Studies in Avian Biology No. 37:28–45

DISTRIBUTION AND STATUS OF BREEDING LANDBIRDS IN NORTHERN SONORA MEXICO

Aaron D. Flesch

Abstract. Northern Sonora, Mexico is dominated by steep elevation and rainfall gradients and a variety of vegetation communities with affinity to the Sonoran, Madrean, Sinaloan, and Chihuahuan biogeographic provinces. Despite high environmental diversity and moderate accessibility, current information on distribution and abundance of breeding landbirds is limited throughout much of this vast region. Between 2000 and 2007, I surveyed landbirds in northern Sonora in four of the six primary watersheds that occur within 125 km of the US. I detected 161 species of landbirds that I presumed were breeding (59% confirmed) and four additional species that were possibly breeding during 568 site visits to 306 localities. I did not detect seven species that had been presumed to breed in the past, six of which likely still occur, or 10 species that I suspect may breed locally or irregularly in the study area. Based on probabilistic methods, I estimate that as many as 178 species of landbirds likely breed in the study area. Species richness within each of 16 secondary watershed regions increased as the number of major vegetation communities that were present increased, and presence of broadleaf riparian woodland, Madrean evergreen woodland, and Madrean montane conifer forest had the greatest influence on richness. Geographic ranges of many species that I observed were much larger than that suggested by previous studies likely as a result of increased effort. Evidence for some species however, suggested that distributions have either expanded or contracted, likely as a result of major changes in vegetation and perhaps climate change. Although some populations await discovery, my findings suggest that northern Sonora supports higher richness of breeding landbirds than any other region of similar area in the borderlands of northern Mexico.

Key Words: borderlands, climate change, distribution, distributional change, landbirds, Mexico, Sonora, transboundary conservation, US-Mexico border.

DISTRIBUCIÓN Y ESTADO DE AVES TERRESTRES REPRODUCTIVAS EN EL NORTE DE SONORA, MÉXICO

Resumen. El norte de Sonora, México esta dominado por un marcado gradiente altitudinal y de precipitación pluvial, así como por una variedad de comunidades vegetales con afinidad a las provincias biogeográficas Sonorense, Madreano, Sinaloense y Chihuahuense. A pesar de la alta diversidad ambiental y cierta accesibilidad, la información actual de distribución y abundancia de aves terrestres reproductivas es limitada en gran parte de esta vasta región. Entre 2000 y 2007, realicé monitoreos de aves terrestres en el norte de Sonora, en cuatro de las seis principales cuencas que se ubican a 125 km o menos, de los Estados Unidos. Detecté 161 especies de aves terrestres que asumí estaban reproduciéndose (59% confirmadas), y cuatro especies adicionales que posiblemente estaban reproduciéndose durante 568 visitas a 306 localidades. No detecté siete especies que se presumían en el pasado como reproductoras, seis de las cuales es probable que todavía ocurran, como tampoco 10 especies que sospecho se reproducen localmente o irregularmente dentro del área. Basado en métodos probabilísticos estimé que hasta 178 especies de aves terrestres probablemente se reproducen en el área de estudio. La riqueza de especies dentro de cada una de las 16 subcuencas incremento en la medida en que aumentaba el número de comunidades vegetales, y la presencia de bosques ribereños de hojas anchas, bosques siempre verdes Madreanos y bosques montanos de coníferas Madreanos tuvieron la mayor influencia en la riqueza. Los rangos geográficos de muchas especies que observé fueron mucho más grandes que lo sugerido por estudios previos, muy probablemente como resultado de un esfuerzo mayor. Sin embargo la evidencia para algunas especies, sugiere que ha habido expansión o contracción de sus distribuciones, probablemente como resultado de cambios mayores en la vegetación y quizás por cambios climáticos. Aunque algunas poblaciones esperan ser descubiertas, mis hallazgos sugieren que el norte de Sonora soporta mayor riqueza de aves terrestres reproductivas que cualquier otra región de área similar, en las tierras fronterizas del norte de México.

Information on the status, distribution, and habitat needs of wildlife are essential for efficient conservation and management. In regions where little information is available and rapid environmental changes are anticipated, detailed information may be required to ensure that populations are identified, managed, and conserved before they are significantly altered or lost. Efforts to identify and manage wildlife populations may be especially challenging near international boundaries because ownership, management objectives, and national priorities often vary and development pressure and security concerns are often high. Despite these challenges, cooperation among neighboring nations can help achieve conservation objectives in trans-boundary landscapes (Mittermeier et al. 2005, Plumptre et al. 2007).

At approximately 600 km in length, the international boundary between the state of Arizona in the US and the state of Sonora in Mexico bisects a region of exceptional diversity. Spanning nearly a 10-fold range of annual rainfall, this region extends from mountains at the northern edge of the Sierra Madre Occidental west to the delta of the Río Colorado and supports both highland vegetation communities of oaks (*Quercus* sp.) and pines (*Pinus* sp.) and vast lowlands of Sonoran and Chihuahuan desertscrub and grassland (Brown 1982). Complex elevation and moisture gradients and convergence of several major biogeographic provinces foster high regional diversity and result in the distributional limits of both Neotropical and Nearctic species of plants and animals (Halffter 1987, Howell and Webb 1995, Turner et al. 1995, Escalante et al. 2004).

Large areas of the Sonora-Arizona borderlands are managed with explicit conservation directives by the Mexican and US federal governments (Cartron et al. 2005, Felger et al. 2007), yet a number of environmental concerns exist (Liverman et al. 1999, Goodwin 2000). Although human population densities are low in many areas of northern Sonora, groundwater use and urban growth are increasing, significant areas of riparian vegetation have been degraded or lost, and security concerns have culminated in ongoing development along much of the international border (Cartron et al. 2005, Búrquez and Martínez-Yrízar 2007, Cohn 2007). These and other factors may threaten long-term conservation objectives unless their effects are understood and information on the distribution and status of plant and wildlife populations are known and monitored. Information on bird communities may be especially valuable because relative to other vertebrates birds are often good indicators of specific environmental conditions upon which they depend (Canterbury et al. 2000, Bryce et al 2002) and because birds are relatively easy to detect and survey (Ralph and Scott 1981, Bibby et al. 2000)

Ornithological investigations in Sonora began well over a century ago and continue to this day (Stephens 1885, Moore 1938, van Rossem 1945, Marshall 1957, Short 1974, Russell and Monson 1998, Rojas-Soto et al. 2002, Villaseñor 2006). Despite these efforts, vast portions of northern Sonora remained little studied by the early 1950s (Phillips and Amadon 1952) after which additional work occurred. Marshall (1957) provided detailed information in pine-oak woodlands in many of the higher mountains in northeast Sonora. Russell and Monson (1998) synthesized information from previous studies and collections from throughout Sonora that they supplemented with field work in some regions of northern Sonora. Since these efforts, Hinojosa-Huerta et al. (2007) summarized status and provided additional records of birds in the lower Colorado River Valley and adjacent areas of extreme western Sonora, Flesch and Hahn (2005) described bird communities in several little-known mountain ranges west of the region visited by Marshall (1957), and Villaseñor (2006) reported on wintering birds at several widely scattered localities. Despite these efforts, the large size of northern Sonora, limited accessibility, and high environmental diversity have precluded a detailed assessment of distribution and status of breeding landbirds.

To provide current information on landbirds in the borderlands of northern Sonora, I surveyed much of the region between 2000 and 2007. Herein I summarize information on distribution and status of breeding landbirds, assess recent distributional changes, and describe patterns of species richness across the region.

METHODS

Study Area

I defined northern Sonora as the area within 125 km of the international boundary with the US. Several major watersheds traverse this region and many originate near the international boundary and flow in a north-south direction (Fig. 1). In northeastern Sonora, the Río Yaqui begins in extreme southeast Arizona and southwest New Mexico and flows south through Sonora toward the Gulf of California. To the west in the Gila watershed, the Ríos San Pedro and Santa Cruz originate in mountains near the border, traverse small portions of Sonora, then flow north into Arizona. To the south, the adjacent Río Sonora, and its tributaries the Ríos Bacanuchi and San Miguel, flow south from mountains within 70 km of the border. Farther west in the Concepción watershed, the Río Altar and Arroyo Sasabe, drain small areas of south-central Arizona and the Río Magdalena and Arroyo Plomo originate immediately south of the border. These and several other tributaries of the Río Concepción flow south before converging and flowing west toward the Gulf of California. In the more arid west, the Río Sonoyta and its tributary the Arroyo Vamori drain a region immediately along the border and empty into the sands of the Gran Desierto

