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DISTRIBUTION AND ABUNDANCE OF BREEDING ARIZONA GRASSHOPPER SPARROW (*AMMODRAMUS SAVANNARUM AMMOLEGUS*) IN THE SOUTHWESTERN UNITED STATES: PAST, PRESENT, AND FUTURE

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Abstract. The Arizona Grasshopper Sparrow (*Ammodramus savannarum ammolegus*) breeds in desert grasslands of southeastern Arizona and southwestern New Mexico in the US, and in adjacent parts of northern Sonora and Chihuahua, Mexico. Roads that were surveyed in 1982 and 1987 in Arizona and New Mexico were relocated and roadside survey protocols were repeated in 2004 and 2005 to identify changes in distribution or abundance of the subspecies during the subsequent 17 yr. The Sonoita and San Rafael valleys in Arizona and the Animas Valley in New Mexico remain as primary population centers, supporting the highest mean numbers of singing males per stop, as well as the largest populations of Arizona Grasshopper Sparrows in the US. Mean number of singing males per stop was highest in the San Rafael Valley. Mean number of singing males per survey stop showed an increasing pattern from 1982–1987 and a subsequent decline to the present (2004–2005). Present bird densities are intermediate in value between 1982 and 1987 values. Small populations remain in the Altar, San Pedro, Sulphur Springs, and San Bernardino valleys in Arizona. The valleys evaluated in this and historical surveys represent the areas in which almost all Arizona Grasshopper Sparrows breed in the US; if any additional areas exist, they support peripheral, small, or remnant populations. Although historic, current, and future land use, and current and future threats differ among valleys, the primary factors posing threats to the future of Arizona Grasshopper Sparrow populations appear to be loss and/or degradation of habitat due to exurban development, overgrazing, and the effects of long-term drought.

Key Words: abundance, *Ammodramus savannarum ammolegus,* Arizona, distribution, Grasshopper Sparrow, New Mexico, semi-desert grasslands, Southwest, status.

DISTRIBUCIÓN Y ABUNDANCIA DE *AMMODRAMUS SAVANNARUM AMMOLEGUS* ANIDANDO EN EL SUROESTE DE LOS ESTADOS UNIDOS: PASADO, PRESENTE Y FUTURO

Resumen. Ammodramus savannarum ammolegus anida en los pastizales desérticos del sureste de Arizona y suroeste de Nuevo México en los Estados Unidos, y en las áreas contiguas del norte de Sonora y Chihuahua en México. Los sitios en los que se realizaron censos durante 1982 y 1987 al margen de caminos en Arizona y Nuevo México fueron ubicados y se repitieron los protocolos en 2004 y 2005 para identificar cambios en distribución o abundancia de estos gorriones después de 17 años. Los valles de Sonoita y San Rafael en Arizona y el Valle de las Animas en Nuevo México se siguen siendo los centros poblacionales principales, manteniendo los promedios más altos de machos territoriales por parada, al igual que las poblaciones más grandes de *A. savannarum ammolegus* en los Estados Unidos. El número promedio más alto de machos territoriales por parada se encontró en el Valle de San Rafael. El promedio de machos por parada mostró un incremento de 1982 a 1987, y una disminución posterior hacia el presente (2004/2005). Las densidades de aves en la actualidad muestran valores intermedios con relación a las densidades de 1982 y 1987. Poblaciones pequeñas continúan existiendo en los valles de Altar, San Pedro, Sulphur Springs y San Bernardino, en Arizona. Los valles evaluados en este trabajo además de las prospecciones históricas representan las áreas en las que casi todos los individuos de *A. savannarum ammolegus* anidan en los Estados Unidos; en caso de que existan áreas adicionales, esas áreas mantienen poblaciones periféricas, pequeñas o remanentes. Aunque la historia del uso de suelo y las amenazas actuales y futuras difieren entre los valles, los factores primarios que imponen amenazas a futuro para las poblaciones de *A. savannarum ammolegus* son aparentemente la pérdida y/o degradación de hábitat debido al desarrollo suburbano, pastoreo intensivo y los efectos de sequía a largo plazo.

Endemic grassland birds have shown steeper, more consistent, and more widespread declines than any other guild of North American bird species (Knopf 1994). Documenting population status and trends, and understanding distribution, life histories, and ecology are essential in conservation planning for such avian species of concern. Southwestern semi-desert grasslands support an important suite of breeding grassland birds of conservation concern (Rich et al. 2004), and much remains to be learned about their status and ecology (Herkert and Knopf 1998).

The Arizona Grasshopper Sparrow (*Ammodramus savannarum ammolegus*) is a subspecies (Oberholser 1942) of the widely distributed Grasshopper Sparrow and has a disjunct breeding population in the desert grasslands of southeastern Arizona, southwestern New Mexico, and adjacent parts of northern Sonora and Chihuahua, Mexico (Vickery 1996, Williams 2007). Although poorly documented, its winter range is believed to extend from southern Arizona south to Sinaloa and Morelos, Mexico, and Guatemala (Land 1970, Vickery 1996). Detailed physical descriptions and discussions of Arizona Grasshopper Sparrow taxonomy can be found in Strong (1988) and Vickery (1996).

Strong (1988) and Corman and Wise-Gervais (2005) adequately document the Arizona Grasshopper Sparrow in Arizona. However, documentation of its presence in New Mexico requires some clarification. Arizona Grasshopper Sparrows were first detected in New Mexico in June 1977, in the Animas Valley (Meents 1979). The first surveys targeting this subspecies were conducted in June 1987 (Williams 1991). Forty-five individuals were counted on a 19-stop Breeding Bird Survey (BBS)-style survey route on 10 June 1987, and seven specimens were collected by Williams on 17 July 1987, which were verified as *A. s. ammolegus* (Williams 1991, 2007). In July and August 1987, Strong (1988) also found Arizona Grasshopper Sparrows in the Animas Valley.

