Comparative Use of Riparian Corridors and Oases by Migrating Birds in Southeast Arizona

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Abstract: *The relative importance of cottonwood-willow riparian corridors and isolated oases to land birds migrating across southeastern Arizona was evaluated during four spring migrations, 1989 to 1994, based on patterns of species richness, relative abundance, density, and body condition of birds. We surveyed birds in 13 study sites ranging in size and connectivity from small isolated patches to extensive riparian forest, sampled vegetation and insects, and captured birds in mistnets. The continuous band of riparian vegetation along the San Pedro River does not appear to be functioning as a corridor for many migrating species, although it may for a few, namely Yellow-breasted Chats (*Icteria virens*), Summer Tanagers (*Piranga rubra*), and Northern Rough-winged Swallows (*Steldigopteryx serripennis*), which account for fewer than 10% of the individuals migrating through the area. Small, isolated oases hosted more avian species than the corridor sites, and the relative abundances of most migrating birds did not differ between sites relative to size-connectivity. There were few differences in between-year variability in the relative abundances of migrating birds between corridor and oasis sites. Between-year variability decreased with overall abundance of species and was greater for species with breeding ranges that centered north of 50°N latitude. Body condition of birds did not differ relative to the size-connectivity of the capture site, but individuals of species with more northerly breeding ranges had more body fat than species that breed nearby. Peak migration densities of several bird species far exceeded breeding densities reported for the San Pedro River, suggesting that large components of these species were en route migrants. Peak densities of Yellow Warblers (*Dendroica petechia*) reached 48.0 birds/ha, of Wilson's Warblers (*Wilsonia pusilla*) 33.7 birds/ha, and of Yellow-rumped Warblers (*D. coronata*) 30.1 birds/ha. Riparian vegetation is limited in extent in the vicinity of our study sites, covering less than 1% of the landscape. We conclude that all riparian patches in southeastern Arizona are important as stopover sites to en route migrants regardless of their size and degree of isolation or connectivity. In light of potential habitat limitation, the protection of both small, disjunct riparian patches and extensive riverine tracts in western landscapes is imperative.*

Uso Comparativo de Corredores Riparios y Oasis por Aves Migratorias en el Sureste de Arizona

Resumen: *Se evaluó la importancia relativa de los corredores riparios de sauces y los oasis aislados para las aves que migran a través del sureste de Arizona durante cuatro migraciones de primavera, de 1989 a 1994, en base a patrones de riqueza de especies, abundancia relativa, densidades y condición corporal de las aves. Estudiamos aves en 13 sitios variando en tamaño y conectividad desde parches pequeños aislados hasta bosques riparios extensos. Muestreamos la vegetación e insectos y capturamos aves con redes. Las bandas continuas de vegetación riparia a lo largo del río San Pedro no aparenta funcionar como un corredor para muchas de las aves migratorias, aunque podría serlo para algunas tales como:* Icteria virens, Piranga rubra *y* Steldigopteryx serripennis, *las cuales corresponen a menos de un 10% de los individuos migrando a través del área. Los oasis pequeños aislados hospedaron mas especies de aves que los sitios de corredor y las abundancias relativas de la mayoría de las especies migrando no fue diferente entre sitios en relación con el tamaño de la conectividad. Existieron pocas diferencias en variabilidad de la abundancia relativa entre años entre*

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Paper submitted October 24, 1996; revised manuscript accepted September 29, 1997.

los corredores y los sitios con oasis. La variabilidad entre años disminuyó en general con la abundancia de especies y fue mayor para especies con rangos reproductivos centrados al norte de los 50° latitud norte. La condición corporal de las aves no difirió en relación con el tamaño de la conectividad del sitio de captura, pero los individuos de especies con rangos de reproducción mas hacia el norte tuvieron mas grasa corporal que las especies que se reproducen en las cercanías. Las densidades pico de migración de varias de las especies de aves excedio por mucho las densidades reproductivas reportadas para el rio San Pedro, sugiriendo que los componentes grandes de estas especies fueron migrantes en ruta. Las densidades pico de Dendroica petechia *alcanzó los 48.0 aves/ha,* Wilsonia pusilla *33.7 aves/ha y* D. coronata *30.1 aves/ha. La vegetación riparia esta limitada en extensión en las áreas vecinas al sitio de estudio, cubriendo menos de 1% del paisaje. Concluimos que todos los parches riparios en el sureste de Arizona son importantes como sitios de reposo para migrantes en ruta independientemente del tamaño y el grado de aislamiento o conectividad. En vista de la potencial limitante del habitat, es imperante la protección tanto de parches pequeños disjuntos como de áreas riverinas extensas en los paisajes del oeste.*

Introduction

Research underlying conservation strategies for Neotropical migrants has concentrated largely on events on breeding and wintering grounds (Gradwohl & Greenberg 1989) and has generally ignored events during the migratory period (Moore et al. 1992). Tremendous energy demands are associated with long-distance migration, however, and many birds cannot successfully complete their journeys without replenishing fat reserves en route (Moore & Kerlinger 1987; Moore et al. 1992). Migrating birds therefore depend on suitable stopover sites, often riparian and other wetland habitats, and must find resources within spatially heterogeneous and temporally dynamic landscapes (Skagen & Knopf 1993, 1994).

Most evaluations of the influences of landscape pattern on habitat selection in birds apply to both breeding and wintering areas (Morse 1985; Brown & Dinsmore 1986; Askins et al. 1992; Freemark & Collins 1992; Robinson 1992). The theoretical basis for landscape-level decisions by migrating birds is now emerging (Hutto 1985*a*; Moore et al. 1992), yet little empirical evidence exists. Hutto (1985*a*) suggests that long-distance en route migrants may base their selection of stopover sites on factors extrinsic to rather than intrinsic to the sites, including meteorological conditions, physiological condition, and landscape-level attributes of the available stopover sites such as patch size and shape, degree of isolation or contagion and connectivity, pateh orientation, and interception probabilities (Hutto 1985*a*; Gutzwiller & Anderson 1992). The relative importance of these attributes may differ between species, depending on migration distance and proximity to destinations.