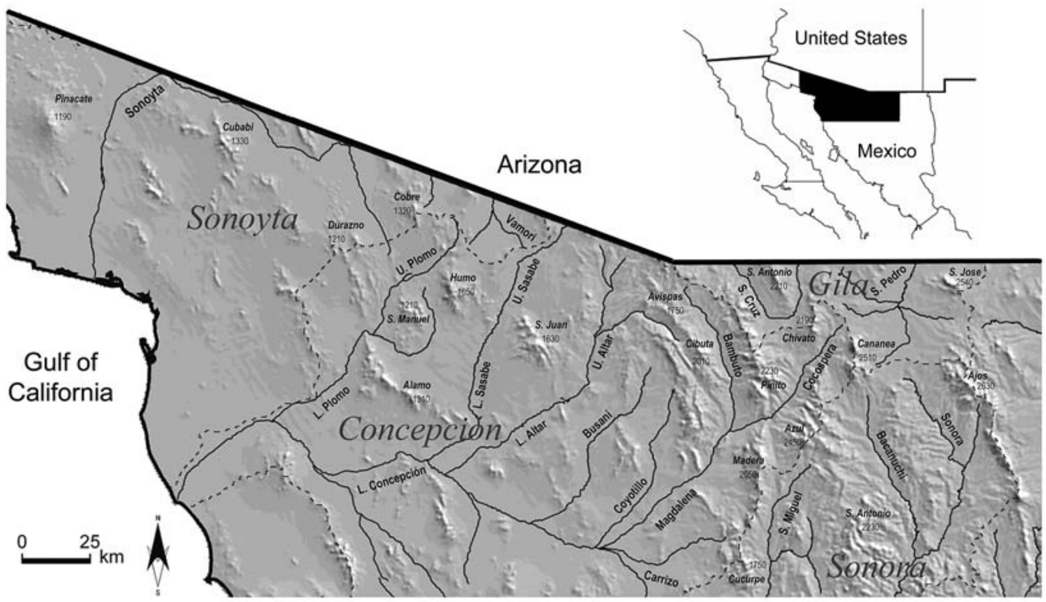

FIGURE 1. Map of study area in northern Sonora Mexico indicating boundaries of primary watersheds (dashed line) and major drainages and mountain ranges. The maximum elevation of each mountain range is in meters. Elevations are based on data from Instituto Nacional de Estadística, Geografía e Informática and my own measurements using a GPS. The small portion of the Yaqui watershed to the east was not considered nor were areas >125 km from the international boundary with the US.

de Altar. Still west is the Río Colorado that drains much of the southwestern US.

In this study, I considered the Sonora, Gila, Concepción, and Sonoyta watersheds that together cover approximately 70% of northern Sonora and excluded the extreme western portion of the Sonoyta watershed which is predominately sand dunes. I did not consider the Yaqui watershed where field work is not yet complete or the much smaller Río Colorado watershed which has been described elsewhere (Hinojosa-Huerta et al. 2007). To describe distribution of breeding landbirds, I subdivided these four primary watersheds into 16 secondary watershed regions (Table 1) by combining some nearby drainages or subdividing long drainages into upper and lower sections.

Vegetation communities in the region included large expanses of Sonoran desertscrub, semi-desert and plains grassland, and smaller areas of Chihuahuan desertscrub, subtropical thornscrub, and montane forest and woodland. In the west, desertscrub of the Lower Colorado River Valley subdivision of the Sonoran Desert was dominant throughout much of the lower Concepción and Sonoyta watersheds and was replaced by desertscrub of the Arizona Upland subdivision at higher elevation. Savannah dominated the Plains of Sonora subdivision and occurred only in the extreme south-central Concepción watershed (Shreve 1951), whereas to the east, Chihuahuan desertscrub occurred only in the lower San Pedro watershed. In the extreme south, Sinaloan thornscrub occurred locally on slopes in the Coyotillo-Magdalena-Carrizo watersheds and was widespread only in the southern portion of the San Miguel and especially in the Bacanuchi-Sonora watersheds. Semi-desert grassland occurred at elevations above desertscrub in north-central Sonora west to the upper Plomo and Vamori watersheds and more open expanses of plains grassland occurred in the San Pedro and in the upper Santa Cruz and Sonora watersheds. Above grasslands, Madrean evergreen woodland was dominated by oaks at low elevation and by oaks and pines at high elevation; isolated stands of oak woodland occurred in mountains as far west as the upper Sasabe (Sierra San Juan) and upper Plomo (Sierra el Humo) watersheds. Woodland transitioned to Madrean montane conifer forest at high elevations in the Sierras el Pinito, Azul, Cananea (Elenita and Mariquita), los Ajos, and to the east in the Yaqui watershed. These forests were dominated by pine and rarely by Douglas fir (*Pseudostuga menziesii*) or white fir

TABLE 1. Survey effort and species richness of breeding landbirds in four primary and 16 secondary watershed regions in northern Sonora, Mexico 2000–2007. Site totals include transect and incidental surveys. Observed species richness is the total number of species detected in each region during the study whereas historical richness indicates additional species that were noted by Russell and Monson (1998) or by Marshall (1957) but were not observed during the study. Estimated species richness was calculated using the jackknife estimator (Burnham and Overton 1979) and observed species abundance distributions in each primary watershed and for the entire study area. Breeding species are those presumed and confirmed breeding. All data are based on observations obtained within 125 km of the international boundary with the US.

	Effort				Breeding species richness			Estimated		
Primary watershed / Watershed region	Transects	Transect visits	Sites	Site visits	Observed	Historical	Total observed	$\hat{N}$	SE	95% CI
Sonoyta	31	66	48	85	82	6	88	88	3.5	81.2–94.8
Lower	19	31	28	40	68	5	73			
Vamori	12	35	20	45	70	3	73			
Concepción	113	286	197	408	150	4	154	156	3.5	149.2–162.8
Lower	18	18	24	24	51	14	65			
Plomo Lower	11	13	14	16	53	6	59			
Plomo Upper	11	47	15	52	83	0	83			
Sasabe Lower	3	6	6	12	49	2	51			
Sasabe Upper	9	38	26	57	90	2	92			
Altar Lower	13	32	17	46	89	0	89			
Altar Upper	10	44	25	67	113	3	116			
Busani	7	22	12	31	73	0	73			
Coyotillo-Magdalena-Carrizo	21	54	44	87	106	3	109			
Cocospera-Bambuto	10	12	14	16	128	6	134			
Gila	6	15	18	27	106	14	120	113	3.7	105.7–119.8
Santa Cruz	3	3	7	7	79	16	95			
San Pedro	3	12	11	20	91	10	101			
Sonora	20	28	43	48	134	14	148	142	4.0	134.2–148.8
San Miguel Upper	18	20	26	31	98	5	103			
Bacanuchi-Sonora Upper	8	8	17	17	120	24	144			
All regions	176	395	306	568	161	6	167	166	3.2	159.7–172.3

(*Abies concolor*) that were restricted to the highest elevations and mainly on east- and north-facing slopes in the Yaqui watershed. Broadleaf riparian woodland and gallery forest occurred along valley bottoms and in canyons within several other vegetation communities and were dominated by willows (*Salix* sp.), Fremont cottonwood (*Populus fremontii*), and velvet ash (*Fraxinus velutina*) at low elevation and by Arizona sycamore (*Platanus wrightii*), Arizona walnut (*Juglans major*), and bigtooth maple (*Acer grandidentata*) at high elevation.

Site Selection

I used three methods to select sites for surveys: (1) random placement of survey transects, (2) non-random placement of survey transects, and (3) incidental observations. Random sampling provided inference to large portions of the study area whereas non-random sampling allowed the flexibility needed to efficiently locate and survey important environments that had low landscape coverage and otherwise low probability of being sampled.

To randomize placement of transects, I generated a random sample of coordinates at elevations ≤1,200 m that I stratified by major vegetation community and allocated in proportion to the coverage of each community. At each point, I established one transect along the closest drainage that was >2 m wide and within 1 km of a road in each of four possible topographic formations (valley bottoms, lower bajadas, upper bajadas, and mountain canyons) that occurred within 20 km of each point. Selection was constrained to low and moderate elevations because most transects were initially established for surveys of Ferruginous Pygmy-Owls (*Glaucidium brasilianum*; Flesch 2003).

To expand coverage across a broader range of elevations, I selected another sample of transects non-randomly. I placed transects along drainages and occasionally on slopes or trails in riparian areas, large canyons, montane woodland and forest, grassland, and focused in areas that were not adequately covered by random transects or where I suspected the occurrence of rare species with specialized habitat requirements. I selected locations for incidental observations opportunistically by noting observations while scouting, traveling between transects, in camp, and at times of day that were not efficient for transect surveys.

Field Surveys

I surveyed from February 2000 to June 2007 and focused during the breeding season between mid-February and late August of each year. I visited some transects only once and visited others up to 11 times depending on timing of initial surveys, accessibility, interest, and the location of other efforts (Flesch and Hahn 2005; Flesch and Steidl 2006, 2007). I prioritized transects for secondary surveys when initial surveys occurred before the anticipated arrival of migratory species and in areas where I suspected occurrence of rare species.