The Grasshopper Sparrow is of conservation concern. Peterjohn and Sauer (1999) found that the species showed a significant range-wide population decline between 1966 and 1996. The Arizona Grasshopper Sparrow subspecies is listed as high priority for desert grassland habitats in the Partners in Flight Bird Conservation Plans for both Arizona (Latta et al. 1999) and New Mexico (New Mexico Partners in Flight 2007). USDI Fish and Wildlife Service (2002) includes Arizona Grasshopper Sparrow on the list for the Sierra Madre Occidental Bird Conservation Region (BCR #34), which includes the desert grasslands of southeastern Arizona and southwestern New Mexico. The subspecies is also classified as Endangered in the State of New Mexico.

The USDI Fish and Wildlife Service (USFWS) contracted two reports on the status of this subspecies in the last 25 yr through the Arizona Natural Heritage Program and the Arizona Game and Fish Department (Mills 1982, Strong 1988), but this information has not been updated in the subsequent 17 yr. Concerns regarding Arizona Grasshopper Sparrow have focused on apparent fluctuations or possible cyclical variations in a relatively small breeding population (Strong 1988, Williams 1997), evidence of a long-term decline in the New Mexico population (Williams 2007), and similar anecdotal information for Arizona. Limited information about its breeding ecology, the effects of habitat loss due to suburban development, and the effects of habitat modification due to overgrazing and alteration of natural fire regime are also concerns. Recent conservation interest has led to recognition of the need for additional information about population status and trends of Arizona Grasshopper Sparrow, as well as home range and territory size, presence of population sources or sinks, and causes of population declines (Latta et al. 1999, New Mexico Partners in Flight 2007).

The objectives of this study were to: (1) document the current distribution and abundance of Arizona Grasshopper Sparrow using historical survey methods in a more clearly described and repeatable format to make any future surveys replicable; and (2) compare current distribution and abundance of Arizona Grasshopper Sparrows with historical data (Mills 1982, Strong 1988).

METHODS

SITES

The grasslands of southeastern Arizona and southwestern New Mexico have been variously described as plains or plains-mesa grasslands and semi-desert or desert grasslands along an elevational gradient (Dick-Peddie 1993, Brown 1994). They support a variety of native annual and perennial bunchgrasses including three-awns (*Aristida* spp.), gramas (*Bouteloua* spp.), curly mesquite (*Hilaria belangeri*), cane beardgrass (*Andropogon barbinodis*), wolftail (*Lycurus phleoides*), and plains lovegrass (*Eragrostis intermedia*), as well as the exotic Lehman (*E. lehmanniana*) and Boer (*E. curvula* var. *conferta*) lovegrasses.

Identification of historical survey locations involved relocating road segments in the US that were surveyed in previous studies (Mills 1982, Strong 1988). Major foci were the Sonoita and San Rafael valleys in Arizona and the Animas Valley in New Mexico, with less intense efforts in Arizona's Altar, San Pedro, Sulphur Springs, and San Bernardino Valleys. The following areas were surveyed (Fig. 1):

Sonoita Valley (Santa Cruz and Pima counties)—from Box Canyon in the north, Mustang Mountains in the east, Canelo Hills in the south, and just beyond

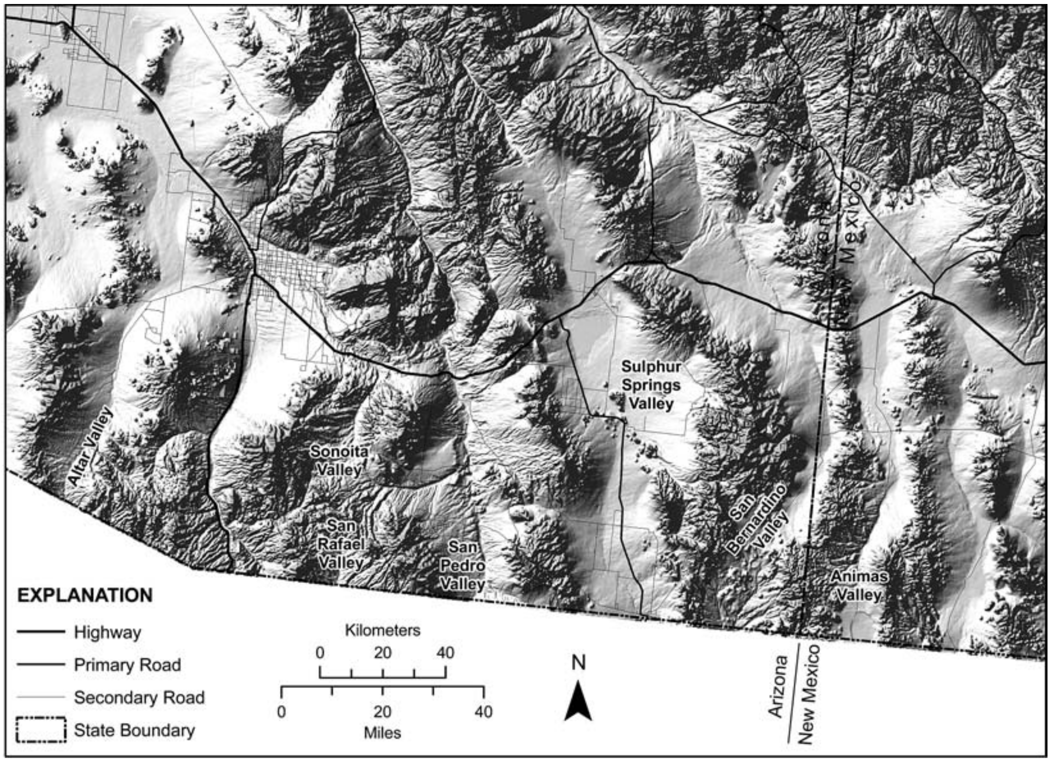

FIGURE 1. Map of valleys surveyed for Arizona Grasshopper Sparrows.

Sonoita in the west (lat/long ranges from 31°35′03″ to 31°44′16″N; and from 110°29′23″ to 110°40′32″W).

