OCCURRENCE AND HABITAT USE OF PASSAGE NEOTROPICAL MIGRANTS IN THE SONORAN DESERT

Paul C. Hardy[1], David J. Griffin[2], Amy J. Kuenzi[3], and Michael L. Morrison[4]

ABSTRACT.—Little is known about stopover habitat use by neotropical migratory birds in the deserts of North America. We determined distribution, abundance, and habitat associations of neotropical migrants during spring migration in the Sonoran Desert of southwestern Arizona along large washes that supported xeroriparian scrub vegetation. We detected 91 bird species during surveys, 50 (52%) of which were passage neotropical migrants. Although xeroriparian scrub covered less than 55% of the area surveyed, 97% of all detections of passage migrants were from this vegetation type. By calculating habitat breadth for each species, we classified 87% of passage migrants as xeroriparian specialists. Richness of passage migrants was strongly associated with the presence of overstory (>2.5 m) mesquite and paloverde. The highest species richness of breeding neotropical migrants was associated with width of the xeroriparian corridor. Habitat characteristics we have shown to be important to neotropical migrants can be preserved and managed by protecting xeroriparian areas, particularly those supporting mature (>2.5 m) paloverde, mesquite, desert willow, and catclaw acacia trees. Additionally, xeroriparian scrub within the creosote-bursage vegetation type may be particularly important to passage neotropical migrants.

Key words: bird abundance, desert, habitat use, migration, Southwest, xeroriparian.

Neotropical migrants generally do not store enough lipids to fly nonstop between wintering and breeding areas (Blem 1980, Moore et al. 1995). Consequently, suitable stopover habitat that enables passage migrants to replenish lipid deposits, repay oxygen debt, and repair damaged tissues is critical to successful migration (Moore et al. 1993, Skagen et al. 1998). Spring migrants unable to restore lipids or repair damaged tissues rapidly could arrive late on the breeding grounds, potentially losing territories and mates; those unable to properly recover may be exposed to increased predation and encounter higher mortality en route (Moore et al. 1993).

Little is known about the ecology of western neotropical migrants in general and neotropical migrants of the southwestern deserts in particular (Rosenberg et al. 1991, Moore et al. 1995). In the southwestern U.S., over 60% of neotropical migrants are known to use mesic riparian areas for stopovers or for breeding (Krueper 1993). Mesic riparian areas of the Southwest provide cover, food, and water in regions where these critical elements are scarce (Wauer 1977, Gori 1992, Skagen et al.

1998). Most avian studies conducted in xeroriparian zones (i.e., arroyos or "washes" rarely receiving surface flow) of the Southwest have focused on breeding birds and have not addressed the ecology of passage migrants (Hensley 1954, Raitt and Maze 1968, Austin 1970, Vander Wall and MacMahon 1984, Parker 1986). In their study of vertebrate use of 2 water developments in southwestern Arizona, Cutler (1996) and Cutler and Morrison (1998) reported on the habitat use of 22 species of birds, 8 of which were neotropical migrants.

In the Sonoran Desert large xeroriparian zones with dense growths of shrubs and trees provide feeding areas for many insectivorous bird species and may also be used as travel and migration corridors (Hensley 1954, Rosenberg et al. 1991). We studied stopover habitat use by neotropical migrants in the Sonoran Desert of southwestern Arizona to (1) determine the distribution, abundance, and habitat associations of passage neotropical migrants using xeroriparian washes; and (2) develop management recommendations for conserving and monitoring passage neotropical migrants.

[1]Feather River Land Trust, Box 1826, Quincy, CA 95971.
[2]San Diego National Wildlife Refuge, U.S. Fish and Wildlife Service, 13910 Lyons Valley Road, Suite R, Jamul, CA 91935.
[3]Biology Department, Montana Tech, Butte, MT 59701.
[4]Corresponding author. White Mountain Research Station, University of California, 3000 East Line St., Bishop, CA 93514.

STUDY AREA

We conducted our study in the Sauceda Mountains of southwestern Arizona, on the Barry M. Goldwater Air Force Range (BMGR), Maricopa County, Arizona. The BMGR contains some of the largest undeveloped Sonoran Desert in North America and is crossed by many large, dry washes, which support xeroriparian scrub vegetation. The climate of our study area is typical of the Sonoran Desert and is characterized by high summer temperatures (mean 38°C), warm winter temperatures (mean 11°C), and low rainfall (Sellers et al. 1985). The rainfall pattern is bimodal and averages 225 mm per year at Ajo, Arizona, 30 km from the study area. Precipitation occurs as rain mostly in July, August, and September during short, intense thunderstorms and also falls as prolonged, soaking showers from December through March. No permanent water occurred on our study area.

The study area ranges in elevation from 375 m to 620 m and contains vegetation from both the Lower Colorado River Valley and Arizona Upland subdivisions of Sonoran Desert scrub (Turner and Brown 1994). Typical vegetation of the study area includes creosotebush (*Larrea tridentata*), bursage (*Ambrosia dumosa* and *A. deltoidea*), paloverde (*Cercidium microphyllum* and *C. floridum*), saguaro (*Carnegiea gigantea*), and cholla cactus (*Opuntia* spp.; Turner and Brown 1994). Large associations of xeroriparian scrub occur along washes within the study area and are dominated by paloverde, ironwood (*Olneya tesota*), mesquite (*Prosopis velutina*), catclaw acacia (*Acacia greggii*), desert willow (*Chilopsis linearis*), desert hackberry (*Celtis pallida*), and burro-bush (*Hymenoclea monogyra;* Turner and Brown 1994).