Each transect consisted of a linear search area approximately 1–6 km in length. To survey transects, I walked linear routes that typically followed drainages and temporarily walked in perpendicular directions to investigate bird activity or areas of interest. I recorded all species of birds that I detected during surveys, estimated numbers of individuals or pairs, noted any evidence of breeding, and walked at variable speeds depending on the amount of bird activity and complexity of the terrain. I often noted only presence and breeding behavior of common species so that I could focus on detecting and estimating abundance of less common species and traverse larger areas during morning. I surveyed during mornings but noted observations at other times of day or night. To rouse birds and augment visual and aural detection probabilities, I often mimicked or broadcast recorded territorial calls of pygmy-owls during surveys, which is similar to the method used by Marshall (1957). Along most transects that I selected randomly, I broadcast calls of Ferruginous Pygmy-Owl at 350–600 m intervals while simultaneously surveying for that species (Flesch 2003). Along transects that I selected non-randomly, I mimicked or broadcasted calls of pygmy-owls at less systematic intervals. At night I broadcasted conspecific vocalizations to elicit responses from nocturnal species on an opportunistic basis. I focused incidental observations on species that were uncommon, rare or of interest, and recorded the number of individuals detected and any evidence of breeding.

Analyses

To describe status within each region, I estimated relative abundance by dividing the number of transects where a species was present by the total number of transects visited during the breeding season. I used these estimates and incidental observations to classify relative abundance as common (frequently encountered as individuals, pairs, or small groups), fairly common (a few individuals or pairs detected), uncommon (present but may not be found in a day or two of field observations), and rare (present but rarely detected and often restricted to localized area), as defined by Russell and Monson (1998: 15). Species that were locally common but restricted to environments with low coverage were often considered uncommon. I presumed breeding was occurring if individuals were singing, paired, territorial, or exhibiting other circumstantial evidence of breeding when birds were in typical breeding habitat during the breeding season. For raptors, I presumed breeding was occurring if adults were present in typical breeding habitat during the breeding season. I used more rigorous standards for species that were in atypical breeding habitat by presuming breeding was occurring only when a territorial pair, courtship, or other behaviors indicative of breeding were observed. I did not presume breeding of migratory species unless observations occurred outside periods when populations typically migrate. To confirm breeding, I used criteria of the North American Ornithological Atlas Committee (1990). To define breeding habitat, distribution, and migration and wintering periods, I supplemented my observations with data from northern Sonora (van Rossem 1945, Marshall 1957, Russell and Monson 1998), adjacent portions of southern Arizona (Monson and Phillips 1981, Rosenberg and Witzeman 1998 and 1999, Rosenberg 2001, Corman and Wise-Gervais 2005), and other relevant literature (Poole 2005). I then compared my findings with information from these sources to assess potential changes in status or distribution.

I calculated observed species richness by summing all species that I presumed or confirmed to be breeding during the study within each region and calculated cumulative observed species richness by including species that I did not detect but that had been either presumed or confirmed breeding in the past (Marshall 1957, Russell and Monson 1998). Because all species are not detected perfectly during surveys, I estimated species richness ($\hat{N}$) based on the abundance distribution I observed and a limiting form of the jackknife estimator (Burnham and Overton 1979) calculated by program SPECRICH (J. E. Hines, available at http://www.mbr- pwrc.usgs.gov/software.html). To assess the range of likely values for each estimate, I calculated 95% confidence intervals. I did not estimate species richness at the scale of watershed regions because sample sizes in some regions were small.

To assess the influence of large-scale geographic and environmental factors on cumulative observed species richness, I used linear regression. As explanatory variables, I calculated the geographic position of each watershed region by estimating latitudinal and longitudinal centers and an index of environmental diversity equaled to the number of major vegetation communities present within each region and considered broadleaf riparian woodland as a community. To determine vegetation communities that had the greatest influence on species richness, I used multiple linear regression with stepwise selection ($P < 0.25$ to enter, $P < 0.10$ to stay). To evaluate adequacy of sampling, I assessed whether observed species richness and the number of species that were at least presumed to breed in the past but not detected during the study varied with effort (site visits).

RESULTS

Effort

I completed 395 surveys along 176 transects, 70% of which I located randomly, and 173 incidental surveys at 130 additional localities (Table 1). Number of surveys per transect averaged 2.7 ± 0.1 (± SE) with 54% of transects visited ≥two times and 27% of transects visited ≥four times. All effort combined yielded 568 site visits to 306 sites, 92% of which were between 11 February and 31 August and 54% were in May or June. I personally completed 77% of site visits, six observers each completed 3–5%, and an additional four observers completed the remaining 3% of visits all of which were incidental observations.

Number of transects and total effort (site visits) were approximately proportional to the size of primary watersheds (Table 1, Fig. 1). In the Concepción watershed, most effort was in the Altar (28%), Coyotillo-Magdalena-Carrizo (21%), Sasabe (17%), and Plomo (17%) watersheds and least effort was in the Busani (8%), lower Concepción (6%), and Cocospera-Bambuto (4%). Effort was higher in Arizona upland desertscrub (45%) and semi-desert grasslands (36%) than in Madrean evergreen woodland (6%). Effort was low in Lower Colorado River Valley (3%) and Chihuahuan (1%) desertscrub, plains grassland (3%), Sinaloan thornscrub (3%), and in Madrean montane conifer forest (1%), communities that covered much smaller portions of the study area. Effort in broadleaf riparian woodland totaled 15% and most of these sites were in semi-desert grassland (44%), Arizona Upland desertscrub (25%), plains grassland (9%), Sinaloan thornscrub (9%), and Madrean evergreen woodland (9%).

I visited virtually all major vegetation communities that occurred in lowlands within each watershed region and only some that occurred in highlands. At high elevations, I surveyed portions of the Sierras los Ajos (Bacanuchi-Sonora), el Pinito and Cananea (Cocospera-Bambuto), Cucurpe (San Miguel and Coyotillo-Magdalena-Carrizo), las Avispas (Upper Altar), San Juan (Upper Sasabe), el Humo (Upper Plomo), el Cobre (Vamori), and el Durazno (Lower Sonoyta) (Fig. 1). Difficult access and time contraints prevented surveys at upper elevations in the San Pedro (Sierra San Jose), Santa Cruz (northeast Sierras el Pinito and San Antonio), Coyotillo-Magdalena-Carrizo (Sierra la Madera), Busani (south of Sierra las Avispas), Lower Sonoyta (Sierra Cubabi), and Lower Concepción (Sierra el Alamo) watersheds and in areas above 1,300 m in the Sierra Azul (Cocospera-Bambuto and San Miguel), 1,200 m in the Sierra San Antonio (San Miguel and Bacanuchi-Sonora), and 1,600 m in the Sierra el Chivato (Santa Cruz).

Species Richness

I observed 66 species of landbirds that I presumed were breeding and another 95 species that I confirmed breeding. Four species (Wild Turkey [*Meleagris gallopavo*], Osprey [*Pandion haliaetus*], Fan-tailed Warbler [*Euthlypis lachrymosa*], Western Meadowlark, [*Sturnella neglecta*]) possibly bred but evidence was not sufficient to presume so. I did not detect seven species that had been at least presumed to breed in the past; five were associated with high-elevation forests (Flammulated Owl [*Otus flammeolus*], Blue-throated Hummingbird [*Lampornis clemenciae*], Magnificent Hummingbird [*Eugenes fulgens*], Pygmy Nuthatch [*Sitta pygmaea*], and Red-faced Warbler [*Cardellina rubrifrons*]), one with low desert (Le Conte's Thrasher [*Toxostoma lecontei*]), and one with grassland (Northern Bobwhite [*Colinus virginianus*]) (Tables 1 and 2). I estimate that 171 ± 3.7 species of landbirds at least possibly breed (upper bound of 95% CI = 178) and that 166 ± 3.2 species at least presumably breed (upper bound of 95% CI = 172) in the study area.

Within primary watersheds, species richness was high in the Concepción and Sonora, and low in the Sonoyta watersheds. Estimates of species richness within each primary watershed were similar to observed values (Table 1); observed richness averaged 5.6 ± 0.6% lower than that estimated and cumulative observed richness differed from that estimated by only 2.9 ± 1.4%.

Cumulative observed richness increased by an average of 15 ± 2 species with each additional vegetation community present in a region (t_{14} = 6.58, P < 0.001; Fig. 2). Although richness also increased from west to east (estimate ± SE = 3 ± 1 species/10 km, t_{14} = 4.04, P = 0.001), once the effect of vegetation was considered, richness did not vary with longitude (t_{13} = 1.21, P = 0.25). Presence of broadleaf riparian woodland, Madrean evergreen woodland, and Madrean montane conifer forest ($t_{12} \leq 2.29$, $P \leq 0.04$) influenced species richness more than presence of other vegetation communities ($t_{11} \leq 1.61$, $P \geq 0.14$); when any of these communities were present, richness averaged at least 40 ± 9 species greater than in regions where these communities were absent.