In western North America insectivorous landbirds migrating in spring prefer riparian habitats for refueling (Johnson et al. 1977; Stevens et al. 1977; Emmerich & Vohs 1982; D. Krueper, personal communication), probably because food and cover are more abundant and predictable there than in other vegetation types in spring. Continuous extensive bands of riparian vegetation may attract more en route migrants than smaller, isolated patches simply because the larger patches are easier to find (Simberloff & Cox 1987). If extensive corridors are easier to find, abundances of en route migrants in continuous riparian forests may be greater and more consistent between years than abundances in smaller riparian patches. On the other hand, small, isolated oases may facilitate migration by providing a "stepping stone" (MacArthur & Wilson 1967:123) arrangement of stopover areas. Small oases in the Sahara desert regularly attract transient passerines for resting and refueling (Bairlein 1988, 1992; Biebach 1990).

We monitored the use of several riparian areas in southeastern Arizona by Neotropical migrant landbirds, short-distance migrants, and residents, and we examined the relative importance of corridors and isolated oases to migrating birds. We evaluated the following attributes of the bird communities: species richness, relative abundances, variability of abundances, and body condition of migrants. Specifically, we predicted that, if extensive corridors attracted more migrating birds than oases, we would detect one or more of the following patterns. Corridor sites would (1) host a greater number of avian species, (2) have greater abundances of migrating birds, (3) exhibit less year-to-year variability in bird abundances, or (4) provide more resources, reflected in greater biomass of insects or better body condition of birds. For a delineated region, we also determined the total area of cottonwood-willow riparian vegetation available to migrating birds in oases and in continuous riverine corridors.

Study Area and Methods

Site Descriptions

During spring migration (early April–mid-May) in 1989, 1991, 1993, and 1994, we conducted weekly bird sur-

veys in 13 riparian sites in southeastern Arizona (Fig. 1). The riparian areas were dominated by Fremont cottonwood (*Populus fremontii*) and Gooding willow (*Salix gooddingii*), each surrounded by dry grasslands, shrub lands, or oak woodlands. The 13 sites, under federal and private ownership (including Bureau of Land Management, The Nature Conservancy, and private individuals), ranged from samples of the continuously vegetated corridor of the San Pedro River to small, isolated oases (Fig. 1). The sites ranged in elevation from 900 to 1600 m and in latitude from 31° 30′ N to 32°20′ N. Sites at Muleshoe Ranch (MULR, MULB) and near Cascabel (CASN, CASS) were surveyed only in the springs of 1989 and 1991.

The study sites were selected because they represented the largest remaining riparian areas in the region, as determined from aerial photos and an overview flight

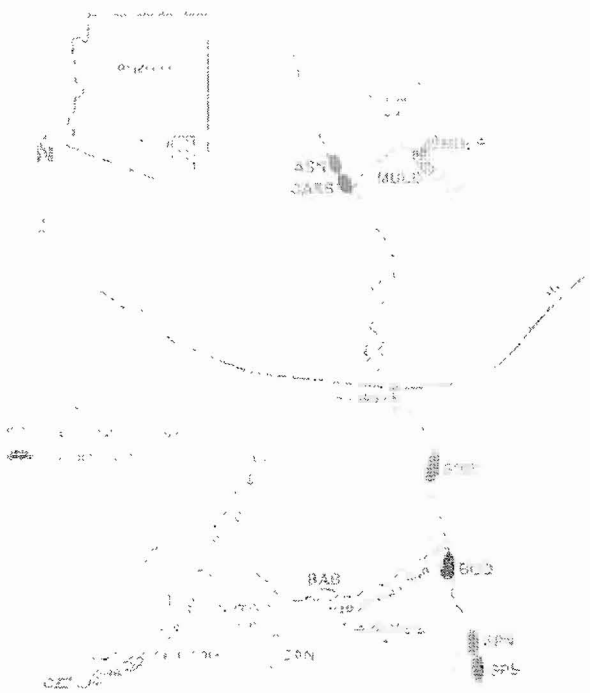

Figure 1. Location of 13 bird survey sites in southeastern Arizona. EC, Empire Cienega Ranch; BAB, Babocomari Ranch; CAN, Canelo Hills Cienega; CZZ, Circle-Z Ranch; PAT, Patagonia-Sonoita Creek Preserve; MULR, Double-R Canyon/Muleshoe Ranch; MULB, Bass Canyon/Muleshoe Ranch; CASN, Cascabel North; CASS, Cascabel South; SDD, St. David's Ditch; BOQ, Boquillas Ranch; SPN, San Pedro House North; SPS, San Pedro House South. Size-connectivity groups are described as oasis sites (small, <4 × 100 km, and relatively isolated), intermediate sites (larger habitat patches, 4–12 km), and corridor sites (part of extensive, linear forest).

in 1989. The San Pedro River sites were selected based on latitude (to match the latitude of oases) and accessibility (influenced by land ownership and occurrence of roads). Even though some sites were on the same water course, we considered sites to be independent if they were separated by 500 m.

Precipitation patterns varied among the years of our study. Monthly precipitation from January through April was below average during 2 years of our study, 1989 (40% of an 85-year average) and 1994 (24% of average). In contrast, monthly precipitation was above average during January and February in 1991 (127%) and 1993 (217%) and below average during March and April of the same years (70% and 45% of average, respectively). Flooding of the San Pedro River resulted from heavy rainfall in January of 1993, when precipitation totaled 270% of the monthly average. Data for weather stations at Sierra Vista and Canelo, Arizona, were provided by the Western Regional Climate Center, the National Weather Service, and the National Oceanic and Atmospheric Administration.

We grouped the 13 survey sites into three categories based on both relative size and connectivity (SC) with similar habitat types. Because riparian woodlands in this study area were linear and narrow (generally 50–200 m wide), it was difficult to separate the effects of the size of riparian forest patches and connectivity to other habitat patches. Oasis sites (SC1: EC, BAB, CAN) were small (limited to the area surveyed, <4 km linear extent) and relatively isolated (>8 km) from similar cottonwood-willow riparian habitats; they ranged in area from 40 to 100 ha. Intermediate sites (SC2: CZZ, PAT, MULR, MULB) were located within larger habitat patches (4–12 km linear extent), ranging in area from 120 to 180 ha. San Pedro River sites (SC3: CASN, CASS, SDD, BOQ, SPN, SPS) were part of an extensive linear forest exceeding 2000 ha and were contiguous with similar riparian vegetation.