METHODS

Point Counts

We surveyed neotropical migratory birds at 3 study sites using point counts (Verner 1985, Ralph et al. 1993). We placed 3 transects in large washes that were bordered by xeroriparian scrub and were readily accessible. One transect was located at lower elevations (~380 m) in the creosote-bursage vegetation type, whereas the other 2 were located at slightly higher elevations (i.e., ~460 m and ~620 m) in areas ecotonal between the creosote-bursage and mixed-cacti vegetation types. Each transect was 3 km long and had 10 count stations spaced at 300-m intervals, for a total of 30 stations.

We collected data at each station during 3-day sampling periods, spaced 10–14 days apart, between late February and early June 1994 through 1996. This interval encompassed the spring migration period. We counted birds at each station for 5 minutes and conducted all surveys within 4 hours after sunrise. We alternated starting points along transects to avoid a temporal bias between visits. We recorded all species of birds seen or heard, means of detection (auditory, visual, or both), estimated distance from observer (0–25 m, 25–50 m, 50–100 m, 100–150 m, 150–200 m, or >200 m), location of bird (paloverde, mesquite, snag; floristic/substrate model, see below), activity of bird (nesting, feeding, resting), number of individuals observed, and general vegetation type in which the bird was observed (xeroriparian scrub, creosote-bursage, mixed-cacti, or rocks/cliffs). We assigned vegetation types by visually determining the dominant vegetative characteristics of the area. The dry xeroriparian scrub vegetation type was dominated by tall (>2 m), dense vegetation bordering washes. The creosote-bursage vegetation type was dominated by creosotebush and bursage. The mixed-cacti vegetation type was dominated by yellow paloverde (*C. microphyllum*), saguaro, and various small shrubs and cacti; this vegetation type generally occurred in areas with greater slopes than the xeroriparian scrub and creosote-bursage vegetation types. The rocks/cliffs vegetation type consisted of areas that were bare rock or steep-sloped cliffs or both.

Vegetation Sampling

We sampled vegetation and substrate along 100-m vegetation transects that radiated from each count station using an adaptation of the point-intercept method (Karr 1968). The direction of the first transect was chosen randomly and remaining transect directions were placed at compass increments of 45°, for a total of 8 transects radiating from each count station. We located sampling points every 5 m along each vegetation transect, for a total of 160 points per count station.

At each vegetation sampling point, we visually assigned vegetation type along the transect according to general vegetation characteristics into 1 of 4 categories: (1) xeroriparian scrub,

(2) mixed-cacti, (3) creosote-bursage, or (4) rocks/cliffs. For each count station, we calculated percent cover of each vegetation type as the frequency of each vegetation type divided by the total number of sampling points (see below vegetation type model).

At each vegetation sampling point, we also recorded the presence of plant species in each of 5 height categories: (1) 0.0–0.1 m (ground level), (2) >0.1–1.0 m (understory), (3) >1.0–2.5 m (mid-canopy), (4) >2.5–6.0 m (overstory), and (5) >6.0 m (tall overstory). We calculated percent cover by height category for each dominant plant species by dividing the frequency of occurrence of live foliage for each height interval by the total number of sampling points. We also calculated percent cover of perennial vegetation by height category, as well as the total cover of perennial vegetation (see below perennial vegetation model).

Analyses

Following Gauthreaux (1992), we classified each species detected during point counts as 1 of 2 types of neotropical migrants, or as nonmigratory. List A neotropical migrants included those species that breed in North America and spend their entire nonbreeding season primarily south of the U.S. List B neotropical migrants included those species that breed and winter extensively in North America but also have populations that winter south of the U.S. All other species were classified as nonmigratory. Based on literature review and personal observation, we further classified neotropical migrants as passage or nonpassage. Species classified as passage migrants were not present during the 1st sampling period each year, seldom sang, and did not persist in the study area for extended periods (present ≤4 weeks). These species were usually detected individually or in small (<10 individuals) mixed- or single-species flocks. The analyses described below are for passage neotropical migrant species only.

We calculated indices of passage migrant abundance (number of individuals detected per number of surveys) for each count station. We calculated these indices for each year of survey data and for the pooled data set (1994–1996 combined). We calculated species richness (total number of passage migrant species detected) at each count station for each year separately and for the pooled data set (1994–

1996). Only detections <150 m from a counting point were used in calculations to lessen double-counting of individuals; all observations were used to determine species richness.

We used multiple regression analysis (Zar 1996) to determine which combination of vegetation and substrate variables best predicted the abundance and richness of passage migrants. We used pooled indices of abundance and pooled richness (1994–1996) as response variables.

The scale at which variables are measured influences the explanatory power of models to predict bird-habitat relationships (Morrison et al. 1998). Consequently, for each response variable we built 3 separate multiple regression models using explanatory variables from different scales: a cover type model, a perennial vegetation model (plant species not taken into account), and a floristic/substrate model (cover of plant species and substrate).

