	0.03
Wild Turkey	13	0.02	0.01	0.14	6	0.01	0.01	0.07									6	0.03	0.01	0.38	18	0.04	0.01	0.28	2	0	0	0.02
Red-tailed Hawk	2	0	0	0.02	4	0.01	0	0.05													3	0.01	0	0.05	2	0	0	0.02
Band-tailed Pigeon	2	0.01	0.01	0.02	3	0.03	0.03	0.04									1	0.09	0.09	0.06	2	0.04	0.03	0.03	2	0.01	0.01	0.02
White-winged Dove	17	0.04	0.02	0.18	21	0.05	0.02	0.25	3	0.18	0.06	0.75	9	0.17	0.05	0.75												
Mourning Dove					7	0.06	0.04	0.08	1	0.08	0.08	0.25	9	0.23	0.1	0.75	1	0.02	0.02	0.06								
Thick-billed Parrot																												
Greater Roadrunner	2	0	0	0.02	3	0	0	0.04													9	0.01	0	0.14				
White-throated Swift	4	0.02	0.01	0.04					1	0.09	0.11	0.25																
Broad-billed Hummingbird	27	4.17	1.48	0.28	3	0.89	0.6	0.04	1	12.7	13.9	0.25					1	1.45	1.56	0.06					6	1.57	0.96	0.06
Magnificent Hummingbird	3	0.36	0.21	0.03																					5	0.57	0.26	0.05
Broad-tailed Hummingbird	1	0.32	0.34	0.01	3	0.24	0.15	0.04													11	1.15	0.47	0.17				
Elegant Trogon	11	0.06	0.03	0.12	13	0.03	0.01	0.15									7	0.09	0.04	0.44	26	0.09	0.02	0.41	52	0.12	0.02	0.52
Mountain Trogon																												
Acorn Woodpecker	19	0.12	0.03	0.2	8	0.05	0.02	0.1					1	0.04	0.04	0.08					10	0.08	0.03	0.16	31	0.17	0.04	0.31
Hairy Woodpecker					3	0.03	0.02	0.04																	2	0.02	0.01	0.02
Arizona Woodpecker	12	0.08	0.03	0.13	14	0.08	0.02	0.17									8	0.36	0.15	0.5	16	0.12	0.03	0.25	11	0.06	0.02	0.11
Northern Flicker	1	0	0	0.01	1	0.02	0.02	0.01													3	0.01	0.01	0.05	5	0.01	0.01	0.05
Greater Pewee	2	0.02	0.01	0.02	4	0.01	0	0.05													5	0.01	0.01	0.08	29	0.14	0.05	0.29
Western Wood-Pewee	37	0.61	0.14	0.39	8	0.08	0.03	0.1													2	0.04	0.03	0.03	27	0.22	0.05	0.27
Cordilleran Flycatcher					1	0.02	0.02	0.01																	2	0.03	0.02	0.02
Buff-breasted Flycatcher																												
Dusky-capped Flycatcher	61	0.42	0.07	0.64	23	0.1	0.02	0.27									14	0.42	0.08	0.88	65	0.4	0.06	1.02	126	0.83	0.11	1.26
Ash-throated Flycatcher	1	0.01	0.01	0.01	28	0.16	0.04	0.33	5	0.59	0.23	1.25	8	0.42	0.16	0.67					5	0.04	0.02	0.08	1	0	0	0.01
Brown-crested Flycatcher	25	0.22	0.06	0.26	2	0.02	0.01	0.02																	19	0.13	0.03	0.19
Sulphur-bellied Flycatcher	5	0.03	0.01	0.05	2	0.01	0.01	0.02																	4	0.02	0.01	0.04
Cassin's Kingbird	7	0.03	0.01	0.07	22	0.14	0.06	0.26													3	0.04	0.03	0.05	2	0.02	0.01	0.02
Thick-billed Kingbird	8	0.05	0.02	0.08																					1	0.01	0.01	0.01
Plumbeous Vireo	3	0.02	0.01	0.03	9	0.07	0.02	0.11													7	0.08	0.04	0.11	14	0.13	0.04	0.14
Hutton's Vireo	20	0.39	0.13	0.21	10	0.16	0.07	0.12									1	0.05	0.06	0.06	10	0.21	0.1	0.16	50	0.54	0.1	0.5
Steller's Jay					18	0.06	0.02	0.21													14	0.09	0.04	0.22	52	0.36	0.1	0.52
Mexican Jay	13	0.04	0.01	0.14	20	0.09	0.02	0.24									11	0.19	0.05	0.69	35	0.22	0.04	0.55	24	0.06	0.01	0.24
Common Raven					2	0	0	0.02													1	0	0	0.02				
Mexican Chickadee																												
Bridled Titmouse	40	0.7	0.14	0.42	15	0.26	0.09	0.18									5	0.59	0.26	0.31	27	0.66	0.13	0.42	57	0.92	0.16	0.57

	Aconchi (95)				Purica (77)				Cabullona (4)				Ceniza (12)				Carboneras (16)				Juriquipa (64)				Opusera (100)			
Species	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA
Bushtit	1	0.03	0.03	0.01	7	0.25	0.1	0.08									1	0.13	0.13	0.06	4	0.17	0.09	0.06	16	0.31	0.08	0.16
White-breasted Nuthatch	34	0.2	0.04	0.36	15	0.08	0.02	0.18									1	0.04	0.04	0.06	12	0.12	0.05	0.19	72	0.48	0.07	0.72
Brown Creeper	5	0.1	0.05	0.05	13	0.34	0.1	0.15													7	0.22	0.1	0.11	52	1.21	0.18	0.52