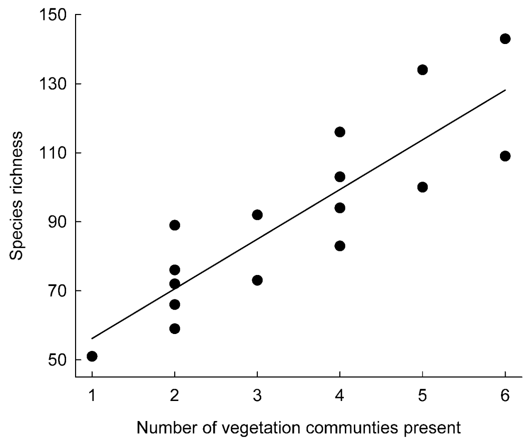

FIGURE 2. Association between species richness and the number of major vegetation communities present within each of 16 watershed regions in northern Sonora, Mexico. Richness equaled the number of landbird species that were presumed or confirmed breeding during the study plus species that I did not detect but that had been presumed or confirmed breeding in the past. Richness increased by 15 ± 2 species with each additional vegetation community (t_{14} = 6.58, P < 0.001).

Observed species richness did not vary with effort (t_{14} = 0.50, P = 0.63), yet the number of species that were at least presumed to breed in the past but not observed during the study decreased as effort increased (t_{14} = 2.20, P = 0.04). On average, observed richness was 7 ± 2% lower than cumulative observed richness and differences were greatest in the lower Concepción (21%), Santa Cruz (17%), and Bacanuchi-Sonora (17%) watersheds (Tables 1 and 2).

Distribution and Status

I detected six species of breeding landbirds that had not been observed previously in the study area and many others that had been observed at few localities. Of species that had not been observed previously, Short-tailed Hawk

TABLE 2. DISTRIBUTION AND STATUS OF BREEDING LANDBIRDS IN FOUR PRIMARY AND 16 SECONDARY WATERSHED REGIONS IN NORTHERN SONORA, MEXICO 2000–2007. DATA ARE BASED ON OBSERVATIONS OBTAINED WITHIN 125 KM OF THE INTERNATIONAL BOUNDARY WITH THE UNITED STATES. SPECIES STATUS IS NOTED AS RARE (R), UNCOMMON (U), FAIRLY COMMON (F), OR COMMON (C). SPECIES THAT WERE NOTED IN RUSSELL AND MONSON (1998) OR BY MARSHALL (1957) BUT THAT WERE NOT OBSERVED DURING THE STUDY ARE NOTED WITH AN ASTERISK AND STATUS WAS ASSESSED BASED ON PAST DESCRIPTIONS AND THE AMOUNT OF HABITAT THAT WAS AVAILABLE DURING THE STUDY. SPECIES FOR WHICH INSUFFICIENT EVIDENCE WAS OBTAINED TO PRESUME BREEDING ARE NOTED WITH A QUESTION MARK. WATERSHEDS ARE LISTED FROM WEST TO EAST.

	Sonoyta		Concepción										Gila		Sonora	
	Sonoyta	Vamori	Lower	Plomo Lower	Plomo Upper	Sasabe Lower	Sasabe Upper	Altar Lower	Altar Upper	Busani	Coyotillo Magdalena	Cocospera-Bambuto	Santa Cruz	San Pedro	San Miguel	Bacanuchi-Sonora
Galliformes																
Wild Turkey (*Meleagris gallopavo*)												?				?*
Scaled Quail (*Callipepla squamata*)	R				R		R				R*			U		
Elegant Quail (*Callipepla douglasii*)											R				U	U*
Gambel's Quail (*Callipepla gambelii*)	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Northern Bobwhite (*Colinus virginianus*)							U*									
Montezuma Quail (*Cyrtonyx montezumae*)		R*					R		R			U	U	U	R	R
Ciconiiformes																
Black Vulture (*Coragyps atratus*)	U	U	F	U	U	F	U	F	U	U	U	U	U*		U	U
Turkey Vulture (*Cathartes aura*)	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Falconiformes																
Osprey (*Pandion haliaetus*)	?															
White-tailed Kite (*Elanus leucurus*)										R		?*		R		
Sharp-shinned Hawk (*Accipiter striatus*)															R*	R
Cooper's Hawk (*Accipiter cooperii*)		R			R			R	U		R	U		U		R
Northern Goshawk (*Accipiter gentilis*)														R		
Common Black-Hawk (*Buteogallus anthracinus*)									R*		R	R			R	R*
Harris's Hawk (*Parabuteo unicinctus*)	F	R	U	U	F	R	R	F		F	U					
Gray Hawk (*Buteo nitida*)		?			?		R	U	F	U	F	F	U	F	F	F
Short-tailed Hawk (*Buteo brachyurus*)												R				R
Swainson's Hawk (*Buteo swainsoni*)		R	R*				U		U	U	U	R	U	U	U	
Zone-tailed Hawk (*Buteo albonotatus*)	U	U		R	F	U	U	U	U	U	U	U	R		R	R*
Red-tailed Hawk (*Buteo jamaicensis*)	F	F	U	U	F	U	F	U	F	U	U	F	U	F	U	U
Golden Eagle (*Aquila chrysaetos*)	R	R			R				R			R	R			R
Crested Caracara (*Caracara cheriway*)	U	F	U	U	U	U	F	U	U	U	U				R	
American Kestrel (*Falco sparverius*)	U	U	U	U	U	U	U	U	U	U	U	U	U	F	U	U
Peregrine Falcon (*Falco peregrinus*)	R				R			R			R	R			R	R*
Prairie Falcon (*Falco mexicanus*)					R					?						
Columbiformes																
Rock Pigeon (*Columba livia*)	F	R	F	R	R	F	U	F	R	F	F	U	R	U	R	R
Band-tailed Pigeon (*Patagioenas fasciata*)									R*			R	R*			R
Eurasian Collared-Dove (*Streptopelia decaocto*)	R						R	R		U	U			R		
White-winged Dove (*Zenaida asiatica*)	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Mourning Dove (*Zenaida macroura*)	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C

TABLE 2. CONTINUED.

	Sonoyta		Concepción										Gila		Sonora	
	Sonoyta	Vamori	Lower	Plomo Lower	Plomo Upper	Sasabe Lower	Sasabe Upper	Altar Lower	Altar Upper	Busani	Coyotillo Magdalena	Cocospera-Bambuto	Santa Cruz	San Pedro	San Miguel	Bacanuchi-Sonora
Inca Dove (*Columbina inca*)	U	R	C	U	R	C	U	C	U	U	U	U	U	U	U	U
Common Ground-Dove (*Columbina passerina*)	R	R	R		R	R	U	U	U	U	C	C	C	C	C	C
White-tipped Dove (*Leptotila verreauxi*)											R				R	U
Cuculiformes																
Yellow-billed Cuckoo (*Coccyzus americanus*)		R	R*			R	R	U	U	U	U	U		U	U	U
Greater Roadrunner (*Geococcyx californianus*)	U	U	U	U	F	U	F	F	F	F	F	F	U	F	F	U
Strigiformes																
Barn Owl (*Tyto alba*)	R				R		R*		R	R	R	R			R	
Flammulated Owl (*Otus flammeolus*)																R*
Western Screech-Owl (*Megascops kennicottii*)	U	U	U	U	F	U	F	F	F	U	F	F	F	F	F	F
Whiskered Screech-Owl (*Megascops trichopsis*)							R		R			F	R*		U	U
Great Horned Owl (*Bubo virginianus*)	C	C	C	C	C	C	C	C	C	C	C	C	R*	C	C	C
Northern Pygmy-Owl (*Glaucidium gnoma*)												R	R			R
Ferruginous Pygmy-Owl (*Glaucidium brasilianum*)	R	U	R	U	U	U	U	U	U	U	U				U	R*
Burrowing Owl (*Athene cunicularia*)														R		
Elf Owl (*Micrathene whitneyi*)	C	C	U	U	C	C	C	C	C	C	C	C	U	U	U	U
Spotted Owl (*Strix occidentalis*)												R	R	R*		R*
Caprimulgiformes																
Lesser Nighthawk (*Chordeiles acutipennis*)	U	C	U	F	C	F	C	C	C	C	C			U	F	F
Common Nighthawk (*Chordeiles minor*)												U		C		U*
Common Poorwill (*Phalaenoptilus nuttallii*)	U	U	R	R	F	U	U	U	F	U	F	U		U	U	U
Buff-collared Nightjar (*Caprimulgus ridgwayi*)					R		R		U		U	U			U	
Whip-poor-will (*Caprimulgus vociferus*)									R			R	R*			R
Apodiformes																
White-throated Swift (*Aeronautes saxatalis*)	R				R				R		R	R		R	R	R
Broad-billed Hummingbird (*Cynanthus latirostris*)		R	R	R	R		U	U	F	F	C	C			C	C
Violet-crowned Hummingbird (*Amazilia violiceps*)							R	R			R	R			U	R
Blue-throated Hummingbird (*Lampornis clemenciae*)																R*
Magnificent Hummingbird (*Eugenes fulgens*)																R*
Black-chinned Hummingbird (*Archilochus alexandri*)					R		R		R				U*	U		R
Anna's Hummingbird (*Calypte anna*)			?		R		R	?			R		R			R*
Costa's Hummingbird (*Calypte costae*)	C	U	C	C	C		C	C	U	U	U	R			U*	U*
Broad-tailed Hummingbird (*Selasphorus platycercus*)																R

TABLE 2. CONTINUED.