We used stepwise selection procedures to build all multiple regression models. Prior to building the microhabitat models, we reduced the data set by eliminating all variables for which the frequency of occurrence was small (≤5 cases per variable) and then tested all variables for multicolinearity (Pearson r). We retained 1 member of each highly intercorrelated pair ($r \geq 0.7$) judged to be more biologically significant and easiest to measure (Norusis 1990). To control for potential differences between transects, an indicator variable for transect and all 2-way interaction terms involving transect were also considered for entry into all models (Belsley et al. 1980). We used a P-value of 0.25 to determine which variables entered into the model and a P-value of 0.10 to determine which variables were removed (Belsley et al. 1980). For all MR models, we evaluated the assumptions of linearity and homogeneity of variances by examining scatterplots of standardized residuals, and the assumption of normality of residuals by examining a histogram of residuals (Belsley et al. 1980). When necessary, we used log, square root, and arcsine transformations (Norusis 1990) to meet these assumptions.

We used Levins' (1968) measure of habitat breadth to classify passage migrants by degree of specialization. We first controlled for differences in the availability of vegetation types by weighting (dividing) the number of birds detected in a given vegetation type by the proportion of each vegetation type along transects.

This generated a distribution of detections for each species that would be expected if survey effort were equal among vegetation types. A species with a proportion of detections across the 4 vegetation types that matched the availability of vegetation types had the broadest possible habitat breadth (B = 4.0), whereas a species restricted to any 1 of the 4 vegetation types had the narrowest possible habitat breadth (B = 1.0).

We used goodness-of-fit *G*-tests (Zar 1996) to determine if passage migrants used microphyllous tree species (i.e., catclaw acacia, desert willow, ironwood, mesquite, and paloverde) out of proportion to their availability. We measured availability as the percent cover of each tree species relative to the total percent cover of all tree species, and considered locations of individual birds to be the sample units. When significant differences were indicated, we used Bailey's simultaneous confidence intervals (Cherry 1996) to identify which tree species were used disproportionately.

A level of significance of α = 0.10 was used for all statistical analyses. We used α = 0.10 instead of α = 0.05 to improve the power of our tests (Eberhardt and Thomas 1991). We used program SPSS/PC+ v5.0.1 (SPSS, Inc. 1992) to perform all statistical analyses.

Results

Point Counts

We detected 91 species during point counts on the transects. Forty-six species (50.5%) were classified as list A neotropical migrants, 28 species (30.8%) as list B neotropical migrants, and 17 (18.7%) as nonmigrants (Table 1). Fifty (57%) neotropical migrants were further classified as passage migrants (Table 2).

Habitat Associations

SPECIES RICHNESS.—The vegetation type model to predict passage migrant richness was weak (R^2_{adj} = 0.250, *P* = 0.005), although increasing species richness was significantly associated with increasing cover of xeroriparian scrub vegetation.

The perennial vegetation model to predict species richness was moderately strong (R^2_{adj} = 0.351, *P* = 0.001) and included variables for overstory perennial vegetation and ground cover of perennial vegetation. Increasing species richness was significantly associated with increasing cover of overstory perennial vegetation and with decreasing ground cover of perennial vegetation.

The floristic/substrate model to predict species richness was moderately strong (R^2_{adj} = 0.583, *P* < 0.001) and included variables for overstory mesquite, overstory desert willow, rock, and vegetative litter. Increasing species richness was significantly associated with increasing cover of overstory mesquite and desert willow and with decreasing cover of rock and litter.

INDICES OF ABUNDANCE.—The vegetation type model explained a substantial amount of variation in passage migrant abundance (R^2_{adj} = 0.62, *P* < 0.001). After controlling for differences in cover of vegetation types among transects, we noted that increasing abundance of passage migrants was significantly associated with decreasing cover of the creosote-bursage vegetation type.

The perennial vegetation MR model explained a moderate amount of variation in passage migrant abundance (R^2_{adj} = 0.32, *P* < 0.001). Species abundance significantly increased with increasing cover of overstory perennial vegetation.

The floristic/substrate model explained a substantial amount of variation in passage migrant abundance (R^2_{adj} = 0.61, *P* < 0.001) and contained variables for overstory mesquite and rock. Increasing abundance of passage migrants was significantly associated with increasing cover of overstory mesquite and with decreasing cover of rock.

HABITAT BREADTH.—Eighty-seven percent of passage migrants (39 of 45; aerial detections >20 m high not included) were classified as xeroriparian scrub specialists (Table 2). Black-chinned Hummingbird, Gray Flycatcher, and Western Kingbird used both xeroriparian scrub and creosote-bursage vegetation types. Townsend's Warbler and Lesser Goldfinch, although occurring primarily in xeroriparian scrub, also used creosote-bursage and mixed-cacti. Bullock's Oriole was unique in roughly dividing use between xeroriparian scrub and mixed-cacti.

USE OF TREE SPECIES.—Passage migrants (all species combined) used tree species out of proportion to their availability (χ^2 = 38.02, 4 df, *P* < 0.0001); desert willow trees were used (13.1% use) more than expected (6.1% availability), and catclaw acacia trees were used

(22.8%) less then expected (31.6%). Paloverde (~23% overall detections for all species), mesquite (~17%), and catclaw acacia (~15%) were the dominant or co-dominant plant species used by the migrants analyzed (Table 1). Although of relatively moderate use overall, flowers of desert willow were used extensively by all hummingbirds except the Black-chinned, which concentrated in saguaro. Most relatively abundant (i.e., >25 detections) species, however, used a wide variety of plant species (Table 1).