Some habitat attributes—elevation, latitude, vegetation structure, size-connectivity—were correlated among sites. But replicates in the sense of classical experimentation are rarely, if ever, possible in landscape or regional studies (Hargrove & Pickering 1992). An ideal experimental design for this study would have allowed the separation of the effects of patch size, connectivity, elevation, latitude, and vegetation structure on bird abundances. In southeastern Arizona, however, most of the isolated sites were higher in elevation, smaller in extent, and lower in shrub volume than the more connected riverine sites. Alternative sites did not exist in this region at the scale of this project.

Bird Surveys

Birds were surveyed weekly at each site for 6 weeks (3 April–14 May) in 1989, 1993, and 1994 and for 4 weeks (20 April–9 May) in 1991. Two or three observers rotated

between sites to reduce observer bias. Using a standard point-count method (Reynolds et al. 1980; Bibby et al. 1992), we recorded all birds heard and seen during 7 minutes at each of 20 points within each study site and specified the distance (0–10, 10–25, 25–50, 50–75, 75–100 m) to each bird. To maximize the area sampled at each site, we placed points approximately 100 m apart. All surveys were begun within 20 minutes of sunrise and were concluded in 4 hours.

To facilitate data analyses, all bird species were grouped into three functional guilds (Table 1) Using information from several references, we categorized bird species by migration pattern, latitudinal ranges, macrohabitat, and foraging microhabitat (National Geographic Society 1981,1987; American Ornithologists' Union 1983; Davis & Russell 1984; Hayman et al. 1986; Banks et al. 1987; Ehrlich et al. 1988; DeGraaf et al. 1991). Migration categories based on distance traveled range from nonmigratory residents (category 1) to species that occur in southeast Arizona only during migration (category 5). We also distinguished species that breed and winter in southeastern Arizona but also migrate to more northern or southern latitudes (category 2) from species that are present only during migration and the breeding season (category 3) and species that occur only during winter and migration (category 4). Macrohabitat guilds separate species that are usually or often associated with riparian areas from those that occur primarily in more upland habitats. Foraging microhabitat guilds primarily distinguish species that forage in different vegetation layers. When searching for patterns relative to size-connectivity, we grouped species according to these functional guilds and also evaluated the data on the basis of individual species.

Vegetation Sampling

We recorded broad habitat features for general classification of sites and more detailed vegetation characteristics at survey points. Broad habitat features included width of the riparian forest, canopy height, and shrub and tree species comprising more than 10% cover. We estimated relative foliage density for each site in 1993 using a modified version of the MacArthur board technique (MacArthur & MacArthur 1961). In four quadrants (northeast, southeast, southwest, northwest; determined

Table 1. Functional guilds of birds recorded during spring migration in southeastern Arizona, 1989–1994.[a]

	Present in southeastern Arizona[b]	*Description*	*Number of species*
Migration category			
1	W, M, B	Resident, primarily non-migratory although altitudinal movements may occur	38
2	W, M, B	Winters in SE Arizona, migrates through SE Arizona, breeds in SE Arizona	50
3	M, B	Winters south of SE Arizona, migrates through SE Arizona, breeds in and north of SE Arizona	48
4	W, M	Winters in and south of SE Arizona, migrates through SE Arizona, breeds north of SE Arizona	29
5	M	Winters south of SE Arizona, migrates through SE Arizona, breeds north of SE Arizona	15
6	—	Vagrant in SE Arizona	6
Macrohabitat guild			
1		Especially or generally near water	35
2		Riparian or water mentioned in habitat accounts	67
3		Woodlands, chaparral-scrub, grasslands, savannah, desert; no mention of water in habitat accounts	84
Foraging microhabitat guild			
0		Terrestrial generalist	25
1		Aerial insectivore, sweeper	7
2		Aerial insectivore, sallying and hawking	23
3		Middle and upper canopy; foliage gleaner	27
4		Lower canopy and shrub layer; foliage gleaner	21
5		Forb layer, ground and litter; gleaner	47
6		Trunk insectivore, trunk and branches; gleaner	8
7		Forest generalist	9
8		Shoreline gleaner, prober	5
9		Aquatic bird	14

[a] *Functional guilds are based on information from the National Geographic Society (1981, 1987); the American Ornithologists' Union (1983), Davis and Russell (1984), Hayman et al. (1986); Banks et al. (1987); Ehrlich et al. (1988); and DeGraaf et al. (1991).*
[b] *Birds are present during winter (W), spring or fall migration (M), and breeding season (B).*

with a compass) around each stake, the distance to the nearest vegetation (including stems, trunks, and dead vegetation) that would obscure one-half of an 8.5 × 11-inch (22 × 28 cm) board was estimated at each of the following heights: 0.25, 0.5, 1, 2, 5, 10, 15, 20, 25, 30, 35, and 40 m. A maximum of 960 estimates was made at each site. We truncated horizontal measurements at 100 m. Clinometers were used to determine height categories. Because the foliage in the lowest layers at some sites was scoured by floods in 1993, measurements were taken again in 1994 at 0.25, 0.5, 1, and 2 m.

We calculated an index of foliage density—the amount of leaf surface area per cubic unit of space—using the following formula: foliage density = ln2/distance. We grouped height intervals into three vegetation layers: ground layer, 0.25 and 0.5 m; shrub layer, 1 and 2 m; and canopy, 5, 10, 15, 20, 25, 30, 35, and 40 m; we computed the foliage density for these three layers as the average of the foliage densities for each height in the layer. Foliage density profiles were used in conjunction with estimates of riparian coverage in subsequent analyses.

Because vegetation within sites was patchy and uneven in coverage and extent, we developed a general index of riparian vegetation coverage. At each stake observers sketched the location and extent of riparian vegetation, upland vegetation, and river channel on a circular template with radius intervals of 25, 50, and 100 m. A dot-grid overlay was used to determine the areal extent of channel and riparian vegetation within 50 m. Values were converted to percentages and averaged to yield the percentage of riparian cover for each site.