Cactus Wren	4	0.02	0.01	0.04	6	0.03	0.01	0.07	4	0.4	0.18	1	13	0.44	0.13	1.08									2	0.01	0.01	0.02
Rock Wren	1	0	0	0.01	1	0.01	0.01	0.01					3	0.11	0.06	0.25									4	0.02	0.01	0.04
Canyon Wren	23	0.3	0.22	0.24	7	0.02	0.01	0.08					1	0.02	0.02	0.08	4	0.11	0.06	0.25	14	0.08	0.03	0.22	28	0.12	0.03	0.28
Bewick's Wren	99	0.96	0.13	1.04	74	0.55	0.08	0.88	1	0.11	0.11	0.25	7	0.5	0.18	0.58	14	1	0.25	0.88	53	0.57	0.11	0.83	114	1.41	0.14	1.14
House Wren																												
Blue-gray Gnatcatcher					5	0.11	0.05	0.06	1	0.47	0.47	0.25					7	0.79	0.25	0.44	15	0.46	0.14	0.23	14	0.25	0.07	0.14
Eastern Bluebird					3	0.02	0.01	0.04													5	0.04	0.02	0.08	6	0.03	0.01	0.06
Townsend's Solitaire																												
Brown-backed Solitaire																												
American Robin	2	0.01	0.01	0.02	7	0.05	0.02	0.08													2	0.03	0.02	0.03	32	0.34	0.08	0.32
Northern Mockingbird	2	0.01	0	0.02	5	0.01	0.01	0.06	6	0.57	0.36	1.5	6	0.19	0.12	0.5					3	0.01	0.01	0.05				
Phainopepla																												
Olive Warbler					3	0.02	0.01	0.04																	2	0.01	0.01	0.02
Crescent-chested Warbler																									2	0.06	0.06	0.02
Grace's Warbler	11	0.08	0.04	0.12	6	0.03	0.02	0.07													4	0.04	0.02	0.06	9	0.24	0.13	0.09
Black-throated Gray Warbler					4	0.07	0.06	0.05													1	0.06	0.06	0.02	1	0.01	0.01	0.01
Rufous-capped Warbler	12	0.2	0.07	0.13																					7	0.11	0.05	0.07
Red-faced Warbler																												
Painted Redstart	55	1.11	0.2	0.58	18	0.29	0.09	0.21									4	0.27	0.15	0.25	25	0.46	0.12	0.39	86	1.01	0.17	0.86
Slate-throated Redstart																												
Spotted Towhee					23	0.16	0.05	0.27	1	0.22	0.22	0.25					1	0.03	0.03	0.06	30	0.24	0.05	0.47	43	0.28	0.05	0.43
Rufous-crowned Sparrow	25	0.56	0.23	0.26	27	0.5	0.22	0.32	5	3.75	3.07	1.25	3	0.18	0.1	0.25	22	0.9	0.15	1.38	29	0.32	0.06	0.45	25	0.18	0.04	0.25
Canyon Towhee	7	0.08	0.04	0.07	6	0.12	0.07	0.07	3	1.63	0.86	0.75	3	0.66	0.38	0.25									4	0.04	0.03	0.04
Yellow-eyed Junco					27	0.46	0.14	0.32																				
Hepatic Tanager	49	0.45	0.08	0.52	43	0.47	0.09	0.51	1	0.28	0.28	0.25					7	0.42	0.16	0.44	34	0.45	0.09	0.53	91	0.96	0.13	0.91
Summer Tanager	8	0.1	0.04	0.08	4	0.06	0.03	0.05																	2	0.02	0.02	0.02
Black-headed Grosbeak	60	0.94	0.23	0.63	50	0.56	0.13	0.6	1	0.08	0.08	0.25	3	0.17	0.11	0.25	25	0.61	0.08	1.56	50	0.43	0.09	0.78	19	0.09	0.02	0.19
Blue Grosbeak	24	0.2	0.07	0.25	2	0	0	0.02					4	0.08	0.05	0.33	2	0.07	0.05	0.13					3	0.04	0.03	0.03
Varied Bunting	13	0.32	0.15	0.14	1	0.01	0.01	0.01					1	0.08	0.08	0.08									3	0.05	0.04	0.03
Brown-headed Cowbird	11	0.17	0.05	0.12	15	0.19	0.06	0.18					2	0.15	0.11	0.17					1	0.01	0.01	0.02	3	0.05	0.03	0.03
Hooded Oriole	5	0.06	0.03	0.05									3	0.3	0.16	0.25									2	0.02	0.02	0.02
Scott's Oriole	20	0.05	0.02	0.21	15	0.04	0.01	0.18					1	0.02	0.02	0.08					14	0.1	0.04	0.22	14	0.03	0.01	0.14
House Finch					5	0.07	0.03	0.06	3	0.93	0.33	0.75	10	1.03	0.29	0.83					1	0.02	0.02	0.02	1	0.01	0.01	0.01
Lesser Goldfinch	12	0.21	0.08	0.13					1	0.34	0.34	0.25									4	0.05	0.03	0.06	5	0.07	0.03	0.05

Appendix C: Densities of 72 species of breeding birds with ≥30 total encounters during 1,851 point counts at 1,562 stations across the Sky Islands and adjacent Sierra Madre Occidental of Sonora and western Chihuahua, Mexico 2009-2012. All density estimates and associated standard errors (SE) are based on distance-sampling methods. Parenthetical numbers are numbers of stations in each range or region of the Sierra Madre. Relative abundance equals number of encounters / total counts.

