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HABITATS AND CONSERVATION OF MOLT-MIGRANT BIRDS IN SOUTHEASTERN ARIZONA

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ABSTRACT—Using mist-netting and observational surveys in southeastern Arizona, we documented use of habitat by 12 species of birds that migrate to this Mexican monsoon region to molt. During the drier monsoon season in 2007, higher proportions of molt-migrants congregated at riparian areas. During the wetter monsoon season in 2008, a wider range of habitats was used. Molt-migrants generally selected habitats similar to those of their breeding territories; however, in some cases, species appeared to shift habitats for molt, in response to environmental effects. For example, high use of grasslands by molting Lucy's warblers (*Oreothlypis luciae*) in 2007 and by lazuli buntings (*Passerina amoena*) and lesser goldfinches (*Carduelis psaltria*) in 2008 suggests variable responses to relative strength of the monsoon season. Our results underscore the need to conserve native grasslands and riparian areas; habitats in which we detected molt-migrants most frequently. Our results also indicate the need to conserve a mosaic of habitats to account for adaptive selection in response to variable environmental conditions.

RESUMEN—Usando redes de niebla y muestreos observacionales en el sudeste de Arizona, documentamos el uso de hábitat de 12 especies de aves en inmigración de muda a esta región del monzón Mexicano. Durante la temporada más seca del monzón en el 2007, proporciones mayores de inmigrantes de muda se agruparon en áreas riparias, mientras que una selección de hábitat más amplia fue observada durante la temporada más lluviosa del 2008. Los inmigrantes de muda generalmente seleccionaron hábitats similares a los de sus territorios de apareamiento; sin embargo, en algunos casos las especies parecían cambiar hábitats para la muda, en respuesta a efectos ambientales, o consecuencia de las dos causas. Por ejemplo, un alto uso de hábitat de pastizal por el chipe rabadilla rufa (*Oreothlypis luciae*) mudándose en el 2007, y por el colorín lázuli (*Passerina amoena*) y el jilguero dominico (*Carduelis psaltria*) en el 2008, sugiere respuestas variables a la fuerza relativa de la temporada del monzón. Nuestros resultados subrayan la necesidad de conservar los pastizales nativos y las áreas riparias, hábitats en los cuales detectamos inmigrantes de muda más frecuentemente. Nuestros resultados también indican la necesidad de conservar un mosaico de hábitats, considerando la capacidad adaptativa de seleccionar hábitats a respuesta a las condiciones ambientales variables.

Most North American land birds undertake a prebasic molt following breeding, during which all feathers are replaced (Pyle, 1997). This annual molt is energetically demanding (Murphy and King, 1991) and critical to survival of birds; yet strategies of molting in birds are poorly documented in comparison to strategies of breeding, wintering, and migration. Land birds become reclusive and inactive during the molting process, few specimens have been collected, and such basic information as location and habitats used for molting are largely unknown. For example, although molt generally is understood to occur on breeding or wintering grounds (Pyle, 1997; Rohwer et al., 2005), locations and habitats for molting may not occur exclusively on nesting or over-wintering territories. Chance encounters (e.g., Cherry, 1985) suggest that adult land birds reported to molt on breeding grounds can travel substantial distances away from breeding territories to molt, but the degree to which these movements vary among individuals and in response to environmental factors is undocumented.

Conservation strategies for land birds have thus far focused on dynamics that occur on breeding and wintering grounds (Faaborg, 2002; DeSante et al., 2005; Saracco et al., 2008). However, without knowing general or specific locations of molting, our ability to preserve adequate habitat for molt-migration stopover of land birds is compromised (Leu and Thompson, 2002; Heglund and Skagen, 2005). Birds may be reproducing successfully on breeding grounds and surviving well on migration and wintering grounds, but if habitats for molting are inadequate or not protected, management efforts on breeding and wintering grounds may not help reverse declines in populations. Locations of molting stopovers for grebes (western saline lakes) and waterfowl (specific wetland areas) have resulted in directed efforts to conserve and manage these important areas (Jehl, 1988; Hohman et al., 1992). Once locations and habitats have been identified, similar conservation and management of habitats should be provided for land birds stopping to molt (Leu and Thompson, 2002).