	Sonoyta		Concepción										Gila		Sonora	
	Sonoyta	Vamori	Lower	Plomo Lower	Plomo Upper	Sasabe Lower	Sasabe Upper	Altar Lower	Altar Upper	Busani	Coyotillo Magdalena	Cocospera-Bambuto	Santa Cruz	San Pedro	San Miguel	Bacanuchi-Sonora
Trogoniformes																
Elegant Trogon (*Trogon elegans*)									R		R	R	R		U	U
Coraciformes																
Green Kingfisher (*Chloroceryle americana*)								R	R		R	R			R	R
Piciformes																
Acorn Woodpecker (*Melanerpes formicivoru*)					?		?		R			U	U	U	U	U
Gila Woodpecker (*Melanerpes uropygialis*)	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Ladder-backed Woodpecker (*Picoides scalaris*)	F	F	F	F	C	F	F	F	F	F	C	F	F	F	F	F
Hairy Woodpecker (*Picoides villosus*)												R				R
Arizona Woodpecker (*Picoides arizonae*)					R		R		R			U	U	R		U
Northern Flicker (*Colaptes auratus*)					R		?		R			U	U	C	R	U
Gilded Flicker (*Colaptes chrysoides*)	C	C	C	C	C	C	C	C	C	C	C	U			U	U
Passeriformes																
Northern Beardless-Tyrannulet (*Camptostoma imberbe*)					R		U	U	U	R	U	U		U	U	U
Greater Pewee (*Contopus pertinax*)												R		R*		R
Western Wood-Pewee (*Contopus sordidulus*)							R	R	U		U	F	F	F	U	F
Buff-breasted Flycatcher (*Empidonax fulvifrons*)												R				R
Cordilleran Flycatcher (*Empidonax occidentalis*)												R				R
Black Phoebe (*Sayornis nigricans*)	R							R	U		U	U	U	F	F	F
Say's Phoebe (*Sayornis saya*)	U		R*	U			R	R	U		U	U	U*	U	R	U*
Vermilion Flycatcher (*Pyrocephalus rubinus*)	R	U	R*		R		U	U	F	U	C	F	C	C	C	F
Dusky-capped Flycatcher (*Myiarchus tuberculifer*)					R		R	R	U		U	U	U	U	U	U
Ash-throated Flycatcher (*Myiarchus cinerascens*)	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Nutting's Flycatcher (*Myiarchus nuttingi*)											R				R	R*
Brown-crested Flycatcher (*Myiarchus tyrannulus*)	C	C	F	F	C	F	F	C	C	C	C	U	U	F	C	U
Sulphur-bellied Flycatcher (*Myiodynastes luteiventris*)									R			R	R*			R
Tropical Kingbird (*Tyrannus melancholicus*)								U	U		U	R			U	R
Cassin's Kingbird (*Tyrannus vociferans*)		R	R*		R		R	U	U	R	U	U	F	F	F	U
Thick-billed Kingbird (*Tyrannus crassirostris*)							R	R	U		U	U	R		U	U
Western Kingbird (*Tyrannus verticalis*)	R*	R	R				R	R	U	U	U	U	U	F		U*
Rose-throated Becard (*Pachyramphus aglaiae*)								R	R		R	R	R		R	R
Loggerhead Shrike (*Lanius ludovicianus*)	R	R	R	R*	R	R	R	R	R	R	R	R	R	U		R
Bell's Vireo (*Vireo bellii*)	U	U	R*	R	R	R	U	U	U	U	U	U	U	U	U	U
Plumbeous Vireo (*Vireo plumbeus*)												R				R
Hutton's Vireo (*Vireo huttoni*)							R		R		R	U	U	R*	R	R
Steller's Jay (*Cyanocitta stelleri*)												R		R*		R

TABLE 2. CONTINUED.

	Sonoyta		Concepción										Gila		Sonora	
	Sonoyta	Vamori	Lower	Plomo Lower	Plomo Upper	Sasabe Lower	Sasabe Upper	Altar Lower	Altar Upper	Busani	Coyotillo Magdalena	Cocospera-Bambuto	Santa Cruz	San Pedro	San Miguel	Bacanuchi-Sonora
Western Scrub-Jay (*Aphelocoma californica*)												R*	R	R*		R*
Mexican Jay (*Aphelocoma ultramarina*)					R		R		R			F	F	U	U	U
Chihuahuan Raven (*Corvus cryptoleucus*)		F	?		U	U	F	?	F	?	?	F	?	F	?	F
Common Raven (*Corvus corax*)	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F
Horned Lark (*Eremophila alpestris*)	U*	R*	R*							R			U*	C		
Purple Martin (*Progne subis*)	U	U	U*	U	F	U	U	F	F	F	U	R			R	
Violet-green Swallow (*Tachycineta thalassina*)	R			R										?		
Northern Rough-winged Swallow (*Stelgidopteryx serripennis*)	R		R*					R	R		R	R	U	U	R	R
Cliff Swallow (*Petrochelidon pyrrhonota*)	R*									R*					R	R
Barn Swallow (*Hirundo rustica*)	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Bridled Titmouse (*Baeolophus wollweberi*)					R		R		R		R	U	C	C	U	U
Verdin (*Auriparus flaviceps*)	C	C	C	C	C	C	C	C	C	C	C	F		F	C	C
Bushtit (*Psaltriparus minimus*)					R		R		R	C	C	F	U	F		
White-breasted Nuthatch (*Sitta carolinensis*)									R			U	F	F		U
Pygmy Nuthatch (*Sitta pygmaea*)												R*		R*		
Brown Creeper (*Certhia americana*)												R		R*		R
Cactus Wren (*Campylorhynchus brunneicapillus*)	C	C	C	C	C	C	C	C	C	C	C	F		R	C	U
Rock Wren (*Salpinctes obsoletus*)	?	R			R	R*	R	R	R		U	U	U	U	U	R
Canyon Wren (*Catherpes mexicanus*)	R	R	R*	R	U		U	R	U		U	F	U		F	F
Sinaloa Wren (*Thryothorus sinaloa*)											R	R			R*	R
Happy Wren (*Thryothorus feliz*)											R					R
Bewick's Wren (*Thryomanes bewickii*)	?	R	R		U		F	F	F	U	F	C	C	C	C	C
House Wren (*Troglodytes aedon*)												R				R
Blue-gray Gnatcatcher (*Polioptila caerulea*)												R		?		R
Black-tailed Gnatcatcher (*Polioptila melanura*)	C	C	C	C	C	C	C	C	C	C	C	R			F	U*
Black-capped Gnatcatcher (*Polioptila nigriceps*)											U	U			U	U*
Eastern Bluebird (*Sialia sialis*)												R	R	R		
American Robin (*Turdus migratorius*)												R	R*			R
Northern Mockingbird (*Mimus polyglottos*)	U	U	U	U	U		U	F	F	U	U	R	F	C	F	U
Bendire's Thrasher (*Toxostoma bendirei*)		R	U*	R*				R	R	R	U	R*				
Curve-billed Thrasher (*Toxostoma curvirostre*)	C	C	C	C	C	C	C	C	C	U	F	F	U*	F	C	U
Crissal Thrasher (*Toxostoma crissale*)	U	U	R*	R	U	U	U	F	U	U	U	R		R	U	R*
Le Conte's Thrasher (*Toxostoma lecontei*)	U*															
European Starling (*Sturnus vulgaris*)	R							R	R		R	R*	R*	R	R*	R
Phainopepla (*Phainopepla nitens*)	C	U	F	U	F	U	C	C	C	U	F	F	C	C	C	F
Olive Warbler (*Peucedramus taeniatus*)												R				R*
Lucy's Warbler (*Vermivora luciae*)	F	F	R	R	C	U	C	C	C	C	C	C	C	C	C	C

TABLE 2. CONTINUED.