Foliage volume indices were calculated as the sum of the products of foliage density, the percentage of riparian cover, and the vertical distance between height intervals within each vegetation layer Indices for ground and shrub layers were based on average foliage densities for 1993 and 1994, which represented years of both above and below average precipitation from January through April

Insect Sampling

We developed an index of insect biomass in 1989 and 1991 by sampling aerial insects at four sites, EC, PAT, SDD, and SPS. We collected aerial insects using sticky board traps (12 × 20-cm squares coated with Tanglefoot™). Traps consisted of four sticky boards attached to a wooden lathe and surrounded by plastic mesh (3 cm), which allowed the passage of insects but not birds. At four randomly chosen stakes at each of the four sites, traps were suspended from branches within the vegetation at two heights, low (2–4 m) and high (6–8 m). Traps were placed immediately after the weekly bird surveys were finished and were removed and replaced 1 week later following the subsequent survey. Traps were disassembled, and sticky boards were frozen in plastic wrap. We identified all insects to order, measured lengths, and applied the following standard formula to estimate an index of biomass of aerial invertebrates for each site: $M = 0.0305\ L^{2.62}$, where M equals biomass (mg) and L equals length in millimeters (Rogers et al. 1976).

Assessment of Body Condition and Data Analyses

In the spring of 1989, we captured birds with mist nets at SPS, SDD, CAN, and PAT, following the animal care guidelines of the American Ornithologists' Union (1988). Measurements and attributes recorded immediately for each bird included body mass (0.1 g, Pesola scales), length of unflattened wing chord, retrix length, age, and sex. We also scored the amount of visible fat in the furcular and abdominal regions on a scale of 0 (no fat) to 6 (very obese), after Helms and Drury (1960).

Analyses of variance and multivariate analysis of variance (MANOVA) were used in detecting patterns of species richness by functional guilds and size-connectivity. We used several measures of relative abundance, defined as the number of birds within 50 m, to examine distribution patterns of functional guilds and individual species by size-connectivity. We minimized double counting of individuals by restricting our data to sightings within 50 m. Our relative abundance measures included the maximum number of each species per guild per site each year and during 1993 and 1994 combined, and the total relative abundance (i.e., the sum of individuals sighted during all surveys) of each guild per site each year and during 1993 and 1994 combined. We used Kruskal-Wallis nonparametric analyses of variance and nonparametric multiple contrast tests (Zar 1984) to determine patterns of distribution relative to size-connectivity. We conducted separate analyses for the 29 most abundant species that together comprised 80% of all sightings and for an additional 15 species, so 80% of all guilds were represented. Because we conducted four surveys in 1991 and six in the other 3 years, we multiplied total relative abundance by 1.5 for 1991 data to allow for between-year comparisons. Total relative abundances were also adjusted if necessary to account for missing data (6% of scheduled surveys were missed because of logistical difficulties). Statistical analyses (parametric and nonparametric analysis of variance, analyses of covariance [ANCOVAs], multiple regressions, Tukey pairwise comparisons, t tests, chi-square analyses, log-likelihood ratio tests) were conducted using SYSTAT 5.0. Findings with p values of 0.10 and greater are reported as nonsignificant.

Two indices of between-year variability were calculated as the coefficient of variation (SD/mean) of total relative abundance, hereafter referred to as CV(abundance), and the coefficient of variation of maximum counts, hereafter CV(maximum), at each of nine sites surveyed across the 4 years of the study. We used

Kruskal-Wallis nonparametric analyses of variance and nonparametric multiple contrast tests (Zar 1984) to determine patterns of variability relative to size-connectivity. Median CV(abundance) and median CV(maximum) across all sites for each species were used in additional analyses.

Density estimates were obtained with Program DISTANCE (Buckland et al. 1993; Laake et al. 1993). Because of potential differences in detection in different habitats, detection curves were calculated for individual sites; data were truncated at 75 m. In distance sampling, double counting does not bias estimates as long as the observations are independent. Maximum densities were calculated for specific days at some sites by means of site-specific detection curves calculated across all days. Model selection followed appropriate guidelines (Buckland et al. 1993; Laake et al. 1993).

Determination of the Extent of Riparian Vegetation

We determined the total amount of cottonwood-willow and mixed broadleaf habitats available to migrants within a delineated land area (≈10,000 km^2) extending from the Mexican border to the northern boundary of Cochise County, Arizona (31°18′ to 32°26′N) along a band extending 40 km on either side of the western boundary of Cochise County (110°00′ to 110°50′ W). We used the Arizona Statewide Riparian Mapping and Inventory database, created by the Arizona Game and Fish Department and based on Landsat images, which defines the location and extent of several vegetation types within permanent riparian areas throughout Arizona. We also used two related databases, one with coverages of the intermittent stretches of the San Pedro River and another including polygon-specific vegetation data collected during ground-truthing.

Using ARC/INFO (Environmental Systems Research Institute 1995), we determined the areal extent of the cover types "cottonwood-willow" and "mixed broadleaf," the vegetation types in which bird surveys were conducted, from both the permanent and intermittent riparian coverages. From the polygon-specific vegetation data, we estimated that 12.2% of the area of salt cedar (*Tamarisk* spp.) stands was composed of cottonwoods and willows. We therefore included 12.2% of the areal extent of salt cedar in our calculations of available habitat because cottonwoods and willows were often subdominant within stands of salt cedar.

Results

Vegetation Profiles

The canopy vegetation of all sites was dominated by Fremont cottonwood and Gooding willow, except for the Muleshoe Ranch sites where Arizona sycamore (*Platanus wrightii*) was abundant. Velvet ash (*Fraxinus pennsylvanica*), Arizona black walnut (*Juglans major*), netleaf hackberry (*Celtis reticulata*), alligatorbark juniper (*Juniperus deppeana*), and oaks (*Quercus* spp.) also occurred at several sites. Lower canopy and understory plants included honey mesquite (*Prosopis glandulosa*), salt cedar, graythorn (*Zizyphus obtusifolia*), elderberry (*Sambucus mexicana*), and seepwillow (*Baccharis* spp.).