Among western North American land birds, ≥15 species recently have been identified as undertaking a molt migration to the Mexican monsoon region of the southwestern United States and northwestern Mexico following breeding. Here they stop and undergo molt in July–October, before continuing migration to their wintering grounds in the Neotropics (Rohwer et al., 2005; Pyle et al., 2009). These species appear to take advantage of a vegetational flush that occurs in the monsoon region in late summer. This flush provides greater availability of nutritional resources than in drier habitats of breeding grounds at this time of year. Documentation of this migration largely has been through examination of specimens (Rohwer et al., 2005), but data from specimens yield little if any insight on selection and requirements of habitats during molt.

To investigate the ecology of these molt-migrant species in the monsoon region and to begin to identify critical requirements of habitats used as stopover sites, we conducted extensive observational surveys and operated mist-netting stations during monsoon seasons of 2007 and 2008 in southeastern Arizona. We believe our results will help shape management and conservation strategies in this important and diverse region.

Materials and Methods—The study area spanned Pima, Santa Cruz, and Cochise counties, centered near Sierra Vista, Arizona. Elevation was 1,120–1,800 m. Here we examined habitats used by 12 molt-migrant species during the molting period in July–September (Pyle et al., 2009). We included the ash-throated flycatcher (*Myiarchus cinerascens*), western kingbird (*Tyrannus verticalis*), warbling vireo (*Vireo gilvus*), Lucy's warbler (*Oreothlypis luciae*), western tanager (*Piranga ludoviciana*), chipping sparrow (*Spizella passerina*), lark sparrow (*Chondestes grammacus*), lark bunting (*Calamospiza melanocorys*), black-headed grosbeak (*Pheucticus melanocephalus*), lazuli bunting (*Passerina amoena*), Bullock's oriole (*Icterus bullockii*), and lesser goldfinch (*Carduelis psaltria*). We selected areas and habitats to survey using data from museum collections on molt-migrants, consultation with local experts, and remote-sensed, GIS-based, habitat imagery. We positioned stations to sample diversity within habitats present in southeastern Arizona, including willow-cottonwood (*Salix-Populus*) dominated riparian zones, native grasslands, mesquite (*Prosopis*) thickets, desert scrub, and oak (*Quercus*) forests.

During 15 July–14 September 2007 and 2008, we established and surveyed 75 area-search stations in the monsoon season. We sampled 48 of these stations in both 2007 and 2008. We opportunistically sited and sampled the other 27 stations only in 2007. We surveyed each station for 20–40 min between sunrise and 5 h after sunrise. Surveys were repeated a variable number of times (1–10) throughout the season, maintaining standardized times of starting and duration for each station both within and between years. Survey plots consisted of selected areas ca. 100 m^2 and surveys consisted of a single observer moving at a constant pace around each plot and recording audio and visual detections of all individuals of molt-migrant species. We summarized data for each station and date as number of individuals detected per minute. We recorded birds in active molt, but could not detect this accurately for the majority of observations. We collected vegetational data at each station using the Habitat Structure Assessment form from the Monitoring Avian Productivity and Survival program (Nott et al., 2003). We grouped survey stations into six broad categories of habitat based on predominant species of plants detected using the Habitat Structure Assessment and in consultation with the United States Geological Survey National Gap Analysis Program (2004); cottonwood riparian, desert scrub, grassland, mesquite woodland, oak woodland, and willow riparian.

We established seven mist-netting stations within the Mexican monsoon region of southeastern Arizona (Pyle et al., 2009). Stations, comprised of 6–15 nets, were in a variety of riparian, mesquite, and oak-dominated habitats and operated for 6–13 days/season during 1 July–9 October. We classified each netting site according to habitat within 50 m of the net as cottonwood riparian, mesquite scrub, oak woodland, or willow riparian (nets were not operated in grassland or desert scrub). We scored birds undergoing active molt of flight feathers (including primary, secondary, or both) and birds undergoing molt of body feathers as absent, trace, light, medium, or heavy. We considered adults and 1st-year birds in active molt if primaries were

TABLE 1—Molt-migrant species of birds detected during observational surveys in southeastern Arizona, 2007 and 2008. For 2007, numbers in parentheses indicate repeated surveys.