	Tigre (111)				Pan Duro (44)				San Luis (96)				Pulpito (80)				Bacadehuachi (46)				SMO-Huachinera (46)				SMO-Cebadilla (77)			
Species	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA
Montezuma Quail	2	0	0	0.02	1	0	0	0.02	8	0.08	0.06	0.08	5	0.02	0.01	0.06	1	0.01	0.01	0.02					1	0.05	0.07	0.01
Wild Turkey	6	0	0	0.05	2	0.01	0	0.05					1	0	0	0.01									2	0	0	0.03
Red-tailed Hawk	1	0	0	0.01					5	0.01	0	0.05	4	0.01	0	0.05												
Band-tailed Pigeon	9	0.03	0.01	0.08	2	0.04	0.03	0.05	9	0.07	0.04	0.09	5	0.04	0.02	0.06	3	0.05	0.03	0.06	2	0.03	0.02	0.04	7	0.06	0.03	0.09
White-winged Dove													7	0.02	0.01	0.09	4	0.02	0.01	0.09								
Mourning Dove	7	0.03	0.01	0.06	2	0.08	0.09	0.05	6	0.02	0.01	0.06	21	0.12	0.03	0.26												
Thick-billed Parrot																												
Greater Roadrunner					2	0	0	0.05	10	0.02	0.01	0.1	2	0	0	0.03					2	0.01	0.01	0.04	1	0	0	0.01
White-throated Swift	5	0.02	0.01	0.05	1	0.01	0.01	0.02									1	0.01	0.01	0.02					2	0.01	0.01	0.03
Broad-billed Hummingbird	4	1.67	1.14	0.04					5	1.16	0.65	0.05	1	0.52	0.56	0.01	2	1.46	1.15	0.04	1	0.69	0.73	0.02	2	0.89	0.85	0.03
Magnificent Hummingbird	4	0.41	0.21	0.04													1	0.24	0.24	0.02	1	0.25	0.25	0.02	5	0.74	0.33	0.06
Broad-tailed Hummingbird	15	1.16	0.51	0.14	2	0.2	0.15	0.05	2	0.17	0.13	0.02	1	0.3	0.32	0.01					7	2.22	1.19	0.15	12	1.64	0.7	0.16
Elegant Trogon	32	0.09	0.03	0.29					7	0.02	0.01	0.07	5	0.01	0.01	0.06	34	0.17	0.03	0.72	19	0.09	0.02	0.41	34	0.1	0.02	0.44
Mountain Trogon																												
Acorn Woodpecker	12	0.06	0.02	0.11	6	0.07	0.04	0.14	18	0.11	0.03	0.19	13	0.1	0.03	0.16	29	0.32	0.07	0.62	6	0.06	0.03	0.13	39	0.27	0.05	0.51
Hairy Woodpecker																	2	0.03	0.02	0.04					4	0.04	0.02	0.05
Arizona Woodpecker	8	0.05	0.02	0.07	11	0.13	0.04	0.25	25	0.16	0.04	0.26	15	0.12	0.04	0.19	3	0.06	0.05	0.06	9	0.12	0.06	0.2	21	0.15	0.04	0.27
Northern Flicker	14	0.03	0.01	0.13	5	0.03	0.01	0.11	6	0.03	0.02	0.06	18	0.11	0.04	0.23	2	0.01	0.01	0.04	2	0.01	0.01	0.04	20	0.09	0.03	0.26
Greater Pewee	13	0.02	0.01	0.12	2	0.01	0.01	0.05	5	0.01	0	0.05	7	0.03	0.02	0.09	13	0.09	0.05	0.28	16	0.06	0.02	0.35	56	0.24	0.07	0.73
Western Wood-Pewee	13	0.13	0.05	0.12	4	0.11	0.06	0.09	25	0.31	0.08	0.26	11	0.09	0.04	0.14	3	0.06	0.03	0.06	6	0.06	0.02	0.13	20	0.32	0.1	0.26
Cordilleran Flycatcher	1	0.01	0.01	0.01	3	0.09	0.05	0.07					1	0.02	0.02	0.01	2	0.06	0.04	0.04	6	0.18	0.07	0.13	17	0.3	0.08	0.22
Buff-breasted Flycatcher	4	0.04	0.02	0.04					2	0.02	0.02	0.02	1	0.02	0.02	0.01	6	0.12	0.07	0.13					22	0.25	0.06	0.29
Dusky-capped Flycatcher	69	0.32	0.05	0.62	14	0.12	0.03	0.32	38	0.18	0.04	0.4	48	0.3	0.05	0.6	47	0.61	0.13	1	45	0.52	0.11	0.98	51	0.44	0.11	0.66