San Rafael Valley (Santa Cruz County)—the central San Rafael Valley and Campini Mesa (from 31°20′05″ to 31°29′06″N; and from 110°29′13″ to 110°39′04″W).

Animas Valley (Hidalgo County)—the Diamond A (formerly Gray) Ranch in the southern part of the valley (from 31°24′10″ to 31°33′14″N; and from 108°52′31″ to 108°55′10″W).

Altar Valley (Pima County)—within and near the Buenos Aires National Wildlife Refuge (NWR) (from 31°29′51″ to 31°38′46″N; and from 111°27′57″ to 111°32′44″W).

San Pedro Valley (Cochise County)—the southern part of the valley in the area around the Coronado National Memorial and Palominas (from 31°20′56″ to 31°26′20″N; and from 110°07′17″ to 110°13′41″W); in 2005, an additional historical survey was repeated in the Allen Flats area northeast of Benson and south of the Winchester Mountains (from 32°13′45″ to 32°17′06″N; and from 110°04′29″ to 110°09′10″W).

Sulphur Springs Valley (Cochise County)—just west and northwest of the Chiricahua Mountains from McNeal to Willcox (from 31°35′26″ to 32°11′43″N; and from 109°25′39″ to 109°45′20″W); in 2005, an additional historical survey was repeated in the Fort Grant area southwest of the Pinaleño Mountains (from 32°33′27″ to 32°35′20″N; and from 109°58′12″ to 110°05′34″W).

San Bernardino Valley (Cochise County)—from Rucker Canyon Road in the southwest to the Geronimo Surrender Monument in the northeast (from 31°36′30″ to 31°41′26″N; and from 109°06′53″ to 109°15′05″W).

Roadside Surveys

Methods and survey locations were designed to cover the known historical range of Arizona Grasshopper Sparrow (Mills 1982, Strong 1988). Methods were replicated, as accurately as possible, to enable comparisons between historical and current data. Based on their written descriptions, the road segments were relocated and resurveyed. Strong described their methodology as "driving roads within [the] historical range [of the Arizona Grasshopper Sparrow]." They "stopped in areas of suitable habitat, or at predetermined intervals in large patches of continuous habitat…stops were made in areas of marginal habitat, but areas of obviously unsuitable habitat were not censused" (Strong 1988:8). Detailed information about stop locations was not available in their reports. However, based on informal surveys conducted in 2002 and 2003, I determined that using a standard 0.5-mile (0.8 km) interval between stops usually resulted in the same number of stops listed by Strong for a particular road segment. On occasion, it was not possible to accurately resurvey a particular road segment, either for safety reasons or because a segment was no longer publicly accessible or identifiable. This resulted in different numbers of road segments, stops on a segment, and/or mileage (Table 1). All roadside survey stops were recorded with a global positioning system unit and described with visual and mileage cues to facilitate relocation in the future. Historical road segments were surveyed and observations were included in these results even if no Grasshopper Sparrows were recorded in 2004 and/or 2005.

Additional surveys of areas not covered in earlier surveys, hereafter termed non-historical surveys, were conducted in the Sonoita, San Rafael, Altar, Sulphur Springs, and Animas valleys to supplement historical routes. These data are included in the initial summaries of birds recorded in 2004–2005, but are not included in the comparisons between historical and current survey results for the valleys supporting the vast majority of the population. Data from non-historical surveys are only mentioned when the information offers additional insights. These additional segments were selected based on personal observation of potentially promising Grasshopper Sparrow habitat within the general breeding distribution of the subspecies.

Most of Mills' and Strong's surveys were conducted from 0445 to 0900 H, and occasionally in late afternoon. On sunny, warm mornings, Grasshopper Sparrow singing activity began to decrease between 0700 and 0800 H; however, on cool, cloudy mornings singing activity continued well beyond 0800 H (J. Ruth, pers. obs.). In 1987, surveys in the Sonoita and San Rafael Valleys were conducted three times during the breeding season (July and August), varying the time to ensure one early survey in order to address any potential temporal variation in singing intensities (Strong 1988). The relatively late timing of breeding surveys, both historical and current, is due to the fact

TABLE 1. SUMMARY INFORMATION ABOUT ROAD SEGMENTS SURVEYED BY VALLEY.

Valley	Mileage[a]			Number of road segments			Total number of stops		
	Mills	Strong	Ruth	Mills	Strong	Ruth	Mills	Strong	Ruth
Sonoita (AZ)	79	79	69/81	25	23	20/24	168	145	139/171
San Rafael (AZ)	50	50	44/48	13	15	14/17	105	99	88/98
Animas (NM)	NA	22	24/33	NA	5	5/7	NA	45	49/56
Altar (AZ)	14	3	14/25	1	2	3/9	11	9	20/51
San Pedro and Allen Flats (AZ)	15	2	11/11	4	1	3/4	30	6	24/24
Sulphur Springs and Fort Grant (AZ)	49	7	23/25	8	1	4/5	34	11	29/34
San Bernardino (AZ)	20	17	16/16	3	2	3/3	19	17	25/25
Santa Cruz (AZ)	16	2	6/6	7	2	2/2	24	6	6/6

[a] Mileage rounded to nearest whole number. Mills' data were gathered in 1982 (Mills 1982) and Strong's data were gathered in 1987 (Strong 1988). Mills and Strong data include some survey segments that could not be repeated in 2004–2005. Ruth data are from 2005 and x/y indicates values for repeated historic surveys (x) and a cumulative value including new surveys conducted (y).

that Arizona Grasshopper Sparrows usually breed in mid- to late-summer in response to the monsoon season, beginning to sing in July and carrying food for young from late July through August (Corman and Wise-Gervais 2005).

Current surveys were conducted between 14 July and 14 August 2004, and between 16 July and 18 August 2005. Most surveys were conducted twice during the breeding season, from 0445 to 1100 H MST in AZ (0545–1100 H MDT in NM). Every effort was made to ensure that one survey on every segment was conducted from 0445 to 0700 H. In areas where historical surveys and my previous informal surveys indicated that Grasshopper Sparrow populations were small or nonexistent, surveys were only conducted once in order to maximize effort in core areas. Methodological differences from Mills and Strong were due primarily to staff and time limitations.