	2007			2008		
Species	Number of surveys	Total number of birds detected	Total number of birds/min	Number of surveys	Total number of birds detected	Total number of birds/min
Ash-throated flycatcher	68 (49)	128 (89)	0.02 (0.02)	30	54	0.02
Western kingbird	50 (42)	106 (90)	0.01 (0.02)	19	35	0.02
Warbling vireo	18 (13)	19 (13)	<0.01 (<0.01)	1	1	<0.01
Lucy's warbler	85 (76)	193 (177)	0.03 (0.03)	29	53	0.02[a]
Western tanager	47 (32)	69 (52)	0.01 (0.01)	6	6	<0.01[a]
Chipping sparrow	37 (12)	149 (76)	0.02 (0.01)	4	10	<0.01[a]
Lark sparrow	39 (31)	110 (97)	0.02 (0.02)	21	68	0.03[a]
Lark bunting	18 (14)	165 (118)	0.02 (0.02)	0	0	<0.01[a]
Black-headed grosbeak	51 (32)	58 (35)	0.01 (0.01)	16	19	0.01
Lazuli bunting	91 (81)	267 (239)	0.04 (0.04)	25	94	0.04
Bullock's oriole	30 (23)	34 (27)	<0.01 (0.01)	15	19	0.01
Lesser goldfinch	203 (160)	479 (387)	0.07 (0.07)	70	168	0.07

[a] Significant inter-annual difference in rate of detection between repeated surveys (logistic regression, $P < 0.05$).

being replaced symmetrically. We considered 1st-year birds of some species that do not replace primaries during preformative molt to be in active molt if score for molt of body feathers was medium or heavy (Pyle et al., 2009). We summarized data by net-hour (one net operated for 1 h) and reported it as captures per 600 net-hours following protocols for Monitoring Avian Productivity and Survival (Nott et al., 2003).

We used logistic-regression analyses to test for differences in rates of detection among habitats and between years. To test assumptions of independence of the data, we included station and date as terms in analyses of data from surveys, and net as a term in analyses of data from netting; habitat-specific levels of significance were the same with and without inclusion of these terms.

RESULTS—We performed 468 surveys for a total of 161 h; 353 surveys (122 h) in 2007 and 115 surveys (39 h) in 2008. In 2007, we performed 278 repeated surveys (94 h) and, in 2008, all 115 surveys (39 h) were repeated.

We detected 1,928 individuals of the 12 molt-migrant species for an overall rate of detection of 0.24 individuals/min (Table 1). At repeated surveys, we detected 1,400 individuals in 2007 (0.25/min) and 528 in 2008 (0.23/min); rates of detection for all species pooled were not significantly different between years ($P > 0.4$). Among species, detection on repeated surveys was significantly greater in 2007 than in 2008 for Lucy's warblers, western tanagers, chipping sparrows, and lark buntings, and it was significantly greater in 2008 for lark sparrows (Table 1). We detected at least one individual of each species undergoing active molt with exception of the warbling vireo and black-headed grosbeak.

When all 12 species of molt-migrants and all surveys from both years were combined, rates of detection varied from 0.12/min in desert scrub to 0.33/min in grassland and willow-riparian habitats (Fig. 1). We recorded significantly higher rates of detection of molt-migrants in grassland, cottonwood-riparian, and willow-riparian habitats than in at least one other type of habitat. Three of the 12 species, warbling vireo, western tanager, and Bullock's oriole, showed no significant difference in rate of detection among the six habitats (Fig. 2), indicating wider selection of habitats during the survey. Only one species, lazuli bunting, showed significantly higher rate of detection in desert scrub than in at least one other habitat, whereas five species showed significantly higher rates of detection in grasslands than in at least one other habitat. Two to four species each showed significantly higher rates of detection in cottonwood-riparian, mesquite, oak, and willow-riparian habitats than in at

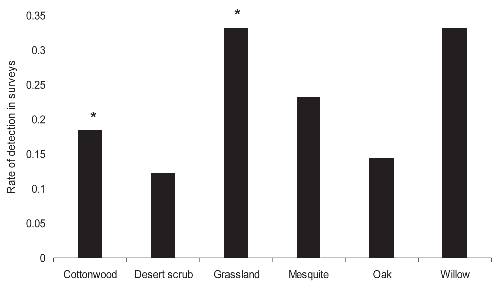

Fig. 1—Rates of detection during observational surveys (number of birds/min) of 12 molt-migrant species of birds combined by habitat in southeastern Arizona. Statistical significance (logistic regression, $P < 0.05$) is indicated: * rates of detection were higher in that habitat than at least one other habitat.

least one other habitat. Rates of detection for Lucy's warblers in mesquite, lazuli buntings in willow riparian, and lesser goldfinches in cottonwood-riparian habitats were greater than in all other habitats combined (Fig. 2).