Ash-throated Flycatcher	1	0	0	0.01					58	0.25	0.05	0.6	43	0.22	0.04	0.54	1	0.01	0.01	0.02	3	0.02	0.01	0.07	5	0.04	0.02	0.06
Brown-crested Flycatcher	9	0.05	0.02	0.08													15	0.2	0.07	0.32					16	0.14	0.04	0.21
Sulphur-bellied Flycatcher	8	0.04	0.01	0.07													3	0.03	0.02	0.06					19	0.13	0.04	0.25
Cassin's Kingbird	2	0.01	0	0.02	9	0.06	0.02	0.2	20	0.07	0.02	0.21	1	0	0	0.01												
Thick-billed Kingbird	3	0.02	0.01	0.03													2	0.03	0.02	0.04								
Plumbeous Vireo	11	0.08	0.02	0.1					11	0.1	0.03	0.11	1	0.01	0.01	0.01	11	0.21	0.08	0.23	12	0.23	0.07	0.26	33	0.33	0.05	0.43
Hutton's Vireo	27	0.31	0.08	0.24	4	0.18	0.13	0.09	21	0.49	0.18	0.22	6	0.13	0.07	0.08	8	0.26	0.13	0.17	9	0.28	0.13	0.2	19	0.46	0.19	0.25
Steller's Jay	30	0.15	0.05	0.27	7	0.08	0.05	0.16	5	0.02	0.01	0.05	3	0.04	0.04	0.04	6	0.05	0.02	0.13	16	0.21	0.08	0.35	18	0.17	0.07	0.23
Mexican Jay	58	0.15	0.02	0.52	17	0.14	0.04	0.39	42	0.15	0.02	0.44	44	0.18	0.03	0.55	19	0.12	0.03	0.4	16	0.11	0.02	0.35	11	0.04	0.01	0.14
Common Raven	4	0	0	0.04					5	0.01	0	0.05																
Mexican Chickadee	12	0.23	0.07	0.11	8	0.46	0.19	0.18					4	0.18	0.14	0.05	3	0.13	0.1	0.06	9	0.41	0.14	0.2	9	0.28	0.12	0.12
Bridled Titmouse	18	0.23	0.06	0.16	12	0.45	0.14	0.27	22	0.37	0.1	0.23	9	0.17	0.06	0.11	12	0.42	0.16	0.26	3	0.1	0.06	0.07	8	0.16	0.05	0.1

	Tigre (111)				Pan Duro (44)				San Luis (96)				Pulpito (80)				Bacadehuachi (46)				SMO-Huachinera (46)				SMO-Cebadilla (77)			
Species	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA
Bushtit	15	0.29	0.09	0.14	1	0.07	0.07	0.02	10	0.29	0.1	0.1	12	0.37	0.1	0.15	5	0.23	0.1	0.11	7	0.39	0.14	0.15	4	0.11	0.07	0.05
White-breasted Nuthatch	10	0.07	0.04	0.09	2	0.02	0.01	0.05	1	0	0	0.01	1	0.01	0.01	0.01	21	0.25	0.05	0.45	7	0.13	0.07	0.15	20	0.17	0.05	0.26
Brown Creeper	22	0.42	0.1	0.2	3	0.12	0.08	0.07	2	0.05	0.05	0.02	2	0.05	0.03	0.03	11	0.56	0.18	0.23	10	0.43	0.16	0.22	38	1.11	0.2	0.49
Cactus Wren																	2	0.02	0.01	0.04	1	0.01	0.01	0.02				
Rock Wren	2	0.01	0.01	0.02					5	0.02	0.01	0.05	7	0.04	0.02	0.09									1	0.01	0.01	0.01
Canyon Wren	30	0.09	0.02	0.27	9	0.06	0.02	0.2	16	0.07	0.03	0.17	4	0.01	0.01	0.05	5	0.05	0.02	0.11	6	0.05	0.03	0.13	24	0.26	0.2	0.31
Bewick's Wren	62	0.43	0.08	0.56	41	0.83	0.13	0.93	120	1.16	0.12	1.25	78	0.86	0.1	0.98	2	0.02	0.01	0.04	25	0.51	0.11	0.54	3	0.03	0.02	0.04
House Wren					1	0.1	0.1	0.02	1	0.01	0.01	0.01					13	0.23	0.09	0.28	5	0.24	0.15	0.11	23	0.25	0.07	0.3
Blue-gray Gnatcatcher	32	0.53	0.1	0.29	12	0.52	0.15	0.27	21	0.44	0.09	0.22	16	0.36	0.1	0.2	8	0.26	0.11	0.17	11	0.44	0.14	0.24	9	0.24	0.08	0.12
Eastern Bluebird																	2	0.02	0.02	0.04					5	0.03	0.01	0.06
Townsend's Solitaire	8	0.04	0.02	0.07					1	0.01	0.01	0.01									1	0.01	0.01	0.02	4	0.03	0.01	0.05