	Sonoyta		Concepción										Gila		Sonora	
	Sonoyta	Vamori	Lower	Plomo Lower	Plomo Upper	Sasabe Lower	Sasabe Upper	Altar Lower	Altar Upper	Busani	Coyotillo Magdalena	Cocospera-Bambuto	Santa Cruz	San Pedro	San Miguel	Bacanuchi-Sonora
Yellow Warbler (*Dendroica petechia*)								U	R		R	U	U	C	U	U
Black-throated Gray Warbler (*Dendroica nigrescens*)												R				R
Grace's Warbler (*Dendroica graciae*)												R				R
Common Yellowthroat (*Geothlypis trichas*)								U	R	R	R	R		F	R	R
Red-faced Warbler (*Cardellina rubrifrons*)																R*
Painted Redstart (*Myioborus pictus*)									R		R	R	R*			R
Fan-tailed Warbler (*Euthlypis lachrymosa*)											?					
Rufous-capped Warbler (*Basileuterus rufifrons*)									R		R	R				R*
Yellow-breasted Chat (*Icteria virens*)	R	R		R*	R		R	U	U	R	U	U	U	U	U	U
Hepatic Tanager (*Piranga flava*)							R		R			U	U		R	U
Summer Tanager (*Piranga rubra*)							R	R	U		U	U	U	F	F	U
Spotted Towhee (*Pipilo maculatus*)							R		R			U	U			U
Canyon Towhee (*Pipilo fuscus*)	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Abert's Towhee (*Pipilo aberti*)													U	U		
Rufous-winged Sparrow (*Aimophila carpalis*)	R	U	R	R	U	R	U	R	U	U	U	U		R	U	R
Cassin's Sparrow (*Aimophila cassinii*)		U		R*	R		U	R	U	R	U	U	F	C	R*	U
Botteri's Sparrow (*Aimophila botterii*)		R											U	C	R*	U
Rufous-crowned Sparrow (*Aimophila ruficeps*)	R*	R*			R		R	R	F		U	F	F	F	U	F
Five-striped Sparrow (*Aimophila quinquestriata*)							R		U		U	U			U	U
Lark Sparrow (*Chondestes grammacus*)									R*			U	U	F		
Black-throated Sparrow (*Amphispiza bilineata*)	C	C	C	C	C	C	F	C	F	F	C	C	U	U	F	U
Savannah Sparrow (*Passerculus sandwichensis*)	R*															
Grasshopper Sparrow (*Ammodramus savannarum*)														C		
Song Sparrow (*Melospiza melodia*)	R							U	U	R	R	U	F	C	U	U
Yellow-eyed Junco (*Junco phaeonotus*)												R	R*	R*		R
Northern Cardinal (*Cardinalis cardinalis*)	U	U	U	U	F	U	U	F	U	U	U	U	U	U	F	U
Pyrrhuloxia (*Cardinalis sinuatus*)	R	U	U	R	U	R	U	R	U	R	U	R*	U*	R*	R	R
Black-headed Grosbeak (*Pheucticus melanocephalus*)					R		R		R			U	R	R	R	R
Blue Grosbeak (*Passerina caerulea*)	R	R	R*	U*	U	U	U	U	F	F	F	F	F	F	F	F
Indigo Bunting (*Passerina cyanea*)						R*			R	R		R				
Varied Bunting (*Passerina versicolor*)	R	R	R*	R	F		F	F	F	F	F	F			F	F
Red-winged Blackbird (*Agelaius phoeniceus*)								R	R	R	R*	R*		U		R
Eastern Meadowlark (*Sturnella magna*)													U	F		
Western Meadowlark (*Sturnella neglecta*)	?															
Great-tailed Grackle (*Quiscalus mexicanus*)	R		F	R	R			U	U	F	F	U	U	U	U	U

TABLE 2. CONTINUED.

	Sonoyta		Concepción										Gila		Sonora	
	Sonoyta	Vamori	Lower	Plomo Lower	Plomo Upper	Sasabe Lower	Sasabe Upper	Altar Lower	Altar Upper	Busani	Coyotillo Magdalena	Cocospera-Bambuto	Santa Cruz	San Pedro	San Miguel	Bacanuchi-Sonora
Bronzed Cowbird (*Molothrus aeneus*)		U	U		R			R	F	R	R	R		R*	U	R
Brown-headed Cowbird (*Molothrus ater*)	U	U	U	U	U	U	U	F	F	F	F	U	F	F	F	F
Hooded Oriole (*Icterus cucullatus*)	U	U	R	R	U		U	U	U	U	U	U	U	U	F	U
Streak-backed Oriole (*Icterus pustulatus*)							?	U	R		R	R				R*
Bullock's Oriole (*Icterus bullockii*)		R			R		U	R	U		U	?	U	F	?	
Scott's Oriole (*Icterus parisorum*)	U	U	R	R	U	R	R	R	U		U	F	U	U	U	U
House Finch (*Carpodacus mexicanus*)	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Lesser Goldfinch (*Carduelis psaltria*)	R		R	R*	U		U	F	U	U	F	F	F	C	U	U
House Sparrow (*Passer domesticus*)	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U

(*Buteo brachyurus*), Eurasian Collared-Dove (*Streptopelia decaocto*), Violet-green Swallow (*Tachycineta thalassina*), and Happy Wren (*Thryothorus felix*) were presumed breeding in at least two watershed regions, and Fan-tailed Warbler and Western Meadowlark were possibly breeding in one. Of species that had been observed previously at only a single locality, I presumed breeding by Cordilleran Flycatcher (*Empidonax occidentalis*) in one additional watershed region, White-tailed Kite (*Elanus leucurus*), White-tipped Dove (*Leptotila verreauxi*), and Nutting's Flycatcher (*Myiarchus nuttingi*) in two, Sinaloa Wren (*Thryothorus sinaloa*) and Rufous-capped Warbler (*Basileuterus rufifrons*) in three, Thick-billed Kingbird (*Tyrannus crassirostris*) in four, and Five-striped Sparrow (*Aimophila quinquestriata*) in five additional watershed regions. Of species that had been observed previously at only two localities, I presumed breeding by Elegant Quail (*Callipepla douglasii*) in one, Streak-backed Oriole (*Icterus pustulatus*) in three, and Buff-collared Nightjar (*Caprimulgus ridgwayi*) in four additional regions (Table 2). All of these species were rare or uncommon.

Breeding distribution of many species was much broader than that suggested by previous studies. For example, I detected several species that typically breed in riparian woodlands including Gray Hawk (*Buteo nitida*), Yellow Warbler (*Dendroica petechia*), and Summer Tanager (*Piranga rubra*) at numerous localities in the Altar, Santa Cruz, and San Pedro watersheds where they had either not been documented or had been presumed to breed at only single localities. Similarly, I detected several species that typically breed in oak woodlands including Whiskered Screech-Owl (*Megascops trichopsis*), Hutton's Vireo (*Vireo huttoni*), and Hepatic Tanager (*Piranga flava*) in the upper Altar and upper Sasabe watersheds which is west of areas where they had been presumed to breed; Northern Flicker (*Colaptes auratus*), Arizona Woodpecker (*Picoides arizonae*), and Dusky-capped Flycatcher (*Myiarchus tuberculifer*) occurred still farther west in oak woodlands in the upper Plomo watershed. I detected species that typically breed in grasslands including Swainson's Hawk (*Buteo swainsoni*) and Botteri's Sparrow (*Aimophila botterii*) west to the Vamori watershed and Cassin's Sparrow (*Aimophila cassinii*) west to the upper Plomo watershed. American Kestrel (*Falco sparverius*), Brown-crested Flycatcher (*Myiarchus tyrannulus*), Bell's Vireo (*Vireo bellii*), and Lucy's Warbler (*Vermivora luciae*) were at least presumed breeding in all 16 watershed regions despite lack of previous records in many of these regions.

Distribution and abundance varied widely among watersheds. Scaled Quail (*Callipepla squamata*), Botteri's Sparrow, Grasshopper Sparrow (*Ammodramus savannarum*), and Eastern Meadowlark (*Sternella magna*) were restricted mainly to the San Pedro and occasionally the Santa Cruz and Vamori watersheds; Scaled Quail occurred locally west to the upper Plomo watershed. White-tipped Dove and Nutting's Flycatcher were restricted to the Bacanuchi-Sonora, San Miguel, and Coyotillo-Magdalena-Carrizo watershed regions, whereas Sinaloa Wren and Black-capped Gnatcatcher (*Polioptila nigriceps*) occurred in these and the Cocospera-Bambuto watershed. I observed Happy Wren at only single localities in both the Bacanuchi-Sonora and Coyotillo-Magdalena-Carrizo watersheds. Sharp-shinned Hawk (*Accipiter striatus*), Northern Goshawk (*Accipiter gentilis*), and Broad-tailed Hummingbird (*Selasphorus platycercus*) presumably bred only in the Sierra los Ajos (Bacanuchi-Sonora watershed); Cordilleran Flycatcher, Buff-breasted Flycatcher (*Empidonax fulvifrons*), and Plumbeous Vireo (*Vireo plumbeus*) occurred in the Sierra los Ajos and to the west in one–two mountain ranges in the Cocospera-Bambuto watershed.

DISCUSSION

Species Richness

Northern Sonora, Mexico supports a wide range of environments and a rich and varied avifauna. Between 2000 and 2007, I recorded 161 species of landbirds that I at least presumed were breeding in the Sonoyta, Concepción, Gila, and Sonora watersheds within 125 km of the international boundary with the US. Including seven additional species that had been recorded previously, 168 species of landbirds have been at least presumed to breed in the region, and all except Northern (Masked) Bobwhite likely still occur. In comparison to estimates from neighboring Arizona between 1993 and 2000 (Corman and Wise-Gervais 2005), northern Sonora supports approximately 35% fewer species of breeding landbirds in an area approximately one-tenth the size and with 45% less elevation range; including additional species in the adjacent northern Yaqui watershed lowers this estimate to at most 31% (Marshall 1957, Russell and Monson 1998; A. D. Flesch, unpubl. data). Although estimates are not available for other regions of northern Mexico, large-scale patterns of bird distribution (Howell and Webb 1995) suggests that northern Sonora supports higher richness of breeding landbirds than any other region of similar area in the borderlands of northern Mexico.