DISCUSSION

The variety of neotropical migrants using the xeroriparian scrub vegetation type demonstrates its importance to these birds on our study area. Eighty-seven percent of passage neotropical migrants were classified as xeroriparian scrub specialists. Indeed, most (>90%) detections of passage migrants were from the xeroriparian scrub vegetation type. Passage migrant richness increased as the amount of xeroriparian scrub cover increased. These findings agree with studies of avian use of mesic riparian areas in the desert Southwest. Johnson et al. (1977) found that of 77 total breeding neotropical migrants in the Southwest, 58 (75.3%) were obligate or preferential riparian species. Stevens et al. (1977) found that 10.6 times the number of passage neotropical migrants per hectare were found on riparian plots than on adjacent, nonriparian plots. Ohmart and Anderson (1982) reported that of 308 avian species regularly occurring in the Sonoran Desert, 56 (18%) were obligate riparian, 197 (65%) were facultative riparian, and 55 (18%) were nonriparian species. At mesic riparian sites in southeastern Arizona, Skagen et al. (1998) reported greater passage migrant species richness at isolated oases than at larger, continuous riparian corridors. However, because of different mechanisms of migration between species and the fact that riparian vegetation is naturally disjunct in the Southwest, Skagen et al. (1998) stressed the importance of both types of riparian vegetation to migrating passerines. Xeroriparian scrub areas are important to avian species and with the widespread destruction and desertification of mesic riparian areas in the arid Southwest continuing at rapid rates (Rea 1983, Krueper 1993), preservation and enhancement of xeroriparian scrub areas may become increasingly important to both breeding and passage neotropical migrants.

Presence and Richness of Bird Species

The pooled richness (all 3 years combined) of spring passage migrants was considerably greater than that found in spring by Hensley (21 species [1954]) or Vander Wall (29 species [1980]) at Organ Pipe Cactus National Monument (OPCNM), approximately 50 km south of our study area. This disparity occurred despite the fact that both studies on OPCNM encompassed the entire spring migration period and included surveys within xeroriparian scrub areas (Vander Wall's study areas were on bajadas or slopes, but included smaller washes). Differences may be due, in part, to the longer duration (3 years instead of 2) and more intensive effort of our study. Cutler (1996) and Cutler and Morrison (1998), whose study was conducted during the same years as ours, reported similar richness (approximately 54 of 130 total species) for passage migrants not including species associated with free-standing water at water-development sites with extensive mesquite bosques (woodlands) on the Cabeza Prieta National Wildlife Refuge (CPNWR) approximately 55 km southwest of our study area. However, only 2 species of passage neotropical migrants (Wilson's Warbler and Yellow-rumped Warbler) could be categorized as "xeroriparian specialists." This difference in species richness between their study and ours is likely due to the fact that Cutler and Morrison (1998) conducted surveys throughout the year. Passage migrants not observed by either Hensley or Vander Wall, but observed by us, were Black Swift, Vaux's Swift, Black-chinned Hummingbird, Calliope Hummingbird, Western Wood-Pewee, Willow Flycatcher, Hammond's Flycatcher, Dusky Flycatcher, Vermilion Flycatcher, Tree Swallow, Cliff Swallow, Swainson's Thrush, Gray Vireo, Solitary Vireo, Virginia's Warbler, Common Yellowthroat, Spotted Towhee, Lincoln's Sparrow, Yellow-headed Blackbird, and American Goldfinch. Cutler (1996) and Cutler and Morrison (1998) did not observe Black Swift, Calliope Hummingbird, Gray Vireo, Virginia's Warbler, or Spotted Towhee. All of these species were uncommon migrants during our study. The fact that these birds were not observed during previous studies at OPCNM and CPNWR, south of our

TABLE 1. Percent of detections[a] by plant species and substrate type, Barry M. Goldwater Range, 1994–1996. Migratory status[b] is indicated (Gauthreaux 1992). Passage migrants are indicated with an asterisk.

Species	LOC1(%)[c]	LOC2(%)[d]	LOC3(%)[e]	Detections
LIST A NEOTROPICAL MIGRANTS				
White-winged Dove	SA(49.5)	PV(20.9)	IW(12.1)	91
Zenaida asiatica				
Black-chinned Hummingbird*	SA(66.7)	CP(33.3)	—	3
Archilochus alexandri				
Costa's Hummingbird	DW(38.9)	MQ(14.4)	PV(12.2)	90
Calypte costae				
Calliope Hummingbird*	DW(100.0)	—	—	2
Stellula calliope				
Allen's Hummingbird*	DW(100.0)	—	—	2
Selasphorus sasin				
Olive-sided Flycatcher*	DW(100.0)	—	—	1
Contopus cooperi				
Western Wood-Pewee*	CC,IW,MQ(33.3)	—	—	3
C. sordidulus				
Willow Flycatcher*	PV(66.7)	MQ(33.3)	—	3
Empidonax traillii				
Hammond's Flycatcher*	CC(50.0)	CR,MQ(25.0)	—	4
E. hammondii				
Dusky Flycatcher*	CC,DW(50.0)	—	—	2
E. oberholseri				
Gray Flycatcher*	PV(40.0)	CC,DW,MQ(20.0)	—	5
E. wrightii				
Western Flycatcher Complex[f]*	MQ(40.5)	CC(23.8)	PV(21.4)	42
Empidonax spp.				
Vermilion Flycatcher	MQ,PV(50.0)	—	—	2
Pyrocephalus rubinus				
Ash-throated Flycatcher	PV(39.6)	IW(19.8)	MQ(15.3)	111
Myiarchus cinerascens				
Brown-crested Flycatcher	CR,DW,IW,MQ(17.8)	—	—	28
M. tyrannulus				
Western Kingbird*	DW,MQ,PV(33.3)	—	—	3
Tyrannus verticalis				
House Wren*	CC(60.0)	DW,MQ(20.0)	—	5
Troglodytes aedon				
Phainopepla	MQ(35.3)	PV(27.1)	CC(18.2)	170
Phainopepla nitens				
Bell's Vireo	DW(46.1)	MQ(23.1)	PV(15.4)	13
Vireo bellii				
Gray Vireo*	PV(100.0)	—	—	1
V. vicinior				
Solitary Vireo Complex[g]*	CC,IW,MQ,PV(25.0)	—	—	4
V. solitarius				
Warbling Vireo*	PV(37.5)	CC(25.0)	CR,DW,MQ(12.5)	8
V. gilvus				
Orange-crowned Warbler*	MQ(41.2)	CC(26.5)	PV(20.6)	34
Vermivora celata				
Nashville Warbler*	MQ(54.5)	PV(36.4)	IW(9.1)	11
V. ruficapilla				
Lucy's Warbler*	MQ(31.3)	PV(28.1)	IW(21.1)	128
V. luciae				
Yellow Warbler*	PV(30.8)	CC,DW,IW,MQ(15.4)	—	13
Dendroica petechia				
Black-throated Gray Warbler*	PV(35.7)	CC,IW(21.4)	—	14
D. nigrescens				
Townsend's Warbler*	MQ(36.7)	CC(23.3)	PV(20.0)	30
D. townsendi				
Hermit Warbler*	CC,IW,PV(33.3)	—	—	3
D. occidentalis				