Brown-backed Solitaire	3	0.01	0.01	0.03													3	0.02	0.01	0.06	8	0.06	0.03	0.17	24	0.11	0.04	0.31
American Robin	36	0.26	0.06	0.32	16	0.28	0.09	0.36	17	0.14	0.04	0.18	4	0.03	0.02	0.05	24	0.39	0.13	0.51	16	0.32	0.1	0.35	37	0.44	0.09	0.48
Northern Mockingbird	2	0	0	0.02					2	0.02	0.01	0.02	6	0.02	0.01	0.08	1	0.03	0.04	0.02	1	0	0	0.02				
Phainopepla																												
Olive Warbler	20	0.17	0.08	0.18	1	0.09	0.09	0.02	2	0.01	0.01	0.02	1	0.01	0.01	0.01	5	0.07	0.04	0.11	2	0.03	0.02	0.04	19	0.35	0.14	0.25
Crescent-chested Warbler																	1	0.07	0.07	0.02	1	0.07	0.07	0.02	9	0.36	0.13	0.12
Grace's Warbler	25	0.19	0.06	0.23	4	0.09	0.07	0.09	3	0.02	0.01	0.03					7	0.18	0.1	0.15	13	0.33	0.14	0.28	25	0.29	0.08	0.32
Black-throated Gray Warbler	3	0.05	0.04	0.03	17	1.05	0.43	0.39	25	0.92	0.32	0.26	17	0.44	0.19	0.21					1	0.02	0.02	0.02				
Rufous-capped Warbler	6	0.08	0.04	0.05													1	0.03	0.03	0.02					1	0.02	0.02	0.01
Red-faced Warbler	12	0.2	0.09	0.11	1	1.19	1.66	0.02	3	0.56	0.51	0.03					2	0.16	0.17	0.04	13	0.72	0.28	0.28	23	1.49	0.6	0.3
Painted Redstart	72	0.76	0.12	0.65	20	0.64	0.15	0.45	22	0.4	0.1	0.23	11	0.15	0.06	0.14	39	1.2	0.27	0.83	28	0.63	0.15	0.61	57	0.82	0.14	0.74
Slate-throated Redstart																	1	0.04	0.04	0.02	9	0.35	0.13	0.2	7	0.16	0.07	0.09
Spotted Towhee	103	0.53	0.07	0.93	24	0.45	0.1	0.55	82	0.73	0.13	0.85	104	0.66	0.08	1.3	6	0.08	0.05	0.13	32	0.36	0.07	0.7	24	0.19	0.05	0.31
Rufous-crowned Sparrow	26	0.25	0.13	0.23	4	0.05	0.02	0.09	59	0.9	0.26	0.61	39	0.66	0.24	0.49	5	0.32	0.28	0.11	8	0.62	0.39	0.17	18	0.63	0.39	0.23
Canyon Towhee	2	0.01	0.01	0.02					5	0.1	0.05	0.05	1	0.03	0.03	0.01					2	0.09	0.07	0.04				
Yellow-eyed Junco	18	0.24	0.08	0.16	1	0.01	0.01	0.02	2	0.01	0.01	0.02	8	0.22	0.11	0.1	8	0.29	0.14	0.17	6	0.07	0.04	0.13	32	0.57	0.17	0.42
Hepatic Tanager	57	0.42	0.06	0.51	4	0.15	0.09	0.09	21	0.25	0.06	0.22	24	0.25	0.06	0.3	37	0.64	0.12	0.79	20	0.49	0.11	0.43	26	0.39	0.08	0.34
Summer Tanager	4	0.04	0.03	0.04					3	0.04	0.02	0.03					1	0.03	0.03	0.02					1	0.02	0.02	0.01
Black-headed Grosbeak	66	0.47	0.12	0.59	2	0.06	0.04	0.05	28	0.31	0.09	0.29	31	0.22	0.08	0.39	10	0.1	0.03	0.21	20	0.34	0.14	0.43	34	0.32	0.08	0.44
Blue Grosbeak	2	0.01	0.01	0.02									3	0.02	0.01	0.04	9	0.12	0.05	0.19	1	0.01	0.01	0.02	1	0	0	0.01
Varied Bunting	4	0.03	0.02	0.04													2	0.14	0.1	0.04								
Brown-headed Cowbird	3	0.04	0.02	0.03	7	0.15	0.06	0.16	13	0.18	0.06	0.14	6	0.09	0.04	0.08	1	0.03	0.03	0.02	4	0.12	0.08	0.09	1	0.02	0.02	0.01
Hooded Oriole	20	0.21	0.07	0.18					1	0.01	0.01	0.01																
Scott's Oriole	14	0.02	0.01	0.13	5	0.05	0.03	0.11	27	0.1	0.03	0.28	15	0.04	0.01	0.19	5	0.02	0.01	0.11	2	0.01	0.01	0.04	9	0.03	0.01	0.12