Sufficient data were collected to test for inter-annual differences in rates of detection of three species plus all 12 molt-migrant species pooled (Fig. 3). For all species pooled, significantly higher rates of detection were recorded in grasslands in 2007 than in 2008, and this was the case for lazuli buntings and lesser goldfinches. The opposite occurred for Lucy's warblers. Additional shifts in habitats for molting between years occurred for all three species: Lucy's warbler (from cottonwood and willow-riparian habitats in 2007 to grasslands in 2008), lazuli bunting (from grasslands and mesquite in 2007 to desert scrub in 2008), and lesser goldfinch (from grasslands in 2007 to desert scrub in 2008).

At the seven mist-netting stations, a total of 4,603 net-hours was accumulated during this study, 2,533 in 2007 and 2,070 in 2008 (Pyle et al., 2009). These included 424 net-hours in cottonwood riparian, 2,264 net-hours in mesquite, 557 net-hours in oak, and 1,358 net-hours in willow-riparian habitats. A total of 188 molting individuals of 10 molt-migrant species was captured; all species listed in Table 1 except the western kingbird and lark bunting. We collected sufficient data to test for inter-annual differences in rates of detection of Lucy's warblers, lazuli buntings, and all 10 molt-migrant species pooled (Fig. 4). Significantly higher rates of capture of all species combined were recorded in nets within cottonwood-riparian habitats in 2007 than in 2008. A similar significant difference was recorded for Lucy's warblers, whereas significantly higher rates of capture of lazuli buntings were recorded in mesquite habitat in 2008 than in 2007. No significant inter-annual difference was recorded for rates of capture of molting individuals in oak or willow-riparian habitats.

Discussion—We document use of habitats for 12 species of molt-migrants in southeastern Arizona. A drawback to our study is that our sample of observed individuals may have included passage individuals as well as molt-migrants. Although we either captured or observed molting adults for all 12 species, we were unable to obtain molting rates during observational surveys, and molting rates of adults at the mist-netting stations were <30% for 3 of the 10 species; ash-throated flycatcher, warbling vireo, and black-headed grosbeak (Pyle et al., 2009). Evidence from specimens further suggests that many individuals of most species in our study can show age-related variation in locations used for molting, they may molt in southeastern Arizona, northwestern Mexico, or both. Northwestern Mexico may be the site of molting for most ash-throated flycatchers (Butler et al., 2006), warbling vireos (Voelker and Rohwer, 1998), western tanagers (Butler et al., 2002), and black-headed grosbeaks (D. Froehlich, pers. comm.), whereas many western kingbirds, western tanagers, and lazuli buntings may molt to the north of our study area (Young, 1991; Butler et al., 2002; Barry et al., 2009). The broad use of habitats we detected by warbling vireos, western tanagers, and Bullock's orioles could be due to the presence of many migrants of these species, which exhibit varying selection of habitats during passage (Hutto, 1985); these and our other species may show more specific selection of habitats for molting north or our study area or in Mexico. Conversely, a general concordance of results from our mist-netting and our observational data suggest that observational data does reflect selection of habitat for molting, at least within our six broad categories of habitat. Continued investigation using refinements to our categories of habitat, as well as sampling additional habitats (e.g., coniferous habitats at higher elevations) would be worth pursuing.