TABLE 1. Continued.

Species	LOC1(%)[c]	LOC2(%)[d]	LOC3(%)[e]	Detections
MacGillivray's Warbler* *Oporornis tolmiei*	CC,GR,MQ,PV(33.3)	—	—	4
Common Yellowthroat* *Geothlypis trichas*	CC,PV(50.0)	—	—	2
Wilson's Warbler* *Wilsonia pusilla*	CC(24.2)	MQ(23.2)	DW(19.0)	95
Western Tanager* *Piranga ludoviciana*	IW(44.4)	DW(33.3)	CC,MQ(11.1)	9
Black-headed Grosbeak* *Pheucticus melanocephalus*	PV(28.6)	DW,IW(21.4)	—	14
Lazuli Bunting* *Passerina amoena*	CC,DH,MQ,PV(25.0)	—	—	4
Varied Bunting *P. versicolor*	CC,DW(33.3)	MQ,WB(16.7)	—	6
Green-tailed Towhee* *Pipilo chlorurus*	GR(44.4)	CC,MQ(22.2)	—	9
Chipping Sparrow *Spizella passerina*	GR(38.5)	CC,IW,MQ(15.4)	—	13
Brewer's Sparrow *S. breweri*	GR(52.6)	CR(15.8)	PV(10.5)	19
Lark Sparrow* *Chondestes grammacus*	GR,PV(50.0)	—	—	2
Lark Bunting *Calamospiza melanocorys*	CC(100.0)	—	—	1
Lincoln's Sparrow* *Melospiza lincolnii*	CR(100.0)	—	—	1
Yellow-headed Blackbird* *Xanthocephalus xanthocephalus*	IW(100.0)	—	—	1
Hooded Oriole *Icterus cucullatus*	PV(59.6)	SA(12.3)	IW(10.5)	57
Bullock's Oriole* *I. bullockii*	IW(40.0)	OC,PV,SN(20.0)	—	5
Scott's Oriole *I. parisorum*	SA(54.5)	PV(25.0)	IW(9.1)	44
LIST B NEOTROPICAL MIGRANTS				
Turkey Vulture *Cathartes aura*	IW(34.2)	MQ,PV(21.1)	—	38
Sharp-shinned Hawk* *Accipiter striatus*	CR(100.0)	—	—	1
Cooper's Hawk* *A. cooperii*	PV(50.0)	MQ,SN(25.0)	—	4
Red-tailed Hawk *Buteo jamaicensis*	SA(50.0)	RO(28.6)	GR(14.3)	14
American Kestrel *Falco sparverius*	SA(87.5)	PV(8.3)	RO(4.2)	24
Prairie Falcon *F. mexicanus*	SA(100.0)	—	—	1
Mourning Dove *Zenaida macroura*	PV(31.7)	GR,MQ(19.5)	—	41
Anna's Hummingbird* *Calypte anna*	CC,DW(50.0)	—	—	2
Say's Phoebe *Sayornis saya*	CR(50.0)	MQ,PV(25.0)	—	4
Rock Wren *Salpinctes obsoletus*	GR(53.6)	RO(35.7)	CR,IW,PV(3.6)	28
Bewick's Wren* *Thryomanes bewickii*	MQ(50.0)	CC,GR(25.0)	—	4
Winter Wren *Troglodytes troglodytes*	SH(100.0)	—	—	1

TABLE 1. Continued.