House Finch					2	0.06	0.04	0.05													1	0.03	0.03	0.02				
Lesser Goldfinch	1	0.01	0.02	0.01									1	0.01	0.01	0.01	2	0.07	0.05	0.04					7	0.14	0.06	0.09

Appendix C continued

	SMO-Pinos Altos (16)				SMO-La India (47)				SMO-El Poleo (16)				SMO-Cinco Millas (34)			
Species	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA
Montezuma Quail	2	0.06	0.05	0.13	1	0	0	0.02								
Wild Turkey													1	0	0	0.03
Red-tailed Hawk	1	0.01	0.01	0.06												
Band-tailed Pigeon					9	0.12	0.04	0.19	1	0.03	0.03	0.06	4	0.05	0.03	0.12
White-winged Dove																
Mourning Dove					1	0.01	0.01	0.02					7	0.06	0.03	0.21
Thick-billed Parrot					1	0	0	0.02					33	0.12	0.05	0.97
Greater Roadrunner																
White-throated Swift																
Broad-billed Hummingbird																
Magnificent Hummingbird					6	1.46	0.58	0.13								
Broad-tailed Hummingbird	2	1.21	1.05	0.13	2	0.53	0.47	0.04	2	1.35	1.18	0.11	3	0.39	0.25	0.09
Elegant Trogon	6	0.08	0.05	0.38	16	0.08	0.02	0.34	1	0.01	0.01	0.06	3	0.02	0.01	0.09
Mountain Trogon					9	0.05	0.04	0.19	9	0.13	0.1	0.5	23	0.17	0.12	0.68
Acorn Woodpecker	4	0.12	0.07	0.25	14	0.15	0.04	0.3	1	0.03	0.03	0.06	1	0.01	0.01	0.03
Hairy Woodpecker					2	0.03	0.02	0.04	7	0.31	0.14	0.39	11	0.26	0.09	0.32
Arizona Woodpecker					12	0.2	0.07	0.26								
Northern Flicker	4	0.06	0.03	0.25	7	0.06	0.03	0.15	6	0.08	0.04	0.33	21	0.2	0.06	0.62
Greater Pewee	8	0.1	0.03	0.5	13	0.08	0.04	0.28	9	0.09	0.03	0.5	13	0.12	0.06	0.38
Western Wood-Pewee	7	0.55	0.26	0.44	11	0.22	0.1	0.23	1	0.05	0.05	0.06				
Cordilleran Flycatcher	1	0.09	0.09	0.06	9	0.26	0.09	0.19	4	0.31	0.14	0.22	13	0.53	0.18	0.38
Buff-breasted Flycatcher	1	0.04	0.04	0.06	10	0.18	0.07	0.21	3	0.11	0.06	0.17				
Dusky-capped Flycatcher	5	0.32	0.24	0.31	17	0.15	0.04	0.36	1	0.03	0.03	0.06	4	0.05	0.03	0.12
Ash-throated Flycatcher					1	0.01	0.01	0.02								
Brown-crested Flycatcher	8	0.5	0.28	0.5	4	0.1	0.07	0.09								
Sulphur-bellied Flycatcher	4	0.13	0.06	0.25	8	0.09	0.03	0.17								
Cassin's Kingbird	3	0.05	0.04	0.19	2	0.01	0.01	0.04	1	0.03	0.03	0.06				
Thick-billed Kingbird	5	0.19	0.11	0.31												
Plumbeous Vireo	4	0.28	0.17	0.25	13	0.19	0.06	0.28	10	0.48	0.13	0.56	2	0.06	0.04	0.06
Hutton's Vireo					5	0.11	0.05	0.11	4	0.22	0.13	0.22	2	0.05	0.04	0.06
Steller's Jay	8	0.51	0.37	0.5	12	0.14	0.06	0.26	6	0.37	0.3	0.33	41	0.77	0.2	1.21
Mexican Jay	3	0.05	0.03	0.19	16	0.1	0.02	0.34					1	0.01	0.01	0.03
Common Raven					1	0	0	0.02								
Mexican Chickadee	6	0.97	0.57	0.38	11	0.43	0.15	0.23	12	1.26	0.42	0.67	30	1.73	0.43	0.88
Bridled Titmouse	3	0.53	0.31	0.19	5	0.16	0.08	0.11								

	SMO-Pinos Altos (16)				SMO-La India (47)				SMO-El Poleo (16)				SMO-Cinco Millas (34)			