Neither Mills (1982) nor Strong (1988) clearly described the amount of time spent at each survey stop, although there was a reference in Strong (1988) to some test surveys that used 3-min intervals (it is possible that this was their standard time frame). Therefore, I used the standard 3 min per stop as described in the BBS methodology. I have no reason to believe detectability of singing males was different either among valleys or years (J. Ruth, pers. obs.). Neither Mills nor Strong mentioned any distance limitation on the recorded observations at their survey stops. For consistency I also recorded all singing males seen or heard from the stop point and did not estimate or record distance. On many occasions singing males were heard, but never seen. Estimating distance to unseen singing males would have been difficult, and would have taken additional time. Limited time and resources to complete these surveys across the region precluded me from adding to the protocol.

Both Mills and Strong used taped playback of Grasshopper Sparrow songs to supplement their surveys. Neither described their protocol other than to say that taped playback was used to stimulate a response if no singing males were heard. Their data did not distinguish between the number of birds recorded without and with taped playback. Therefore, in order to be consistent, I also used taped playback. However, I only played a taped song after the standard 3 min had elapsed at each stop and recorded additional individuals separately in my records. A tape recording that included the primary and sustained songs and the trill was played for 1–2 min, in approximately the four cardinal directions. It was my observation (as well as Mills' and Strong's) that if there were male Grasshopper Sparrows in the area, they responded quickly and aggressively to the recording. Because females sometimes respond by coming in and giving a trill call, I made every effort to separate out these additional individuals in my recorded observations in order to include only one individual of a pair. For purposes of comparability with the data from the historical surveys, these two numbers were combined. The maximum number of singing males recorded (total number during the 3 min + any additional singing males observed with taped playback) was used to calculate mean number of singing males per stop and singing male abundance.

Analyses and Statistical Methods

I analyzed and compared bird survey results using mean number of singing males per stop. This provides a more standardized measure than abundance (total number of singing males); it is not as dependent on repeating the exact number of historical road surveys or survey stops. This is important because, in some cases, a few surveys conducted by Mills and/or Strong were not repeated in 2004 and/or 2005, or it was not possible to survey the same number of stops (Table 1). Surveys that recorded no birds were included in calculations of mean number of singing males per stop in order to be consistent and comparable with historical survey reports. In general, calculating the mean without the zero segments would have resulted in slightly higher values. Information about the total number of singing males recorded for a particular valley and year are presented in the text, where appropriate, and in Table 2.

Among-year differences in the mean number of singing males per stop for each valley, using road segments as replicates, were evaluated using one-way analysis of variance (ANOVA). Regional among-year and among-valley differences in numbers of singing males per stop, using road segments as replicates, were evaluated using two-way ANOVA. For the two-way ANOVA, data from the three valleys supporting the main populations of Arizona Grasshopper Sparrows were used, and only those segments with data available for all four years were included. In all cases, Tukey's multiple comparison procedure, with alpha = 0.05, was used to compare means among years.

RESULTS

An assumption of this study is that it documents the breeding distribution and abundance of Arizona Grasshopper Sparrows. The

TABLE 2. COMPARISON OF MEAN (SE) NUMBER OF SINGING MALE ARIZONA GRASSHOPPER SPARROWS PER STOP FOR EACH VALLEY, USING A ONE-WAY ANOVA TO EXAMINE ANNUAL DIFFERENCES. LETTERS REPRESENTING THE TUKEY GROUPING (A, B) ARE PLACED BEHIND EACH YEAR. TOTAL NUMBERS OF SINGING MALES RECORDED IN EACH VALLEY BY YEAR ARE PROVIDED FOR REFERENCE.

Valley	Year	N[a]	Mean number of singing males per stop (SE)	Results of ANOVA	Total number of singing males
San Rafael	1982 B	13	1.22 (0.26)	$F_{3,57}$ = 6.90; P < 0.01	130
	1987 A	15	2.51 (0.29)		265
	2004 A	16	2.49 (0.23)		205
	2005 A	17	2.79 (0.24)		269
Sonoita	1982 A	25	1.07 (0.16)	$F_{3,92}$ = 1.72; P = 0.17	204
	1987 A	23	1.67 (0.27)		300
	2004 A	24	1.60 (0.22)		271
	2005 A	24	1.48 (0.18)		263
Animas	1982	NA			
	1987 A	5	1.84 (0.57)	$F_{2,16}$ = 0.38; P = 0.69	87
	2004 A	7	1.44 (0.42)		68
	2005 A	7	1.27 (0.39)		76
Altar	1982 A	1	0.18 (—)	$F_{3,14}$ = 0.88; P = 0.48	2
	1987 A	2	1.15 (0.65)		11
	2004 A	6	0.59 (0.12)		15
	2005 A	9	0.59 (0.20)		18
San Pedro	1982 A	4	0.25 (0.15)	$F_{3,8}$ = 2.00; P = 0.19	9
	1987 A	1	1.33 (—)		8
	2004 A	3	0.67 (0.33)		11
	2005 A	4	0.50 (0.19)		11
Sulphur Springs	1982 A	8	0.04 (0.04)	$F_{3,14}$ = 1.63; P = 0.23	1
	1987 A	1	0.00 (—)		0
	2004 A	4	0.15 (0.09)		4
	2005 A	5	0.26 (0.12)		10
San Bernardino	1982 A	3	0.04 (0.04)	$F_{3,8}$ = 0.45; P = 0.72	1
	1987 A	2	0.19 (0.19)		3
	2004 A	4	0.06 (0.06)		2
	2005 A	3	0.11 (0.11)		3

[a] N = number of road segments.

objectives of the study did not include confirming the breeding status of this subspecies, which is documented elsewhere (Vickery 1996; Corman and Wise-Gervais 2005). However, during the surveys I did record numerous individuals and pairs of Arizona Grasshopper Sparrows carrying food in the Sonoita, San Rafael, and Animas Valleys, a behavior regularly recognized by Breeding Bird Atlas projects (Corman and Wise-Gervais 2005) as confirming breeding. All of these observations occurred during the time period of August 4–16 in either 2004 or 2005.