In general, small, isolated sites had smaller indices of foliage volume than other sites for all vegetation layers (Fig. 2). This was due to differences in foliage densities and smaller percentages of riparian cover in the small,

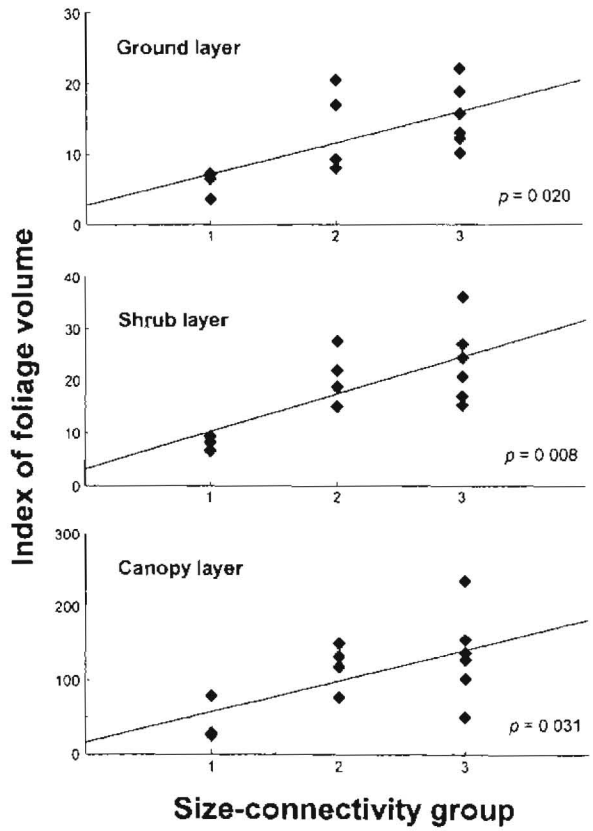

Figure 2. Indices of foliage volume for ground layer (heights 0.25 and 0.5 m), shrub layer (heights 1 and 2 m), and canopy (heights 5–40 m) at 13 sites grouped by size-connectivity (1, small isolated; 2, intermediate; and 3, large connected). Index is the sum of the products of foliage density at each height interval within the vegetation layer, the average percentage of riparian cover of 50-m radius circles, and the vertical distance from the height interval immediately below. Indices for canopy are based on data from 1993 and for ground and shrub layers on average foliage densities for 1993 and 1994.

isolated sites relative to other sites. Foliage volumes of all layers were negatively correlated with elevation ($r = -0.630$, df = 12, $p < 0.02$ for ground layer; $r = -0.829$, df = 12, $p < 0.001$ for shrub layer; $r = -0.486$, df = 12, $p < 0.10$ for canopy). Latitude and elevation were negatively correlated ($r = -0.585$, df = 12, $p < 0.05$); the northern sites on the San Pedro River, CASN and CASS, were at the lowest elevations.

Species Richness

Migrant and resident birds of 186 species were recorded during 230 surveys in four spring field seasons; total sightings approximated 85,500 birds, primarily passerines. The numbers of species recorded at the 13 sites during 1993 and 1994 were significantly correlated with size-connectivity of the sites ($F = 7.787$, df = 1.11, $p = 0.018$; Fig. 3). The isolated oases sites hosted more species (101-109) than corridor sites (84-102), with more species in migration categories 2, 4, and 5 ($F = 9.064$, df = 1.11, $p = 0.012$, $F = 4.680$, df = 1.11, $p = 0.053$; and $F = 4.423$, df = 1.11, $p = 0.059$, respectively; Fig. 3). The 10 species that occurred only in oases during 1993 and 1994 were rarely sighted, however, averaging only 1.1 (±1.34 SD) sightings per year. More species occurred at higher elevations ($F = 11.269$, df = 1.11, $p = 0.006$) and at lower latitudes ($F = 5.544$, df = 1.11, $p = 0.038$).

Oases had more species of ground-foraging birds than intermediate sites and corridor sites (Table 2), but there were no differences between oases and corridor sites in numbers of shrub- and canopy-foraging birds. Intermediate sites hosted more shrub-foraging birds than did oases and corridor sites (Table 2). There were no significant relationships between numbers of species and foliage volume for three foraging microhabitat guilds (ground-, shrub-, and canopy-foraging birds; Table 2).

Patterns of Relative Abundance

During 1993 and 1994, the 15 most abundant species composed 60.2% of all bird sightings (42,206 total sightings within 50 m) and 54.7% of the maximum numbers

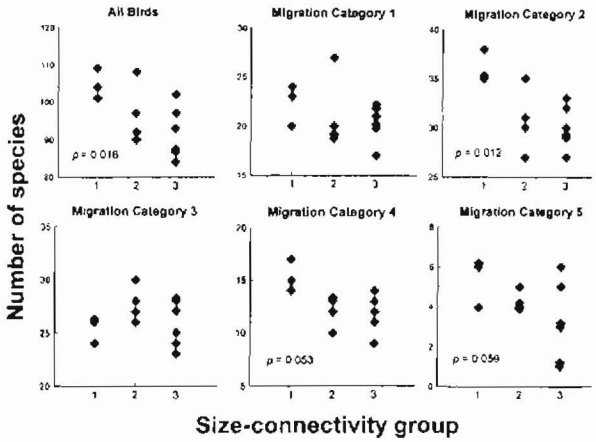

Figure 3. The numbers of bird species relative to the size-connectivity groups (defined in Fig. 2 legend) and migration categories (defined in Table 1) at 13 survey sites during the springs of 1993 and 1994 (p = 0.284 and p = 0.350 for migration categories 1 and 3, respectively).

for all species (9706 individuals). Species in migration categories 3 and 2 were the most numerous (Table 3), whereas species in migration categories 4 and 5 accounted for fewer than 10% of all sightings and for 15% of the maximum numbers. Total abundances of all birds within 50 m at all sites during the study and percentage of representation by species are available from S. K. S.

Some patterns of distribution relative to size-connectivity were evident for migration category and macrohabitat guild. For the five migration categories, the sums of the maximum counts of all birds during the springs of 1993 and 1994 were greater in corridor sites than in oases, but only for migration category 3 ($H = 7.775$, df = 2, $p = 0.02$; Fig. 4). The largest numbers of birds in migration categories 4 and 5 occurred at two of the isolated oases (EC and BAB).