Species	LOC1(%)[c]	LOC2(%)[d]	LOC3(%)[e]	Detections
Ruby-crowned Kinglet* *Regulus calendula*	PV(35.3)	CC(23.5)	MQ(17.6)	17
Hermit Thrush* *Catharus guttatus*	PV(100.0)	—	—	2
American Robin *Turdus migratorius*	MQ,CC(40.0)	CR(20.0)	—	5
Northern Mockingbird *Mimus polyglottos*	MQ(30.7)	PV(20.4)	SA(19.3)	88
Sage Thrasher *Oreoscoptes montanus*	CC,CR,DW,MQ(25.0)	—	—	4
Bendire's Thrasher *Toxostoma bendirei*	IW,PV,SA(33.3)	—	—	3
Loggerhead Shrike *Lanius ludovicianus*	SA(38.9)	MQ,PV(16.7)	—	36
Yellow-rumped Warbler* *Dendroica coronata*	PV(46.7)	MQ(33.3)	CC,GR,IW(6.7)	15
Spotted Towhee* *Pipilo maculatus*	CC,GR(50.0)	—	—	2
Vesper Sparrow *Pooecetes gramineus*	CH,PV(50.0)	—	—	2
Black-throated Sparrow *Amphispiza bilineata*	GR(41.7)	CR(29.8)	PV(9.5)	84
White-crowned Sparrow *Zonotrichia leucophrys*	GR(50.0)	MQ(15.9)	IW(11.4)	44
Dark-eyed Junco* *Junco hyemalis*	DW,GR(50.0)	—	—	2
Brown-headed Cowbird *Molothrus ater*	PV(39.1)	CC(21.7)	SA(17.4)	23
Lesser Goldfinch* *Carduelis psaltria*	MQ(41.7)	CC,DW,IW(1.7)	—	12
American Goldfinch* *C. tristis*	CR(100.0)	—	—	1

NONMIGRANTS

Species	LOC1(%)[c]	LOC2(%)[d]	LOC3(%)[e]	Detections
Harris' Hawk *Parabuteo unicinctus*	PV,SA(44.4)	MQ(11.1)	—	9
Gambel's Quail *Callipepla gambelii*	GR(80.2)	MQ,SA(5.0)	—	121
Greater Roadrunner *Geococcyx californianus*	GR(88.9)	RO(11.1)	—	9
Gila Woodpecker *Melanerpes uropygialis*	SA(51.2)	PV(17.8)	MQ(16.3)	129
Gilded Flicker *Colaptes chrysoides*	SA(76.9)	IW(6.7)	PV,SN(3.8)	104
Ladder-backed Woodpecker *Picoides scalaris*	MQ(35.5)	SA(22.6)	PV(16.1)	31
Common Raven *Corvus corax*	RO(50.0)	IW,SA(25.0)	—	4
Verdin *Auriparus flaviceps*	PV(41.9)	MQ(18.1)	IW(13.2)	265
Cactus Wren *Campylorhynchus brunneicapillus*	SA(34.6)	PV(14.1)	CC(10.3)	78
Canyon Wren *Catherpes mexicanus*	RO(66.7)	GR(33.3)	—	12
Black-tailed Gnatcatcher *Polioptila melanura*	PV(30.8)	MQ(17.9)	IW(17.3)	156
Curve-billed Thrasher *Toxostoma curvirostre*	SA(25.0)	MQ(19.7)	PV(11.8)	76
Crissal Thrasher *T. crissale*	GR(57.1)	MQ(28.6)	DW,PV(14.3)	7

TABLE 1. Continued.

Species	LOC1(%)[c]	LOC2(%)[d]	LOC3(%)[e]	Detections
Northern Cardinal	MQ(26.8)	PV(22.0)	CC,DW(17.1)	41
Cardinalis cardinalis				
Pyrrhuloxia	CC(33.3)	PV(18.2)	MQ(15.2)	33
C. sinuatus				
Canyon Towhee	GR(33.9)	CC(21.0)	PV(14.5)	62
Pipilo fuscus				
House Finch	SA(46.2)	PV(15.4)	IW(12.8)	39
Carpodacus mexicanus				

[a]Groups of individuals of the same species counted as $n = 1$ detection. Detections of high-flying individuals (>20 m) and nocturnal species are not included in Table 1.
[b]List A contains species that breed in North America and spend their nonbreeding season primarily south of the U.S. This list contains species generally recognized as neotropical migrants. List B is composed of species that breed and winter extensively in North America, although some populations winter south of the U.S. (adapted from Gauthreaux 1992).
[c]Dominant plant species or substrate in which species was most frequently observed: CC = catclaw acacia, CP = chuparosa, CR = creosote, DW = desert willow, GR = ground, IW = ironwood, MQ = mesquite, OC = ocotillo, PV = paloverde spp., RO = rock, SA = saguaro, SH = unknown shrub spp., SN = snag, WB = wolfberry (*Lycium* spp.).
[d]Co-dominant plant species or substrate in which species was frequently observed.
[e]Co-dominant plant species or substrate in which species was frequently observed.
[f]Includes Pacific-slope (*Empidonax difficilis*) and Cordilleran (*E. occidentalis*) Flycatchers; all individuals of known identity were Pacific-slope Flycatchers.
[g]Includes Plumbeous Vireo (*Vireo plumbeus*) and Cassin's Vireo (*Vireo cassinii*).

study area, suggests that they are uncommon migrants through the region as well.

Indices of Abundance

For the pooled data set, the most abundant spring passage migrants, in descending order, were Wilson's Warbler, Western Flycatcher, Orange-crowned Warbler, and Townsend's Warbler. Phillips et al. (1964) reported each of these species to be common spring migrants in the Sonoran Desert of southwestern Arizona. All 4 species were commonly observed in spring at OPCNM by Hensley (1954) and Vander Wall (1980), and at CPNWR by Cutler (1996).