Although, as discussed elsewhere, use of measures of total numbers of singing males recorded in a valley to look for difference among valleys or years is generally inappropriate, use of these measures as an index of which valleys support the largest populations of Arizona Grasshopper Sparrows is acceptable. This is because the surveys were designed to sample the entire area in each valley that supported birds, given the limits imposed by available roads. Therefore, those valleys in which large numbers of singing males were recorded represent valleys with large populations, and those with substantially lower numbers have small populations. In 2004–2005 the San Rafael, Sonoita, and Animas Valleys supported the largest populations of Arizona Grasshopper Sparrows in the US, and the other valleys supported much smaller populations (Table 2).

ANNUAL VARIATION BY VALLEY

Comparisons of mean number of singing males per stop among years are first presented separately for each valley due to the likelihood that different factors (e.g., land use, management practices, precipitation, soil characteristics) act differently on birds and habitats in different valleys and therefore temporal patterns may vary among valleys. For ease of reference, the dates used for Mills' and Strong's surveys are 1982 and 1987, respectively, the years in which they collected data.

Sonoita Valley

I found no evidence of significant differences in mean number of singing males per stop among years in the Sonoita Valley (Table 2). However, the pattern was one of lowest numbers in 1982, highest in 1987, and was intermediate in 2004 and 2005. I found no evidence of overall expansion or contraction of distribution in the valley—of the 20 historical road segments that were resurveyed, birds continued to be recorded on 18 segments, birds were recorded on one that had not had Grasshopper Sparrows historically, and no birds were recorded on one that had birds historically. The four new (non-historical) road segments were located within the portion of the valley that had been historically surveyed, three of them within the Bureau of Land Management (BLM) Las Cienegas National Conservation Area.

San Rafael Valley (including *Campini Mesa*)

I found significant differences in mean number of singing males per stop among years in the San Rafael Valley (Table 2). Values in 1982 were significantly lower than the values in 1987, 2004, and 2005. There was no evidence of significant differences among the latter 3 yr, although the pattern was for the highest numbers in 2005 and intermediate numbers in 1987 and 2004. I found no evidence of overall expansion or contraction of distributions in the valley—of the 14 historical road segments that were resurveyed, birds continued to be recorded on all 14. The four new (non-historical) road segments were located in the southern portion of the valley that had been historically surveyed, in the new San Rafael Short Grass Prairie Preserve State Park (Arizona).

Animas Valley

Mills (1982) did not conduct surveys in the Animas Valley, so data are only available for 1987, 2004, and 2005. I found no evidence of significant differences in mean number of singing males per stop among years in the Animas Valley (Table 2). However, the pattern was one of highest numbers in 1987, and declining numbers in 2004 and 2005. I found some evidence of a minor southward contraction of distributions in the valley—on the northernmost of the five historical road segments, six individuals were recorded in 1987, but only one was recorded in 2004 and none in 2005. This area appeared to no longer contain optimal habitat, since it was dominated by shrubs with little grass cover (J. Ruth, pers. obs.). The two new (non-historical) road segments were located at the southern end of the portion of the valley that had been historically surveyed.

Interpreting results for the remaining valleys requires more caution. The sample sizes of road segments surveyed were small, total numbers of individuals recorded were low, and in these sparsely populated valleys, different locations and numbers of road segments were surveyed in different years (both historical and current). The values for mean number of singing males per stop are substantially lower for all of these valleys than for the previous three valleys (Table 2).

Altar Valley

I found no evidence of significant differences in mean number of singing males per stop among years in the Altar Valley (Table 2). However, the pattern was one of the lowest numbers in 1982, highest in 2005, and numbers were intermediate in 1987 and 2004. I found some evidence that the size and distribution of the small population in the Altar Valley has shifted during the time period between these surveys and historical surveys. Of the three historical road segments that were resurveyed, birds continued to be recorded on two of them. However, the majority of the singing males recorded in 2004 and 2005 were observed on new (non-historical) road segments centered on the road called Pronghorn Loop on the USFWS Buenos Aires NWR.

San Pedro Valley

I found no evidence of significant differences in mean number of singing males per stop among years in the San Pedro Valley (including Allen Flats; Table 2). The pattern was one of the lowest numbers in 1982, highest in 1987, and numbers were intermediate in 2004 and 2005. An additional observation from 2005 is notable. Five of the 11 singing males recorded for the San Pedro Valley were observed on a new (non-historical) road segment and were singing from territories in two large center-pivot irrigated alfalfa fields along Palominas Road (runs north from Palominas, AZ between Highway 92 and Hereford Road; 31°24′07″N, 110°07′24″W).

Sulphur Springs Valley

I found no evidence of significant differences in mean number of singing males per stop among years in the Sulphur Springs Valley (including the Fort Grant area) (Table 2). The pattern was one of the lowest numbers in 1987 (zero), highest in 2005, and numbers were intermediate in 1982 and 2004. Three of the ten individuals in 2005 were recorded on a new (non-historical) road segment (Turkey Creek Road—running east from the intersection of the 90°bend in Highway 181 and Kuykendall Cutoff Road).

San Bernardino Valley

I found no evidence of significant differences in mean number of singing males per stop among years in the San Bernardino Valley (Table 2). The pattern was one of the lowest numbers in 1982, highest in 1987, and numbers were intermediate in 2004 and 2005.

Regional Variation by Valley and Year

When looking for regional patterns using the data from the three valleys that support the majority of the Arizona Grasshopper Sparrow population in the US (San Rafael, Sonoita, and Animas valleys), I found evidence of significant differences in mean number of singing males per stop among both valleys and years (Table 3). Using pooled data across years, the San Rafael Valley shows significantly higher values than either the Sonoita or Animas valley, but the Tukey test results do not allow discrimination between the Sonoita and Animas valleys. However, the general pattern is one of lowest numbers for Animas Valley and intermediate numbers for Sonoita Valley. Using pooled data across valleys, 1982 shows significantly lower numbers than 1987, but the Tukey test results do not allow discrimination among the other years. However, the general pattern was one of the lowest numbers in 1982, highest for 1987, and intermediate numbers for 2004 and 2005. I found no evidence of interactions between valley and year affecting mean number of singing males per stop (Table 3).