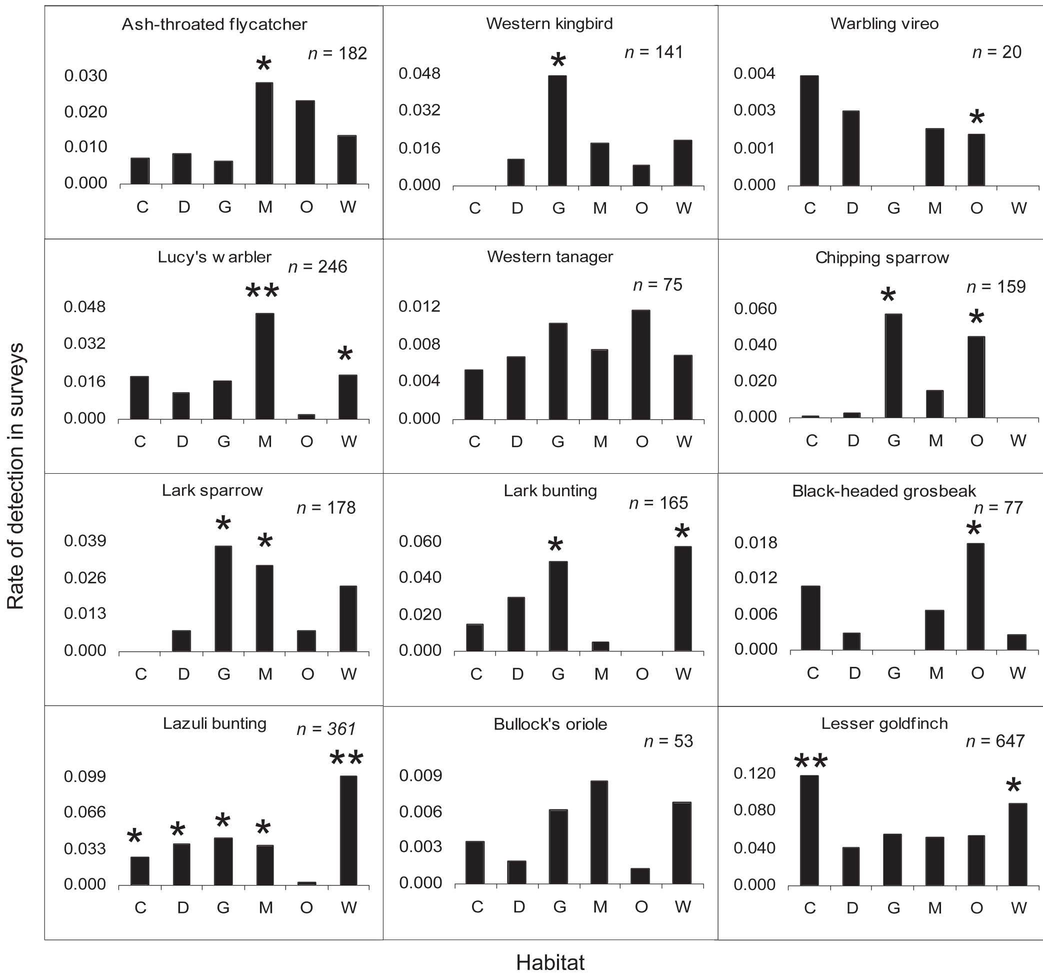

FIG. 2—Rates of detection during observational surveys (number of birds/min) of 12 molt-migrant species of birds by habitat in southeastern Arizona (C, cottonwood riparian; D, desert scrub; G, grassland; M, mesquite; O, oak; W, willow riparian). Statistical significance (logistic regression, $P < 0.05$) is indicated: * rates of detection were higher in that habitat than at least one other habitat; ** rates of detection were higher in that habitat than in all other habitats combined.

In descending order, molt-migrants selected native grassland, willow-riparian, mesquite, cottonwood-riparian, oak, and desert-scrub habitats. Habitats selected at a significantly higher rate than at least one other habitat included grasslands by five species (western kingbirds, chipping and lark sparrows, and lark and lazuli buntings), willow riparian by four species (Lucy's warblers, lark and lazuli buntings, and lesser goldfinches), mesquite by four species (ash-throated flycatchers, Lucy's warblers, lark sparrows, and lazuli buntings), cottonwood riparian by three species (Lucy's warblers, lazuli buntings, and lesser goldfinches), oak by two species (chipping sparrows and black-headed grosbeaks), and desert scrub by one species (lazuli buntings). These generally are similar habitats to those selected by each species for breeding (Ehrlich et al., 1988), although some species appeared to select different habitats for molting. These included chipping sparrows, lark sparrows, and lazuli buntings selecting grassland habitats, Lucy's warblers and lark buntings selecting willow-riparian habitats, lazuli buntings selecting mesquite habitats, and Lucy's warblers selecting cottonwood-riparian habitats. The apparent se-