Habitat Associations

High passage migrant richness was strongly associated with tall (mid-canopy and overstory) height classes of catclaw acacia, mesquite, and paloverde. Given this result, it is not surprising that the presence of several passage migrant species was also associated with tall height classes of mesquite (MacGillivray's Warbler, Orange-crowned Warbler, Ruby-crowned Kinglet, Western Flycatcher, Wilson's Warbler, and Yellow-rumped Warbler), and tall height classes of paloverde (Black-throated Gray Warbler, Lazuli Bunting, Sharp-shinned Hawk, and Western Flycatcher). In addition, passage migrants often selected areas with dense cover of tall mesquite. Passage migrants present at count stations with significantly

greater cover of tall mesquite than was available overall included MacGillivray's, Nashville, Orange-crowned, and Wilson's Warblers, and Western Flycatcher.

Mesquite bosques in the southwestern deserts have been shown to produce an abundance of arthropods and to receive heavy use by insectivorous passage and breeding migrants (Ohmart and Anderson 1982, Rosenberg et al. 1991, Cutler and Morrison 1998). On a per-tree basis, mesquite provides one of the richest pollen and nectar sources in the Sonoran Desert (Ohmart and Anderson 1982). Simpson et al. (1977) reported that mesquite produces more pollen per floral unit than any other insect-pollinated desert tree in North America. A large number of insects use this rich food resource while it is available (Simpson et al. 1977). On our study area the flowering of mesquite coincided with spring migration during all 3 years of our study (personal observation).

Passage migrants as a group (all species combined) used catclaw acacia significantly less than expected. However, when we examined the percent of detections by location, we saw that 23% of all detections of passage migrants were from catclaw acacia, and that approximately 22% of all detections of breeding neotropical migrants were from catclaw. In 1995 and 1996 the flowering cycle of catclaw coincided with the period of heaviest migration (mid-April through mid-May; personal

TABLE 2. Habitat distributions of passage neotropical migrant landbirds on the Barry M. Goldwater Range, Arizona, 1994–1996. Numbers represent the percentage of detections[a] within each vegetation type weighted by the estimated availability of each vegetation type in the study area. Species were classified as single vegetation type specialists if their habitat breadth was ≤1.3, two-vegetation type specialists if between 1.3 and 2.3, and broad generalists if ≥2.3. Migratory status[b] is indicated (Gauthreaux 1992).

Species	(N)	Vegetation Type[c]			Breadth[d]
		XR	CB	MC	
A. XERORIPARIAN SPECIALISTS					
List A Migrants					
Calliope Hummingbird	2	100.0	—	—	1.00
Allen's Hummingbird	2	100.0	—	—	1.00
Olive-sided Flycatcher	1	100.0	—	—	1.00
Western Wood-Pewee	5	100.0	—	—	1.00
Willow Flycatcher	3	100.0	—	—	1.00
Hammond's Flycatcher	4	100.0	—	—	1.00
Dusky Flycatcher	3	100.0	—	—	1.00
Western Flycatcher[e]	61	95.9	4.1	—	1.09
House Wren	5	100.0	—	—	1.00
Blue-gray Gnatcatcher	1	100.0	—	—	1.00
Gray Vireo	2	100.0	—	—	1.00
Solitary Vireo[f]	4	100.0	—	—	1.00
Warbling Vireo	8	100.0	—	—	1.00
Orange-crowned Warbler	40	100.0	—	—	1.00
Nashville Warbler	13	100.0	—	—	1.00
Yellow Warbler	17	86.2	—	13.8	1.30
Black-throated Gray Warbler	14	100.0	—	—	1.00
Hermit Warbler	3	100.0	—	—	1.00
MacGillivray's Warbler	10	100.0	—	—	1.00
Common Yellowthroat	4	100.0	—	—	1.00
Wilson's Warbler	118	93.7	—	6.3	1.13
List A Migrants					
Western Tanager	11	100.0	—	—	1.00
Black-headed Grosbeak	17	100.0	—	—	1.00
Lazuli Bunting	4	100.0	—	—	1.00
Green-tailed Towhee	16	100.0	—	—	1.00
Lark Sparrow	2	100.0	—	—	1.00
Lincoln's Sparrow	1	100.0	—	—	1.00
Yellow-headed Blackbird	2	100.0	—	—	1.00

observation). The large, aromatic flowers of catclaw attract an abundance of pollinating insects (Ohmart and Anderson 1982). Indeed, over 90% of the individual birds detected in catclaw were observed foraging (unpublished data), suggesting that catclaw is an important feeding site for many species of neotropical migrants. This apparent contradiction between observed/actual use and reported results may be due to the growth form of catclaw, which tends to grow very thickly throughout its height, often forming an impenetrable mass of branches. This growth form contrasts with the more open growth form of mesquite and paloverde. The point-intercept method we used to determine percent cover tends to seldom miss catclaw acacia due to its thickness, but may often miss mesquite and paloverde because of their open growth forms. Although percent cover of a plant species is often used to approximate its availability in habitat selection studies, for species like catclaw acacia, it may be a poor approximation. The interior of catclaw may be so thick that it is unavailable to some species of birds, or more likely it may obscure the observer's view, making a bird less detectable. Thus, less of the tree is actually available than that estimated by percent cover.