DISCUSSION

Distribution and Status of Arizona Grasshopper Sparrow

To the best of my knowledge, the valleys sampled in this and historical surveys represent the areas in which almost all Arizona Grasshopper Sparrows breed in the US. In Arizona, this is consistent with the results of the Arizona Breeding Bird Atlas (Corman and Wise-Gervais 2005). If any additional areas exist, they support peripheral, remnant populations with small densities and numbers. For example, a rapidly declining, small population has been monitored in the Playas Valley, New Mexico, just to the east of the Animas Valley population (Williams 1997), and some historically surveyed road segments in the Santa Cruz Valley were informally surveyed, but the habitat was suboptimal and no birds were recorded in 2005 (J. Ruth, pers. obs.). In addition, Arizona Grasshopper Sparrows bred in northern Sonora, Mexico, in 1982 (Mills 1982) and 1986 (Strong 1988) and Flesch (2008) reports a relatively high density of Grasshopper Sparrows (0.84 ± 0.09 territories/ha) at Rancho Los Fresnos in the Upper San Pedro watershed along the border in northern Sonora. Based on observations in the Animas Valley just north of the border, they are probably found in the grasslands that stretch into northwestern Chihuahua as well.

Concentrations of Arizona Grasshopper Sparrows, both mean number of singing males per stop and total number recorded, in the Sonoita, San Rafael, and Animas Valleys of the US in 2004–2005 are consistent with their distribution 20–25 yr ago (Mills 1982, Strong 1988). Of all areas surveyed, these three valleys have also retained the largest stretches of continuous, open, high-quality desert grassland with little shrub component. Although breeding

Table 3. Comparison of regional mean (se) number of singing male Arizona Grasshopper Sparrows per stop in the three valleys supporting the majority of the population, using a two-way ANOVA to examine differences by year and by valley. Letters representing the Tukey grouping (A,B) are placed behind each valley or year.

Variable class	Variable	N[a]	Mean number of singing males per stop (se)	Results of ANOVA
Valley	San Rafael A	40	2.29 (0.21)	$F_{2,124} = 9.74$; $P < 0.01$
	Sonoita B	80	1.55 (0.12)	
	Animas B	15	1.24 (0.28)	
Year	1982 B	30	1.19 (0.15)	$F_{3,124} = 6.37$; $P < 0.01$
	1987 A	35	2.09 (0.22)	
	2004 AB	35	1.81 (0.20)	
	2005 AB	35	1.77 (0.21)	
Valley × Year				$F_{5,124} = 1.57$; $P = 0.17$

[a] N = number of road segments.

Notes: Values for mean number of singing males per stop are pooled across years or across the three valleys for this analysis. Valley × Year represents an interaction term between the two variable classes.

Grasshopper Sparrows tolerate a small shrub component in their grassland habitat, for the most part they avoid grassland with extensive shrub cover (Vickery 1996; J. Ruth, pers. obs.).

Despite differences in numbers of birds among the valleys, it would be difficult to state with certainty which of the three valleys supported the largest populations based on these data. Total numbers of singing males recorded represents an inappropriate measure, being potentially confounded by several variables—differences in the amount of land in appropriate grassland habitat within the valleys, differences in the mean number of singing males per stop, as well as total mileage, number of road segments, and number of stops surveyed. Perhaps the best example of this would be a comparison of data on the Sonoita and San Rafael Valleys. According to Southwest ReGAP data (USGS National Gap Analysis Program 2004), the Sonoita Valley supports 44% more grassland (339,800 km^2, primarily in the Apacherian-Chihuahuan piedmont semi-desert grassland and steppe land-cover classification) than the San Rafael (190,000 km^2 of the same classification). In addition, in 2005 about 70% more miles and 75% more stops were surveyed in the Sonoita Valley than the San Rafael Valley (Table 1). In spite of this, in 2005 the total number of singing males recorded in the San Rafael was basically the same as the Sonoita Valley (Table 2). This phenomenon may be at least partially explained by the fact that mean number of singing males per stop were significantly higher in the San Rafael Valley than in the Sonoita Valley (Table 3). It is not appropriate to take the values of mean number of singing males per stop as calculated in this study and extrapolate to a population estimate.

Although most of the analyses did not show statistically significant differences among years, the overall pattern in Arizona Grasshopper Sparrow population, as measured in this study, is one with the lowest numbers in 1982, highest numbers in 1987, and subsequent declines from 1987 to 2004–2005. In most cases numbers recorded in 2004–2005 were lower than 1987 but higher than 1982, with the exception of the San Rafael Valley.

Some cautionary notes should be offered regarding the value of these survey data to determine long-term trends. First, much of the information we have suggests that, like many southwestern grassland species, Arizona Grasshopper Sparrow populations show substantial annual and/or short-term fluctuations. Using only four survey data points from widely separate years can obscure short-term fluctuations and provide misleading information about long-term trends. We can not determine where these four points fall along what may be a fluctuating line. As an example, Strong (1988) reported the results of some additional surveys conducted in 1986. For the Sonoita and San Rafael Valleys, substantial declines occurred in mean number of singing males per stop and total number of singing males recorded between 1982 (Mills 1982) and 1986 and then a large increase occurred from 1986–1987 (Strong 1988). These results and my observations from informal surveys prior to 2004 (J. Ruth, unpubl. data) indicate that substantial annual variation can occur in Arizona Grasshopper Sparrow numbers. In a system with substantial short-term fluctuations, there is no real substitute for continuous, long-term datasets for determining long-term population trends. Having recognized these caveats, we can state that our results provide evidence that current Arizona Grasshopper Sparrow populations in the two valleys in Arizona supporting the largest populations have not increased beyond the values recorded in 1987 nor have they declined below the values recorded in 1982.