We examined distribution patterns of 29 species that collectively comprised 80% of all sightings (hereafter abundant species) in 1993 and 1994 and of an additional

Table 2. Relationship between numbers of bird species, size-connectivity, and foliage volume of 13 survey sites in southeastern Arizona during spring migration of 1993 and 1994.

	Size-connectivity[a]		*Foliage volume*
Foraging microhabitat	F (p)[b]	*Relationship*[c]	F (p)[b]
Ground and forb layer	4.772 (0.039)	1 > 2 = 3	1.195 (0.303)
Shrub and lower canopy layer	7.669 (0.011)	2 > 1 = 3	0.475 (0.508)
Middle and upper canopy	2.763 (0.116)	1 = 2 = 3	1.063 (0.330)

[a] *Size-connectivity groups are defined as 1: oasis sites, small (<4 km by 100 m) and relatively isolated; 2: intermediate sites located in larger habitat patches (4-12 km), 3: part of extensive linear forest.*
[b] *From multiple regression analyses, df = 2,10.*
[c] *Relationship of the number of species in three size-connectivity groups, from Tukey pairwise comparison tests.*

Table 3. Patterns of bird species abundance relative to size-connectivity based on maximum counts of individual species during four spring migrations, 1989–1994.

Migration category and species[a]	*Percentage of migration category*	p[b] *1989*	*1991*	*1993*	*1994*
1					
Abert's Towhee[c,d]	21.5	<0.001	<0.001	<0.005	<0.005
Gila Woodpecker[c,d]	20.0	ns	ns	ns	ns
House Finch[c,d,e]	13.1	ns	ns	ns	ns
Bushtit[c,d,e]	6.9	ns	ns	ns	ns
Ladder-backed Woodpecker[d]	5.5	ns	ns	ns	ns
Bridled Titmouse[d]	4.8	(<0 005)	(<0.005)	ns	ns
Northern Cardinal[d,e]	4.7	ns	<0.10	<0.01	ns
European Starling[d,e]	4.7	ns	ns	ns	ns
White-breasted Nuthatch	4.5	ns	(<0.001)	ns	ns[f]
Gambel's Quail	2.8	<0.001	<0.001	ns[f]	ns[f]
2					
Bewick's Wren[c,d]	18.3	<0.001	ns	ns	ns
Yellow-rumped Warbler[c,d,e]	9.9	ns	ns	ns	ns
Song Sparrow[c,d,e]	8.5	ns	<0.001	ns	ns
Common Yellowthroat[c,d,e]	8.4	ns	ns	ns	ns
Vermillion Flycatcher[c,d]	7.3	ns	ns	<0.001	<0.05
Mourning Dove[c,d,e]	7 2	ns	ns	ns	ns
Lesser Goldfinch[c,d]	7.0	ns	ns	ns	ns
White-winged Dove[c,d]	6.0	ns	ns	ns	ns
Brown-headed Cowbird[c,d,e]	4.0	ns	ns	ns	ns
Ruby-crowned Kinglet[c,d,e]	3.6	ns	ns	ns	ns
Black Phoebe[c]	2.9	ns	ns	ns	ns
Lincoln's Sparrow[c,e]	2.8	ns	ns	ns	(<0.005)
Northern Flicker	2.4	ns	(0.001)	ns	(0.001)
3					
Yellow Warbler[c,d,e]	35.5	ns	<0.10	ns	ns
Lucy's Warbler[c,d]	13.3	ns	ns	<0.001	<0.005
Summer Tanager[c,d]	8.2	<0.001	<0.001	<0.001	<0.001
Yellow-breasted Chat[c,d,e]	5.1	<0.001	<0.001	<0.001	<0.001
Cassin's Kingbird[c,d]	4.4	(<0.05)	ns	ns	ns
Bell's Vireo[c,d]	4.2	<0.001	ns	<0.001	<0.001
Bullock's Oriole[c,d,e]	4.1	ns	ns	<0.005	<0 005
Hooded Oriole[c,d]	3.9	ns	ns	ns	ns
Black-chinned Hummingbird[c,d,e]	3.2	ns	ns	ns	ns
Ash-throated Flycatcher[c]	2.8	<0.001	ns	ns	<0 001
Brown-crested Flycatcher	2.4	<0.001	<0.001	<0.05	<0.05
Northern Rough-winged Swallow[c,e]	2.0	<0.001	ns	<0.001	<0.05
Black-headed Grosbeak	1.7	ns	ns	ns	ns
Western Kingbird	1.4	ns	(<0.001)	ns	(<0 001)
4					
Chipping Sparrow[c,d,e]	41.2	ns	ns	ns	ns
White-crowned Sparrow[d,e]	10.4	ns	ns	ns	ns
Cedar Waxwing[d,e]	9.8	ns	ns	ns	ns
Green-tailed Towhee[d]	9.4	ns	ns	ns	ns
Pine Siskin[d,e]	9.1	ns	ns	(<0.005)	ns
5					
Wilson's Warbler[c,d,e]	83.2	ns	ns	(<0.001)	ns
Lazuli Bunting	3.9	ns	ns	(<0.001)	ns

[a] *Category 1 had 16.0% of all sightings and 14.9% of maximum numbers; category 2, 33.9% and 32 8%, respectively; category 3, 41.3% and 36.8%, respectively; category 4, 4.6% and 7.9%, respectively, category 5, 4.3% and 7.6%, respectively.*

[b] *The* p *values are from multiple comparison tests following Kruskal-Wallis nonparametric analyses of variance (ns,* $p > 0.10$*). The* p *values without parentheses indicate that more birds occurred in corridor sites;* p *values in parentheses indicate that more birds occurred at oases than at corridor sites*

[c] *One of the most abundant species, comprising 80% of all sightings.*

[d] *One of the most abundant species, comprising 80% of the migration category.*

[e] *Breeding ranges extend north of 50°N latitude.*

[f] *No differences in bird abundances between corridors and oases, but abundances at intermediate sites differ from corridor and oasis sites*