Using probabilistic methods, I estimated that as many as 178 species of landbirds likely breed in the study area. Information from Sonora (Russell and Monson 1998; A. D. Flesch, unpubl. data) and neighboring southern Arizona (Corman and Wise-Gervais 2005), combined with vegetation associations that I observed, suggest 10 additional species may breed locally or irregularly in the study area (Ruddy Ground Dove [*Columbina talpacoti*], Long-eared Owl [*Asio otus*], White-eared Hummingbird [*Hylocharis leucotis*], Berylline Hummingbird [*Amazilia beryllina*], Lucifer Hummingbird [*Calothorax lucifer*] Flame-colored Tanager [*Piranga bidentata*], Chipping Sparrow [*Spizella passerina*], Black-chinned Sparrow [*Spizella atrogularis*], Red Crossbill [*Loxia curvirostra*] and Pine Siskin [*Carduelis pinus*]). Rusty Sparrow (*Aimophila rufescens*) was once detected just south of the study area (Thayer and Bangs 1906) and could also breed locally in the Bacanuchi-Sonora region. Although I obtained evidence that Hermit Thrush (*Catharus guttatus*) and Western Tanager (*Piranga ludoviciana*) breed in mixed-conifer forest just east of the Yaqui-Sonora divide (A. D. Flesch, unpubl. data), in Sonora these species and possibly Warbling Vireo (*Vireo gilvus*) are likely restricted to the upper Yaqui watershed. Breeding species that have been observed combined with those I expect may occur suggest estimates of species richness that I calculated are accurate.

Not surprisingly, species richness increased markedly with the number of major vegetation communities that were present in a region. As such, regions in the east that had broader elevation ranges and therefore greater environmental diversity had higher richness. Presence of broadleaf riparian woodland, Madrean evergreen woodland, and Madrean montane conifer forest had the greatest influence on species richness indicating that these vegetation communities supported more species with specialized requirements than other communities in the region. In contrast, although richness was also high in regions with Sinaloan thornscrub, this community likely had less of an overall effect on richness because many species that are associated with thornscrub, such as Buff-collared Nightjar, Black-capped Gnatcatcher, and Five-striped Sparrow, also occurred away from thornscrub in dense desertscrub and woodland.

Distribution Patterns

Bird species that occurred in desertscrub were universally more common and widespread than species that were typically associated with grassland, thornscrub, oak woodland, or conifer forest. Species that were found predominantly in oak woodland, grassland, and broadleaf riparian woodland were typically rare and had much narrower and more fragmented distributions. Species associated with conifer forest were rarest and were largely restricted to high elevations in the Sierra los Ajos, Cananea, Pinito, and as described by Marshall (1957), in the Sierra Azul. Grassland species were especially rare in the west with some species reaching the western edge of their distribution on the east sides of the Sierras el Humo and el Cobre. Grassland species were more abundant and widespread in the upper Santa Cruz and especially in the upper San Pedro watersheds where plains grassland with high levels of horizontal and vertical vegetation cover still persist. Breeding populations of species that occurred only in broadleaf riparian woodland did not occur west of the Río Altar and were largely restricted to the Riós Altar, Bambuto, Magdalena, and portions of other major valley bottoms to the east.

Northern Sonora supports the westernmost and northernmost patches of some vegetation communities and these patterns have important implications for bird distribution. Isolated stands of oak woodland in the Sierra el Humo for example, are the westernmost Madrean evergreen woodland in the Madrean Sky Islands, mountains that form the northern and western extensions of Sierra Madre Occidental (Marshall 1957, Warshall 1995). As such, populations of birds that are associated with oak woodland in the Sierra Madre Occidental, such as Arizona Woodpecker, reach the western edge of their global distribution in the Sierra el Humo (Flesch and Hahn 2005). Similarly, oak woodland in the nearby Sierra San Juan supported several additional species of birds that I did not detect to the west in the Sierra el Humo, including Whiskered Screech-Owl, which reach the northwestern edge of their global distribution here and in the neighboring Baboquivari Mountains of Arizona (Phillips et al. 1964). Species typically associated with Neotropical environments such as Elegant Quail, White-tipped Dove, Nutting's Flycatcher, and Sinaloa Wren were restricted mainly to three or four watersheds in the more humid south-central and southeast portions of the study area. The northernmost patches of Sinaloan thornscrub that had similar structure and composition to that found further south occurred in and northeast of the Sierra Cucurpe and at low to moderate elevations in the Bacanuchi-Sonora region and these were the only regions where I observed Happy Wren.

Changes in Distribution and Status

Patterns of animal distribution represent a complex response to a range of factors including the arrangement and size of resource patches, physiological tolerances, and biotic interactions that vary in space and time (Andrewartha and Birch 1954, MacArthur 1972, Brown 1995). In northern Sonora, my observations indicate that a wide range of species are distributed across much larger areas than suggested by previous studies. Determining whether these patterns are due to actual changes in bird distribution or limited effort during past studies is difficult because few data on localities where species were undetected are available and because there are few historical accounts of vegetation conditions and change in Sonora.

Limited fieldwork in many regions of northern Sonora likely explains the wider patterns of distribution that I observed of a broad range of species. Russell and Monson (1998) for example, cited just four records of Brown-crested Flycatcher west of the Río Bambuto, north of the Río Concepción, and east of the Río Sonoyta, yet this species and its habitat are common or fairly common in all 11 watershed regions in this vast region. Distribution of other widespread migratory species such as Bell's Vireo and Lucy's Warbler were also understated, yet this pattern was somewhat less evident for resident species, suggesting that survey effort during the breeding season had been limited. Similarly, many rare species that occurred in isolated or otherwise disjunct vegetation communities had also gone undetected. If Phillips and Amadon (1952) or Russell and Monson (1998) had visited oak woodlands in the Sierra San Juan and Sierra el Humo during the breeding season rather than in fall, they probably would have detected many of the same species that I recorded. Previous fieldwork seems to have been most limited in the San Pedro, Altar, Busani, Sasabe, Vamori, and Plomo watersheds where many breeding species had not been previously documented.

Where known, patterns of vegetation change in northern Sonora have been complex and variable (Bahre and Hutchinson 2001, Turner et al. 2003), and these changes have likely influenced bird distribution. In high-elevation pine forests in the Cocospera-Bambuto watershed for example, presence of Cordilleran Flycatcher, Buff-breasted Flycatcher, and Plumbeous Vireo in mountain ranges where they were not observed by Marshall (1957) is likely attributable to recovery of these forests following extensive logging that occurred just prior to Marshall's visits. In contrast, although presence of species that are associated with oak woodland in the Sierras San

Juan and el Humo could also be related to vegetation change, evidence suggests distribution of these woodlands has been largely stable in the region during recent times (Bahre and Minnich 2001) despite some recession at lower elevations (Turner et al. 2003).

In vegetation communities that are typically more dynamic, such as broadleaf riparian woodland (Webb et al. 2007), attributing changes in bird distribution to vegetation change is more difficult. In the San Pedro Valley for example, many riparian species such as Gray Hawk, Yellow Warbler, and Summer Tanager may not have been widely documented because gallery forests were once rare or absent. In 1892 and 1893, Mearns (1907) observed only scattered broadleaf trees along the Río San Pedro at the international boundary, and gallery forests of cottonwood and willow did not develop until the 1960s and especially in the late 1970s and 1980s (Webb et al. 2007).

In the Altar Valley, however, where most species of riparian birds had been described only in the extreme upper watershed at Rancho la Arizona (van Rossem 1931), broadleaf riparian woodland has likely been present for some time. Nentvig et al. (1980) for example, described presence of permanent surface water along many portions of the Río Altar in 1764 and Shreve (1951) noted that virgin mesquite woodlands persisted near Tubutama into the 1950s despite elimination from virtually all other major valley bottoms in the Sonoran Desert at that time. Therefore, despite only recent description of breeding bird communities in the cottonwood-willow forests along the Río Altar, these communities have likely been present for some time.

Although lack of previous effort and vegetation change may explain why I observed much broader patterns of distribution for some species, distribution and abundance of many of these same species may in fact be much more limited than in the past. Along the Río Altar, for example, completion of the Cuauhtémoc Dam and Reservoir (Presa Cuauhtémoc) in 1950 diverted surface water and likely contributed to increased vegetation clearing for agriculture, degradation of gallery forests, and subsequent declines in distribution and abundance of birds associated with these forests. Early descriptions of birds and vegetation along the lower Río Concepción are available (Stephens 1885, Neff 1947, Phillips and Amadon 1952). Undoubtedly, complete elimination of the once extensive mesquite woodland near Pitiquito and Caborca caused the local extirpation of many species of birds and in part, explains why I failed to detect 21% of species that had been at least presumed to breed in this region in the past. Similarly, although I found small, localized populations of some grassland birds south and west of Sasabe, these species were likely much more abundant and widespread before these grasslands were largely degraded or lost (Brown 1900, 1904; Bahre 1991, Turner et al. 2003), as suggested by Stephens' (1885) observation of the now extirpated Northern Bobwhite.