Secondly, a major assumption in this study and its predecessors is that measures of mean number of singing males per stop and abundance are reliable measures of good habitat. The literature indicates that this is not always the case (Van Horne 1983, Vickery et al. 1992). Birds may be found in habitats or areas because of loss of or exclusion from optimal habitats, habitat degradation, competition, or site fidelity (something that Vickery et al. [1992] found for some Grasshopper Sparrow populations). Just as no good substitute for long-term population monitoring exists for determining population trends, demographic studies are important for determining whether birds are successfully reproducing and surviving in particular habitat types or sites. However, in a recent literature review, Bock and Jones (2004) found that per capita reproductive success usually is positively correlated with density.

Thirdly, in making comparisons across years and across different surveys, it is always important to ensure consistent methodologies. The use of replicable methodologies such as limited-radius point counts or distance sampling in both the historical and current surveys would have provided more consistent approaches and would have allowed for easier replication in the future. It would have had the additional advantage of allowing for actual density estimates. Another consistency factor relates to observer differences. It is possible that significant differences existed in the abilities of Ruth, Strong, and Mills to detect

Grasshopper Sparrow song—notoriously high-pitched and difficult for some observers to detect. In 1987 Mills and Strong did conduct a joint test of observer differences, and found no obvious differences in the total number of singing males observed along a road segment, although stop-by-stop comparisons showed more variation (Strong 1988). Surveys in 2004–2005 were all conducted by a single observer (J. Ruth). Although not a formal test of the sort reported by Strong, I informally tested my ability to detect Grasshopper Sparrow songs on one occasion in the field with an experienced colleague. We each recorded similar numbers of singing individuals during timed intervals.

Finally, one of the limitations of the current surveys is the lack of habitat data collected, primarily a result of limited time and resources. The collection of data about the habitat type and condition, and the land use characteristics at the survey points (e.g., rural vs. exurban, ungrazed vs. moderately grazed vs. heavily grazed, cropland) would have allowed for comparisons of bird data with habitat condition or type and would have provided valuable baseline information for future replications.

Factors Potentially Affecting Grasshopper Sparrow Habitat

The scope of this study did not permit a detailed evaluation of the factors influencing desert grassland ecosystem dynamics, a subject about which there are many differing opinions. However, many good references do exist that provide details about the history and ecology of this region (Dick-Peddie 1993, McClaran and Van Devender 1995, Finch 2004). Several, often inter-related factors influence desert grassland ecosystem dynamics, and therefore Arizona Grasshopper Sparrow populations. Major factors include grazing practices, suburban and agricultural development, drought, changes in historical fire regimes, and encroachment by shrubs and exotic plants.

The issue of grazing impacts in the arid Southwest is a contentious one (Finch 2004). However, there seems little doubt that historical overgrazing in this part of the country (Bahre 1995, Finch 2004) have had long-term, substantial impacts on the structure, composition, and distribution of desert grasslands today, and that such intense grazing has had negative effects on grassland bird species (Saab et al. 1995, Finch 2004). Nevertheless, the effects of grazing vary widely depending on grazing intensity, stocking rates, season and length of grazing, environmental conditions, and land use history (Merola-Zwartjes 2004).

Although we have no data on sparrow numbers prior to domestic cattle grazing, the results of this study provide no reason to conclude that well-managed grazing is incompatible with Arizona Grasshopper Sparrow habitat, because some of the highest numbers were recorded on grazed lands in the San Rafael and Sonoita Valleys. Without sites that have never been grazed by domestic cattle, it is not possible to know how numbers in historically ungrazed habitats might compare. However, evidence shows that Arizona Grasshopper Sparrows do respond to grazing pressures in arid grasslands. Studies have shown that they were significantly more abundant on ungrazed sites than on grazed sites (Bock and Webb 1984, Bock et al. 1984, Bock and Bock 1988) and suggest that Grasshopper Sparrows respond negatively to grazing due to its effects on grass structure (J. Ruth et al., unpubl. data).

In much of southeastern Arizona, low-density suburban or exurban development is a substantial threat (Bahre 1995, Merola-Zwartjes 2004). This was predicted by both Mills (1982) and Strong (1988). The complete loss of grassland habitat is the most obvious result of suburban, or agricultural, development, but less is known about the effects of habitat degradation in remaining, fragmented grasslands. Bock et al. (2008) found Grasshopper Sparrow abundance in the Sonoita Valley to be lower in undeveloped grassland plots than in exurban grassland plots, and abundance was negatively correlated with the number of homes within 250 m. These results indicate that although many bird species were positively associated with exurban development, Grasshopper Sparrow was not one of them.

The impacts of drought on desert grasslands is something over which humans have little direct control. However, drought interacts extensively with, and may exacerbate the impacts of, grazing, fire, shrub encroachment, plant structure, and community composition in affecting grasslands and the bird species that live there.

The History and Future of Arizona Grasshopper Sparrow Habitat

Each of the valleys surveyed have different land-use histories and are influenced by different combinations of the above-mentioned factors, which have implications for Arizona Grasshopper Sparrow populations.

The Sonoita Valley supports an extensive area of good grassland habitat. Ranching has been the primary land use and will continue to be important in the future. However, the primary threat, especially around Sonoita and Elgin, may be exurban development. Agricultural development in the form of an expanding local wine industry poses a secondary threat (Strong 1988). Land ownership offers some habitat protection. The Audubon Appleton-Whittell Research Ranch comprises private and federal land dedicated to research and preservation and has not been grazed since 1968. Much of BLM land is part of the Las Cienegas National Conservation Area (NCA) and is bordered by additional state or USDA Forest Service land; it is managed for multiple-use and leased for grazing but protected from development. The central portion of the valley is primarily privately owned, and is the main focus of exurban and agricultural development pressure. As a primary population center of Arizona Grasshopper Sparrows, development, grazing practices, and other management decisions in the Sonoita Valley will have significant impacts on the future of this subspecies.