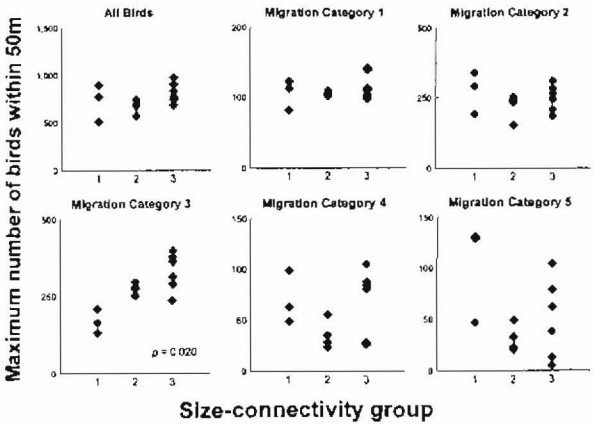

Figure 4. The maximum number of birds recorded within 50 m during all surveys, springs of 1993 and 1994, by migration category and size-connectivity group. See Table 1 for definitions of migration categories. The p *values are for all species combined in the respective migration categories (*p *= 0.575, 0.389, 0.202, and 0.149 for migration categories 1, 2, 4, and 5, respectively).*

15 species, so that 80% of each functional guild was represented. Maximum counts of 12 (41%) of the 29 abundant species were higher in corridor than oasis sites in at least 1 year and were consistently so for 3–4 years for five (17%) of these species (Table 3). Abundant species in migration category 3 were more likely associated with corridor sites than abundant species in migration categories 1 and 2 ($G = 3.771$, df = 1, $p = 0.052$). Eight (73%) of 11 abundant species in migration category 3 were associated with corridor rather than oasis sites in at least one year (Table 3); whereas only 4 (25%) of 16 abundant species in migration categories 1 and 2 and none of the 6 abundant species in migration categories 4 and 5 were associated with corridor rather than oasis sites (Tahle 3). Of the five abundant species associated with corridor sites for 3–4 years, four were in migration category 3 (Summer Tanager [*Piranga rubra*], Yellow-breasted Chat [*Icteria virens*], Bell's Vireo [*Vireo bellii*], and Brown-erested Flycatcher [*Myiarchus tyrannulus*]), and one (Abert's Towhee [*Pipilo aberti*]) was in migration category 1 (Table 3). Another species in migration category 3, the Northern Rough-winged Swallow (*Steldigopteryx serripennis*), also preferred riverine sites during 3 years.

Species in macrohabitat guilds 1 and 2 (generally or sometimes associated with riparian areas) were more likely to prefer the river sites than species in macrohabitat guild 3 ($G = 6.863$, df = 1, $p = 0.009$). Four (24%) of 17 species in macrohabitat guilds 1 and 2—Abert's Towhee, Summer Tanager, Yellow-breasted Chat, and Bell's Vireo—were associated with corridor sites for 3–4 years (Table 3). Macrohabitat guild 1 was comprised of nearly 75% Wilson's Warblers (*Wilsonia pusilla*), Abert's Towhees, Song Sparrows (*Melospiza melodia*), and Common Yellowthroats (*Geothlypis trichas*), based on relative abundance within 50 m in 1993 and 1994, and more than half of maerohabitat guild 2 was Yellow Warblers (*Dendroica petechia*), Bewick's Wrens (*Thryomanes bewickii*), Lucy's Warblers (*Vermivora luciae*), and Summer Tanagers. None of the 14 species in macrohabitat guild 3, including Yellow-rumped Warblers (*D. coronata*), Mourning Doves (*Zenaida macroura*), Lesser Goldfinches (*Carduelis psaltria*), House Finches (*Carpodacus mexicanus*), and Chipping Sparrows (*Spizella passerina*), were associated with corridor sites in even 1 year.

The breeding ranges of several species in migration categories 2 and 3 extend north of 50°N latitude (Table 3), suggesting that some individuals are migrating through rather than breeding in the area. We estimated the proportion of seven abundant species in these two migration categories that are en route migrants by comparing peak migration densities (using the highest counts at a given site on a given day) with peak breeding densities along the San Pedro River (Krueper 1992) We also calculated the peak density of the most abundant through-migrant, Wilson's Warbler. Peak migration densities of Yellow Warblers reached as high as 48.0 birds/ha, of Wilson's Warblers as high as 33.7 birds/ha, and of Yellow-rumped Warblers as high as 30.1 birds/ha (Table 4). Based on these comparisons, it seems likely that nearly 90% of the peak populations of Yellow Warblers and Bullock's Orioles (*Icterus bullocki*), 79% of Song Sparrows, and 65% of Yellow-breasted Chats are en route migrants (Table 4). Fewer Common Yellowthroats and Summer Tanagers were likely en route migrants because their peak migration densities were more similar to breeding densities. Presnmably, all Yellow-rumped Warblers were migrating through because they do not breed in the riparian areas even though they breed in southeast Arizona (D. Krueper, personal communication). All Wilson's Warblers are en route migrants here. Peak migration densities of Yellow Warblers were lower at the more southern San Pedro River sites (12.4 birds/ha at SDD and 14.2 birds/ha at SPN) than at the more northern river sites (Table 4).

Variability in Abundances and Body Condition

Patterns of variability in abundance were evaluated at the original nine sites for 33 species representing the 7 most abundant species in five migration categories for which there were adequate data (Table 3; additional species in migration categories 4 and 5 included Hammond's Flycatcher [*Empidonax hammondii*], Orange-crowned Warbler [*V. celata*], Townsend's Warbler [*D. townsendti*], Nashville Warbler [*V. ruficapilla*], and Hermit Warbler [*D. occidentalis*]). For each species, us-

Table 4. Peak densities (birds/ha) of eight bird species in which all or some individuals are en route migrants.