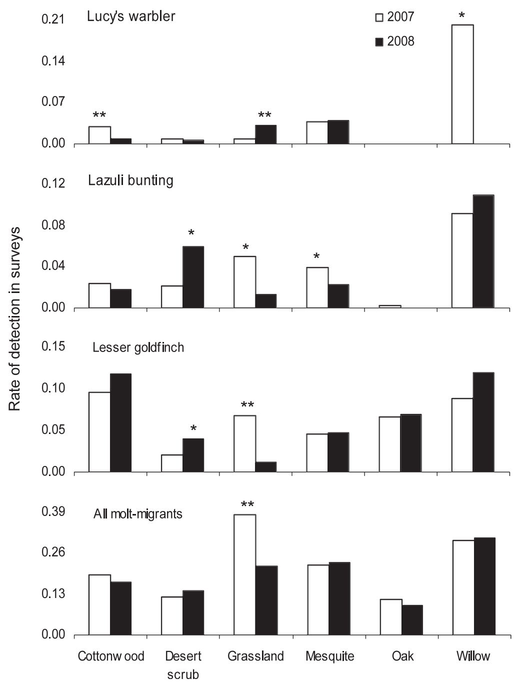

FIG. 3—Inter-annual differences between rates of detection of molt-migrant species of birds (number of birds/min) in six habitats in southeastern Arizona between a dry year (2007) and a wet year (2008). Statistical significance (logistic regression) is indicated: * $P < 0.05$; ** $P < 0.01$.

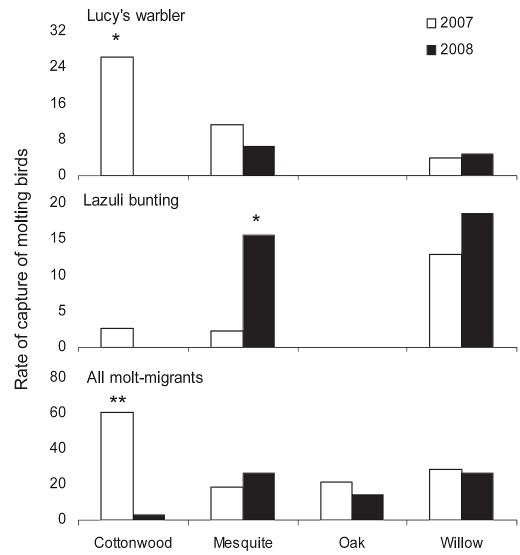

FIG. 4—Rates of capture (number of birds molting/600 net-hours) of molting birds in mist nets set in four habitats in southeastern Arizona during 2007–2008. Statistical significance (logistic regression) is indicated: * $P < 0.05$; ** $P < 0.01$.

lection of specific habitats for molting that differ from those selected for breeding underscore the need to consider habitats used for molting separately in conservation strategies for these species.

According to some measures, the monsoon season in 2007 was the 5th driest and the monsoon season in 2008 was the 10th wettest in Arizona during 1896–2008 (Pyle et al., 2009). This difference in monsoon seasons was reflected in our results: we detected significantly more molt-migrants in grasslands in 2007 than in 2008. We suggest that the higher rates of molt-migrants in grasslands in 2007 reflects more production of seeds by grasses as is typical in drier years (Brown et al., 1997). Chipping and lark sparrows, as well as lark and lazuli buntings, all showed significant selection of grasslands and are granivorous species that would benefit from increased production of seeds. Availability of seeds might also explain increased rates of detection of lazuli buntings in mesquite habitats in 2007.

We also detected higher rates in 2007 than in 2008 for Lucy's warblers in both riparian habitats and lazuli buntings in mesquite habitats. In 2008, we detected more Lucy's warblers in grasslands and lazuli buntings and lesser goldfinches in desert scrub. These inter-annual differences appear to reflect a broadening of habitats used during 2008 compared to 2007; presumably, in response to the wetter monsoon season of 2008. Molt-migrants, especially insectivorous species, had more choices among drier habitats such as grasslands and desert scrub, which presumably experienced a greater vegetational flush than in 2007. Thus, these birds do not need to target riparian habitats as much in wetter years. Pyle et al. (2009) documented a similar effect for molt-migrants throughout the monsoon region.

A surprising result of this study, perhaps, is the reliance on grasslands by molt-migrants in southeastern Arizona, especially in 2007. Grasslands have declined and changed substantially in southeastern Arizona during the past century, and conservation efforts have been aimed at increasing and managing these habitats (Brown et al., 1997; Kepner et al., 2000; Desmond et al., 2008). The importance of grasslands to granivorous and other molt-migrant species in drier monsoon seasons underscores the need to protect and manage such habitats in the future. Likewise, riparian cottonwood and willow habitats are under conservation threat in Arizona and northwestern Mexico (Heglund and Skagen, 2005; Hinojosa-Herta et al., 2008; Villaseñor-Gómez, 2008) and appear to be needed for successful molt by these species during drier years. Differences between seasons and the broad range of habitats selected by molt-migrants in Arizona also emphasize the need to protect a mosaic of native habitats for molting by this suite of species.

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