Species	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA	No.	D	SE	RA
Bushtit	1	0.13	0.14	0.06	1	0.04	0.04	0.02	2	0.26	0.18	0.11	4	0.26	0.13	0.12
White-breasted Nuthatch	6	0.21	0.07	0.38	9	0.16	0.07	0.19	11	0.32	0.09	0.61	15	0.4	0.2	0.44
Brown Creeper	4	0.47	0.28	0.25	16	0.72	0.18	0.34	9	0.92	0.34	0.5	17	1.12	0.31	0.5
Cactus Wren																
Rock Wren																
Canyon Wren					5	0.04	0.02	0.11								
Bewick's Wren	1	0.1	0.1	0.06	2	0.03	0.02	0.04								
House Wren	11	0.57	0.22	0.69	19	0.48	0.18	0.4	23	1.44	0.43	1.28	15	1.3	0.52	0.44
Blue-gray Gnatcatcher	1	0.07	0.07	0.06	3	0.11	0.08	0.06								
Eastern Bluebird					8	0.09	0.03	0.17	1	0.03	0.03	0.06				
Townsend's Solitaire	1	0.03	0.03	0.06	5	0.06	0.03	0.11	3	0.09	0.05	0.17	6	0.09	0.04	0.18
Brown-backed Solitaire					1	0.01	0.01	0.02								
American Robin	10	0.52	0.23	0.63	15	0.52	0.18	0.32	17	0.83	0.21	0.94	14	0.45	0.19	0.41
Northern Mockingbird																
Phainopepla																
Olive Warbler	4	0.35	0.25	0.25	3	0.04	0.02	0.06	8	0.27	0.09	0.44	30	0.53	0.12	0.88
Crescent-chested Warbler					16	1.04	0.35	0.34	4	0.68	0.41	0.22	14	1.26	0.44	0.41
Grace's Warbler	3	0.18	0.13	0.19	17	0.33	0.12	0.36	12	0.74	0.28	0.67				
Black-throated Gray Warbler																
Rufous-capped Warbler																
Red-faced Warbler	2	0.12	0.08	0.13	14	0.81	0.37	0.3	8	0.6	0.26	0.44	39	2.06	0.55	1.15
Painted Redstart	6	0.51	0.38	0.38	24	0.53	0.13	0.51	7	0.28	0.13	0.39	3	0.06	0.04	0.09
Slate-throated Redstart					3	0.11	0.07	0.06	2	0.2	0.14	0.11	28	1.47	0.4	0.82
Spotted Towhee	1	0.24	0.24	0.06	6	0.07	0.03	0.13	1	0.02	0.02	0.06	2	0.04	0.04	0.06
Rufous-crowned Sparrow	4	0.87	0.76	0.25	2	0.03	0.02	0.04								
Canyon Towhee																
Yellow-eyed Junco	9	0.72	0.29	0.56	19	0.41	0.14	0.4	20	1.13	0.39	1.11	21	0.95	0.28	0.62
Hepatic Tanager	12	0.53	0.21	0.75	19	0.33	0.09	0.4	5	0.27	0.11	0.28	2	0.03	0.02	0.06
Summer Tanager					1	0.03	0.03	0.02								
Black-headed Grosbeak	6	0.6	0.36	0.38	18	0.17	0.05	0.38	3	0.12	0.1	0.17	15	0.32	0.1	0.44
Blue Grosbeak					1	0.01	0.01	0.02								
Varied Bunting	1	0.17	0.19	0.06												
Brown-headed Cowbird					1	0.03	0.03	0.02								
Hooded Oriole																
Scott's Oriole	5	0.09	0.05	0.31												
House Finch					1	0.03	0.03	0.02								
Lesser Goldfinch					1	0.03	0.04	0.02								

Appendix D: Distribution and frequency of occurrence (%) of dominant tree species within 50 m of bird survey stations in the Sky Islands and adjacent Sierra Madre Occidental in Sonora and Chihuahua, Mexico, 2009-2012. Only species that comprised ≥5% of vegetation volume were considered dominants. Parenthetical numbers are the number of survey stations where vegetation was measured.