The San Rafael Valley supports an extensive area of good grassland habitat. The main land use is ranching and it is primarily in private ownership, with the exception of some Coronado National Forest and Arizona State Park land. Ranching and grazing practices will continue to be a primary factor influencing grassland habitat in the foreseeable future. Although the threat of exurban development seems less immediate here, there is land currently on the market, posing the threat of future development. If development activities in the San Rafael Valley increase in the future, they could have significant impacts on a primary population center of Arizona Grasshopper Sparrows.

The Animas Valley also supports an extensive area of grassland habitat. However, the current condition of the grasslands reflects the impacts of a combination of recent grazing practices and severe drought (Williams 2007; J. Ruth, pers. obs.) The primary land use in the southern part of the Animas Valley is ranching and will likely continue to be in the future. Land is primarily in private ownership and faces no immediate threat from development. Arizona Grasshopper Sparrow habitat is located primarily on the Diamond A (formerly Gray) Ranch, administered by The Animas Foundation as a working ranch. A continuous, long-term data set from Arizona Grasshopper Sparrow surveys exists for the Animas Valley (and adjacent Playas Valley) (Williams 2007). Because these surveys were conducted earlier in the breeding season, it is not possible to compare results directly with the results of this study. However, the patterns are consistent and the results disturbing. Williams (2007) documents a significant population decline in the Animas and Playas Valleys over 15 yr (1992–2006). In 2005 and 2006, a slight upswing was observed in the Animas Valley—a time when cattle were removed from the Diamond A due to the ongoing drought. Although the Playas Valley initially supported a population similar to the Animas Valley (Williams 1991), it now appears nearing extirpation (Williams 2007). As a result of these findings, the New Mexico Department of Game and Fish changed its listing of Arizona Grasshopper Sparrow from Threatened to Endangered in 2006. Grazing management decisions in the Animas and Playas Valleys, in combination with future precipitation levels, will likely have significant impacts on populations there.

The Altar Valley is at the western edge of the Arizona Grasshopper Sparrow's range (Brown 1994, Flesch 1997). In the 1800s it was primarily open grassland but is now quite degraded; mesquite encroachment is a substantial problem (Bahre 1995, Flesch 1997). Remaining open grasslands administered by the Buenos Aires NWR, have not been grazed since establishment in 1985 and do not face threats from development. The presence of more Arizona Grasshopper Sparrows in the Altar Valley than historical surveys indicated is consistent with other recent findings (Flesch 1997, Corman and Wise-Gervais 2005). This is encouraging evidence that this small population is at least somewhat larger and more broadly distributed than historical surveys suggested. The suitability of grasslands in the Altar Valley for this small population is dependent on the ongoing efforts of the refuge to restore the desert grassland ecosystem through shrub and exotic grass reduction and prescribed fire.

In their current condition, the remaining valley grasslands within the historical range of the Arizona Grasshopper Sparrow do not provide either prime or substantial habitat. Grassland habitat in the San Pedro Valley, including Allen Flats, has been almost entirely lost or degraded due to suburban and agricultural development. The few patches of remaining fragmented grassland support the relict of a larger population with little hope for future improvements. Arizona Grasshopper Sparrow use of irrigated alfalfa fields raises a concern; it seems likely that the timing of harvest poses threats to nesting birds (i.e., destruction of nests and fledglings), therefore creating a potential sink for this remnant population.

The Sulphur Springs Valley, including the Fort Grant area, has been severely impacted by agricultural development and is primarily private and state land. Abandonment of historical cropland (Bahre 1995) has left a fragmented landscape of degraded desert grassland, abandoned agricultural fields, and desert scrub habitat. Much of the remaining grassland is tobosa (*Hilaria mutica*) grassland, which did not appear to provide habitat for the few remaining Arizona Grasshopper Sparrows in 2004–2005 (J. Ruth, pers. obs.). The Sulphur Springs Valley population is a relict population maintaining a precarious existence in the few suitable grassland patches remaining.

The San Bernardino Valley has a long history of cattle grazing, and ownership is a patchwork of state and private lands. Strong (1988) reported that the valley held suitable habitat although he recorded only a few individuals. During 2004–2005, it was my assessment that very little open grassland remained in the valley, and what remained was sparse, heavily grazed, and degraded from conversion to desert scrub. The habitat appeared extremely marginal, as evidenced by survey results. However, Corman and Wise-Gervais (2005) report observations of Arizona Grasshopper Sparrows in parts of the San Bernardino Valley that were not accessible (private land with no public roads) during this study. In addition, anecdotal observations in 2007 (J. Ruth, pers. obs.) suggest that some areas may provide more promising Grasshopper Sparrow habitat in years with better rains.

FUTURE—INFORMATION AND RESEARCH NEEDS

My results suggest that we are observing either a gradual decline in Arizona Grasshopper Sparrow numbers, at least in the short-term, and/or the subspecies is at the low end of a fluctuating population cycle. The following research priorities would provide the scientific information that land managers need to manage grasslands for Arizona Grasshopper Sparrows and other associated species.

1. *Continuous, regular surveys to monitor the status of Arizona Grasshopper Sparrow populations.* It might be most efficient to target limited resources toward regular monitoring of populations in the primary population centers—Sonoita, San Rafael, and Animas Valleys—with occasional surveys in areas supporting smaller populations.
2. *Life-history research.* Research is needed to understand the habitat preferences, breeding ecology, life history, and demographics of Arizona Grasshopper Sparrows in order to identify factors that influence reproductive success and survivorship throughout the subspecies' range, and to determine if differences exist between this subspecies and others. It would be particularly useful to conduct studies in all three valleys supporting major populations to determine variation within the subspecies.
3. *Research on causes of population declines*. Without more intensive, directed research on the effects of various management regimes and land use changes on bird numbers and demographics, we cannot determine the causes of the population trends. Implementing conservation measures is hopeless without such information. This will require collaborative efforts between land managers and researchers to design and monitor management activities, hopefully in an iterative, adaptive management framework where the results of the monitoring and research will influence future management decisions.

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