Costa's Hummingbird, the only breeding neotropical migrant hummingbird on our study area, and 3 species of passage migrant hummingbirds (Calliope, Allen's, and Rufous), were detected from desert willow trees more than any other plant species (Table 1). Male Costa's

TABLE 2. Continued.

Species	(N)	Vegetation Type[c]			Breadth[d]
		XR	CB	MC	
List B Migrants					
Northern Harrier	1	100.0	—	—	1.00
Sharp-shinned Hawk	4	100.0	—	—	1.00
Cooper's Hawk	7	100.0	—	—	1.00
Anna's Hummingbird	2	100.0	—	—	1.00
Bewick's Wren	4	100.0	—	—	1.00
Ruby-crowned Kinglet	23	89.6	—	10.4	1.23
Hermit Thrush	2	100.0	—	—	1.00
Yellow-rumped Warbler	19	100.0	—	—	1.00
Spotted Towhee	3	100.0	—	—	1.00
Dark-eyed Junco	2	100.0	—	—	1.00
American Goldfinch	2	100.0	—	—	1.00
B. TWO-VEGETATION TYPE (XERORIPARIAN SCRUB AND CREOSOTE-BURSAGE) GENERALISTS					
List A Migrants					
Black-chinned Hummingbird	6	57.1	42.9	—	1.96
Gray Flycatcher	6	57.1	42.9	—	1.96
Western Kingbird	7	61.6	38.4	—	1.90
Townsend's Warbler	36	84.4	9.3	6.3	1.38
List B Migrants					
Lesser Goldfinch	23	77.0	13.7	9.3	1.61
C. TWO-VEGETATION TYPE (MIXED-CACTI AND XERORIPARIAN SCRUB) GENERALISTS					
List A Migrants					
Bullock's Oriole	9	43.7	—	56.3	1.97

[a] Groups of individuals of the same species counted as $n = 1$ detection. Detections of high-flying individuals (>20 m) and nocturnal species not included in Table 2.

[b] List A contains species that breed in North America and spend their nonbreeding season primarily south of the U.S. This list contains species generally recognized as neotropical migrants. List B is composed of species that breed and winter extensively in North America, although some populations winter south of the U.S. (adapted from Gauthreaux 1992). Vaux's Swift, and Tree, Violet-green, Northern Rough-winged, and Cliff Swallow were not included because of their aerial behavior (could not assign to a vegetation type).

[c] Vegetation type: XR = xeroriparian scrub, CB = creosote-bursage, and MC = mixed-cacti; no use of rocks or cliffs was observed (and is not included in the table).

[d] Habitat breadth = $1/\Sigma p_i^2$, where p_i = proportion of weighted detections in vegetation type i.

[e] Includes Pacific-Slope and Cordilleran Flycatchers; all individuals of known identity were Pacific-slope Flycatchers.

[f] Includes Plumbeous and Cassin's Vireos.

Hummingbirds most frequently sang from this tree species (unpublished data). Desert willow trees occurred primarily along 1 transect and were in bloom during the time spring passage migrant hummingbirds were observed (personal observation). Desert willow flowers are a major source of nectar for hummingbird species in the Sonoran Desert (Calder 1993, 1994), and the abundance of desert willow trees along 1 transect may help explain why 14 of 19 observations of passage migrant hummingbirds occurred in this area.

Ironwood was important as a foraging and nesting substrate for some neotropical migrants (personal observation). Passage neotropical migrants frequently observed foraging in iron-wood trees were Black-throated Gray Warbler, Western Tanager, Black-headed Grosbeak, and Bullock's Oriole. Lucy's Warbler was a common breeding neotropical migrant that used cavities in ironwood for nesting (personal observation).

Conservation and Management Implications

We have established a baseline for monitoring natural and human-influenced changes in the abundance of neotropical migrants and their habitat on our study area. We recommend that land managers, including the U.S. Air Force and adjacent land managers such as the Bureau of Land Management, use our protocols to

monitor neotropical migrants, sample vegetation along transects, and establish additional transects when necessary. Bird abundance and habitat association data will aid land managers in identifying areas critical to neotropical migrants.

The habitat characteristics illustrated as important to neotropical migrants can be preserved and managed by protecting xeroriparian areas, particularly areas that support mature (>2.5 m) paloverde, mesquite, desert willow, and catclaw acacia trees, or have the potential to support these species. Our data suggest that xeroriparian scrub within the creosote-bursage vegetation type may be particularly important to passage neotropical migrants, whereas the width of riparian areas may be an important factor for breeding neotropical migrants. When considering the use of washes by breeding and passage neotropical migrants, managers may choose to limit or close washes to recreational use and vehicular traffic either seasonally or permanently (Luckenbach 1977). Potential impacts of other uses of the washes, such as livestock grazing and wood cutting, should also be examined.

While certain attributes of woody perennial vegetation exhibit little interannual variation (e.g., density of plants), other attributes of woody vegetation (e.g., fruit production, flowering, and leaf cover) can vary considerably over time. These ephemeral aspects of woody vegetation could be monitored over time, especially as they relate to food availability. Herbaceous vegetation is extremely ephemeral in the Sonoran Desert (Wiens 1991) and could be sampled each year that bird surveys are conducted to account for this spatial and temporal variation. Due to the importance of desert mistletoe (*Phorodendron californica*) to many neotropical migrants (personal observation), at the very least, we recommend monitoring this plant species' numbers, health, and fruit production over time. Future vegetation sampling need not be done with the rigor of the current protocol, but should be standardized.

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