Tree species	Humo (20)	San Juan (30)	Esmeralda (14)	Avispas-Cíbuta (52)	Pinito (95)	Madera (30)	Chivato (33)	Azul (53)	Cucurpe (20)	Mariquita (48)	Elenita (30)	San Antonio (22)	San José (34)	Ajos (90)	Aconchi (95)	Púrica (76)	Cabullona (4)	Ceniza (12)	Carboneras (16)	Juriquipa (64)	Oposura (100)	Tigre (111)	Pan Duro (42)	San Luis (93)	Púlpito (80)	Bacadéhuachi (46)	SMO-Huachinera (46)	SMO-Cebadilla (77)	SMO-Pinos Altos (16)	SMO-India (45)	SMO-Poleo (18)	SMO-Cinco Millas (26)
Cupressus arizonica																						2	36	46		11	11	34	6	29		
Juniperus spp.			7	39	56	97	73	38	15	50	43	96	100	59		46			13	84		53	74	79	68	2	41	25	63	42		39
Abies concolor														20																		46
Pinus discolor					18		36			2	3		82	12								19	33	60	26		2					
Pinus arizonica					42			49		75	100			50	21	38				5	31	55	43	5	6	46	48	46	50	42	100	77
Pinus engelmannii				21	36	23		26		17	67	9		71	18	15			25	56	46	39	83	9	29	54	37	27	44	58		
Pinus chihuahuana					21	50		2		2				32	7	1			56	17	5	24	91	28	20	30	35	21	38	29	11	27
Pinus lumholtzii																															6	
Pinus ponderosa var. scopulorum													9																	11	22	15
Pinus strobiformis								28		73				28							21	28		1		15	28	25	50	20	33	92
Pinus yecorensis																			19							22	48	26		7		
Pseudotsuga menziesii														7								16	12	12			7	10				92
Acer grandidentatum								9						41		1				3		23	31	14			15	34	13	13	6	8
Acer glabrum																																4
Rhus glabra									10					1																		
Ilex rubra																					1							1				
Alnus oblongifolia														21							11	1				9		31		2		
Ostrya virginiana																						1						18		11		
Arbutus arizonica				8	50	40	3	30	5	23	47	9	3	36	42	15			38	42	46	31	38	7	36	37	72	18	13	44		4
Arbutus xalapensis															13						11	12				28	26	4	19	2	6	8
Eysenhardtia orthocarpa						3																										
Lysiloma watsonii															1							1										
Prosopis velutina		33		29			12		25			14			8	20		83				5					2					
Robinia neomexicana										2				9		1									3							
Quercus arizonica	50	70	36	94	73	60	91	68	15	67	57	64	97	82	65	59	100		94	98	79	69	57	56	89	70	70	47	31	44	17	
Quercus chihuahuensis																					1					22				2		

Tree species	Humo (20)	San Juan (30)	Esmeralda (14)	Avispas-Cibuta (52)	Pinito (95)	Madera (30)	Chivato (33)	Azul (53)	Cucurpe (20)	Mariquita (48)	Elenita (30)	San Antonio (22)	San José (34)	Ajos (90)	Aconchi (95)	Púrica (76)	Cabullona (4)	Ceniza (12)	Carboneras (16)	Juriquipa (64)	Oposura (100)	Tigre (111)	Pan Duro (42)	San Luis (93)	Púlpito (80)	Bacadéhuachi (46)	SMO-Huachinera (46)	SMO-Cebadilla (77)	SMO-Pinos Altos (16)	SMO-India (45)	SMO-Poleo (18)	SMO-Cinco Millas (26)
Quercus coccolobifolia														2	15						17	11				39	44	12	13			
Quercus durifolia																						1						38	13	36		
Quercus emoryi	100	93	93	44	27	27	91	21	10		3	32	50	12	12	43		42			1	3	33	41	60		2	1				
Quercus gambelii										4			21	18		8						2			5			16				15
Quercus hypoleucoides				42	71	57	9	57		85	83	32	38	67	55	34			88	83	62	49	91	61	61	30	76	48	6	47		
Quercus mcvaughii																					15	32				35	39	20	44	20	6	12
Quercus oblongifolia	95	67	79	15	20	50	67	30	100		3	86	3	9	35	34	100	75	6	31	27	14	14	5	9	26	20	21	50			
Quercus rugosa								13							28	9					10	18	17	24	6	7	22	13		31	33	19
Quercus sideroxyla																													44	33	100	69
Quercus tarahumara																										24						
Quercus toumeyi					16	3			50		3	5				1			25	3		5		8	8			1				
Quercus viminea				27	25	13		8	5					1	4	4			63	41	36	14				44	24	13	6	18		
Garrya laurifolia																												3				
Juglans major				25	4		9					5	3	17	1	13				3	7	7	17	3	1	4		17		4		
Morus microphylla																										2						
Fraxinus gooddingii						7																										
Fraxinus velutina or *F. pappilosa*					6		36		45	8		9	27	34							6	20	31	12	26		13	20		18		15
Platanus wrightii				19	16		67	23		6		9	9	22	26	22				16	16	12	5	12	10	13	9	38	38	33		
Cercocarpus montanus										6				2								1			3							
Prunus serotina var. virens				2	1	3		4		8	10		6	4	4	7				5	8	9	2	1	3	9	2	3	25	2		12
Populus monticola												5			4	1					1											
Populus fremontii				2			33	2					3	6								1			3			1				
Populus tremuloides					1					6	3			2		7												10				50
Salix spp.								4					3	1								5		1			4					12
Sapindus drummondii																						1										
Tilia americana																												1		4		
Celtis reticulata				6					15							1		33														
Ulmus pumila																1																

Plate 8: Spotted Owl nest with two young (1 June 2012) in silver-leaf oak at 2,100 m in the Sierra Aconchi that was the second nest and confirmed breeding record for Sonora.

Plate 9: Montane riparian forest dominated by maple and alligator juniper at La Sal on the Ajos-Bavispe forest reserve on the east side of the Sierra los Ajos, July, 2006.