More widespread distributions of some species are likely the results of range expansion that has occurred largely independent of major changes in vegetation. Comparing my findings with previous observation from Sonora (Russell and Monson 1998) and the southwestern US suggests recent range expansions of the following species: White-tailed Kite (Monson and Phillips 1981, Gatz et al. 1985), Short-tailed Hawk (Corman and Wise-Gervais 2005, Williams et al. 2007), Buff-collared Nightjar (Bowers and Dunning 1997), Thick-billed Kingbird (Phillips 1968, Monson and Phillips 1981), Sinaloa Wren (Russell and Monson 1998), Rufous-capped Warbler (Rosenberg and Witzeman 1999), Five-striped Sparrow (Groschupf 1994), and Streak-backed Oriole (Corman and Monson 1995, Corman and Wise-Gervais 2005). Eurasian Collared-Dove rapidly expanded across much of North America since arriving in Florida in the early 1980s (Romagosa and McEneaney 1999) and recent arrival in Sonora since at least 2004 (Gómez de Silva 2004) is not surprising. Although I found Zone-tailed Hawk (*Buteo albonotatus*) to be much more common and widespread in western Sonora than had been described previously, its presence in western Arizona since at least 1939 (Phillips et al. 1964) suggests distribution has been largely static in this region despite recent expansion to the north (Johnson 1994, Corman and Wise-Gervais 2005). In contrast, although I also found Gray Hawk at many new localities, especially in the west and at somewhat higher elevations, this species has likely expanded its range due to vegetation change and other factors. Gray Hawk were not documented along the Río San Pedro until 1963 (Phillips et al. 1964) and have recently expanded into central Arizona (Corman and Wise-Gervais 2005).

Most species that I found to be more widely distributed or present for the first time in northern Sonora have likely expanded their geographic ranges from more tropical regions to the south (e.g., Short-tailed Hawk, White-tipped Dove, Buff-collared Nightjar, Thick-billed Kingbird, Sinaloa Wren, Happy Wren, and Rufous-capped Warbler). Although wider occurrence of some of these species could be attributable to increased effort, this seems unlikely, because many of these same species have recently occurred for the first time or become regular summer residents in southern Arizona where effort has been much more extensive (Monson and Phillips 1981, Rosenberg and Witzeman 1999, Corman and Wise-Gervais 2005). These patterns and those in other areas of western North America (Johnson 1994) and southern Texas (Brush 2005) suggest some southern species are expanding northward possibly in response to changing resource distributions resulting from climate change and a widening of tropical atmospheric circulations during recent decades (Seidel et al. 2008). Although poleward shifts in species distributions in response to climate change have been observed on nearly every continent (Parmesan and Yohe 2003, Root et al. 2003, Parmesan 2006), time and additional study are required to further elucidate these trends in northern Mexico.

Effort—Past, Present, and Future

Although my coverage was extensive, it was limited in some regions. After comparing my findings with those of previous studies, I failed to detect an average of 7% of all species that had been at least presumed to breed in a watershed region, and this quantity varied with effort (Tables 1 and 2). Although some species that I failed to detect may no longer occur, more effort especially at high elevations would have produced additional data, particularly in the Santa Cruz, Bacanuchi-Sonora, San Pedro, and San Miguel watershed regions. Upper elevations in several mountain ranges in northern Sonora have likely never been visited by ornithologists including the Sierras San Antonio, San Jose, el Chivato, la Madera, Cucurpe, Cubabi, el Alamo, and San Manuel. Aside from my efforts, bird observations at upper elevations in the Sierras el Pinito, Cananea, and los Ajos had not been reported for over five decades (Marshall 1957) and other lower yet regionally significant mountains such as the Sierras San Juan and el Humo had not been visited during the breeding season. Additional effort in these and other areas of northern Sonora will yield new and valuable information especially when the adjoining Yaqui watershed is considered.

Despite more than a century of ornithological work in northern Sonora, Mexico (van Rossem 1945, Russell and Monson 1998) status and distribution of many species had remained little known in some regions. This is in sharp contrast to neighboring portions of Arizona where a great deal of historical (Swarth 1914, Brandt 1951, Phillips et al. 1964) and recent (Monson and Phillips 1981, Rosenberg and Witzeman 1998 and 1999, Rosenberg 2001, Corman and Wise-Gervais 2005) information is available. Availability of biological information in many areas of northern Sonora should increase as accessibility is improved and as interest in the diversity, uniqueness, and preservation of this region is enhanced.

Conservation and Threats

Information on distribution and abundance of wildlife is essential for conservation. Without these data, conservation priorities may be misguided and important populations may be lost or degraded before they can be managed and protected. Prospects for conserving, managing, and enhancing populations of landbirds in northern Sonora are promising because human population densities throughout much of the region are low and because vast areas of natural vegetation remain relatively intact and unfragmented (Stoleson et al. 2005, Felger et al. 2007). Further, recent federal laws in Mexico have created a system that could aid landowners in conservation and sustainable use of wildlife especially once these programs are improved and additional resources are provided (Valdez et al. 2006, Weber et al. 2006, Sisk et al. 2007). In recent years there has also been an increase in activity by private conservation organizations in northern Sonora. These efforts have been led by Biodiversidad y Desarrollo Armónico, Naturalia, and The Nature Conservancy in northeast Sonora, by Pronatura in northwest Sonora, and assisted by partnerships with public agencies through organizations such as Sonoran Joint Venture. When enhanced by data on distribution, status, and habitat needs of landbirds, these efforts can produce valuable results.

Despite good prospects for conservation, significant threats exist. Loss and degradation of riparian areas due to agriculture, unsustainable grazing practices, and excessive groundwater pumping are having a profound influence on the structure and function of these systems. Cottonwood forests along the Río Magdalena between Magdalena de Kino and Santa Ana have been steadily declining for some time and no longer occur more than a few kilometers below Magdalena de Kino (A. D. Flesch, pers. obs.). Riparian forests throughout much of the Santa Cruz Valley have been highly degraded and although conditions are generally better in the San Pedro Valley, regeneration of broadleaf trees is limited in many areas. Riparian forest along the Río Altar is also declining locally above Tubutama and especially near Saríc where quantity of surface water declined greatly between 2000 and 2007. Other significant threats to landbirds in northern Sonora include overgrazing and degradation of grasslands, limited regeneration of important nest-cavity substrates such large trees and saguaros (*Carnegiea gigantea*), excessive fuel-wood cutting, and urbanization on a local scale (Flesch 2003, Búrquez and Martínez-Yrízar 2007). Grazing intensity in northern Sonora is generally much higher than in adjacent Arizona (Balling 1988), and if better managed could reduce the ecological costs and enhance the economic benefits of this nearly ubiquitous land use.

Cross-border partnerships between government and non-governmental organizations, scientists, and private citizens have the potential to optimize conservation, management, and restoration efforts in the borderlands. This need for coordination is emphasized by the ecological connections we share across the border and our joint stake in conserving natural resources for future generations. The international border is a political, not a biological boundary and as such, persistence of many populations depends on the actions and priorities of our two nations.

ACKNOWLEDGMENTS

I am grateful to my field assistants. They include Sky Jacobs, Greg Greene, Elliott Swarthout, and Glenn Johnson who surveyed transects and Gabriel Valencia Ortega, Andrés Villareal Lizárraga, Shawn Lowery, Jeremy Russell, Jon Green, and Robert Hunt who contributed incidental observations. I thank Sky Jacobs, Mac Hudson, and Lisa Hahn for companionship in the field. For logistical support in Sonora, I thank Eduardo Lopez Saavedra of Biodiversidad y Desarrollo Armónico, Jaqueline Garcia Hernandez of Centro de Investigacion en Alimentacion y Desarrollo, and Elvira Rojero Diaz and the staff of the Ajos-Bavispe Reserve, Comisión Nacional de Áreas Naturales Protegidas. I thank Bob Steidl for administrative support and Juan Carlos Bravo and Gerardo Carreón Arroyo for Spanish translation. Indirect financial support was provided by of the USDI Fish and Wildlife Service, National Park Service, and Arizona Department of Transportation. Direct financial support was provided by Sonoran Joint Venture, T&E, Inc., and mainly through personal contributions. I thank Glenn Johnson, Stephen Russell, and two anonymous reviewers for comments on earlier versions of the manuscript. Finally, I thank the people and landowners of northern Sonora for welcoming us on their lands. This effort is dedicated to the memory of Benjamin M. Chameides who inspired me to explore.