Species	Site and date[b]	Peak density (birds/ha)[a] Density[c]	95% CI	CV (%)[d]	N(detect)[e]	San Pedro River breeding density[f]	Estimated percentage en route
Wilson's Warbler	BAB, 6 May 94	33.5	25 0-44.8	14.4	476	0	100
	SPN, 3 May 94	33.7	24 5-46.3	15.5	428		
Yellow Warbler	CASS, 21 April 94	48.0	37.2-62.0	12.8	428	5.7	88
	CASN, 7 April 94	42.4	33.6-53.5	11.7	609		
Yellow-rumped Warbler	SPS, 3 May 94	30 1	18.1-50.0	25.5	282	0	100
Song Sparrow	PAT, 2 May 94	7 1	5.1-9.9	16.9	429	1.5	79
Common Yellowthroat	SPN, 26 April 94	4.2	3 3-5 4	12.5	440	3.7	12
Yellow-breasted Chat	CASS, 7 May 94	8.0	6 2-10.2	12.2	262	2.8	65
Bullock's Oriole	SPS, 3 May 94	7.9	5 1-12.2	21.4	220	0.9	89
Summer Tanager	SDD, 8 May 93	5.3	3.6-7.7	18.9	456	4.2	21

[a] *Based on the highest count during one survey during the entire study; two values are given for the most abundant species*
[b] *See Fig. 1 for site codes.*
[c] *Calculated using program distance (Buckland et al. 1993).*
[d] *Coefficient of variation expressed as a percentage.*
[e] *N (detect): the sample over which detection curves were developed equals all sightings of a given species at a given site in the 4-year period Minimum sample sizes of 60-80 are recommended for calculation of detection curves (Buckland et al. 1993).*
[f] *Estimates of maximum breeding densities from the San Pedro River (Krueper 1992).*

ing nonparametric analyses of variance, we determined if total relative abundances and yearly maximum abundances for each site were more variable between years at the oases sites than in corridor or intermediate sites. Patterns of variability reflected by CV(abundance) and CV(maximum) were similar. Twenty-eight (85%) of the 33 species did not differ in variability between sites (p values ranged from 0.105 to 0.868). Our data suggest that five species (15%) were more variable in oases. The CV(abundance) and CV(maximum) were greater in oases than along the river for Yellow-breasted Chats (p = 0.082 and p = 0.064, respectively), Song Sparrows (p = 0.066 and p = 0.067), Cedar Waxwings (*Bombycilla cedrorum*; p = 0.061 and p = 0.046), and Bridled Titmice (*Parus wollweberi*; p = 0.066 and p = 0.067).

The CV(abundance) but not CV(maximum) was greater in oases than corridor sites for Abert's Towhees (p = 0.047 and p = 0.112, respectively). Between-year variability of both total abundance and maximum counts was greater in species that breed farther north and that were less abundant. Median CV(abundance) and median CV(maximum) were both significantly negatively correlated with the latitude of the estimated center of the breeding range (partial t = 2.607, df = 2.30, p = 0.014; partial t = 2.832, df = 2.30, p = 0.008; Fig. 5) and ln(median abundance) (partial t =7.910, df = 2.30, p < 0.0001; partial t = 6.037, df = 2.30, p < 0.0001; Fig. 5).

We captured 263 individuals of 36 species between 1 April and 2 May 1989. Nearly half (49%) of these captures were of five species, Wilson's Warblers, Bewick's Wrens, Abert's Towhees, Yellow-rumped Warblers, and Lincoln's Sparrows (*M. lincolnii*). Fat scores of all individuals averaged 1.04 (±1.30 SD) and ranged from 0 to 5. There were no differences in body condition (reflected by fat scores) attributable to size-connectivity of the capture site (p = 0.244) or to date of capture (p = 0.141). The distance that birds had yet to travel (expressed relatively as the latitude of the center of the species' breeding range) significantly influenced body condition of birds (partial t = 7.453, df = 2.260, p < 0.001); individuals of species that breed the farthest north (center of breeding range >45°N; Wilson's Warblers, Yellow-rumped Warblers, Lincoln's Sparrows, White-crowned Sparrows [*Zonotrichia leucophrys*], Orange-crowned Warblers; n = 103) carried more fat than more southerly breeding individuals (Bewick's Wrens, Abert's Towhees,

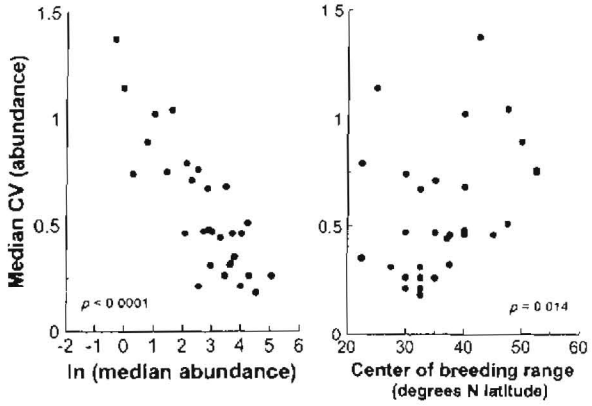

Figure 5. Relationships among between-year variability (median CV(abundance)), median abundance (log-transformed) for 4 years at nine original sites, and the latitude of the center of the breeding range for 33 species. The patterns are similar for CV(abundance) based on maximum counts rather than total relative abundances.

Yellow-breasted Chats, Lucy's Warblers, Song Sparrows, Chipping Sparrows, Common Yellowthroats, Green-tailed Towhees [*P. chlorurus*], Yellow Warblers; n = 167). Time of day also significantly influenced fat levels (partial t = 3.987, df = 2,260, $p < 0.001$); birds captured in the afternoon and evening had higher fat scores than birds captured in the morning.

Insect Biomass and Extent of Riparian Vegetation

The biomass of aerial insects at the four sites was significantly greater in 1989 than in 1991 (average biomass 654.5 g/site ± 144.25 SE and 206.7 g/site ± 40.09 SE for 1989 and 1991, respectively; p = 0.001; Kruskal-Wallis test), primarily because of greater average insect lengths rather than greater numbers of insects. Although EC and PAT occasionally had greater biomass of insects, differences in biomass between sites were not statistically significant in either 1989 or 1991. There were no relationships between aerial insect biomass and indices of foliage volume in seven of eight samples, and in one sample in 1989 insect biomass was negatively correlated with foliage volume, primarily because of large Diptera occurring in the grazed oasis (EC).

The four prominent vegetation types in these riparian areas—cottonwood-willow, mixed broadleaf, tamarisk, and mesquite—together totaled about 8100 ha, or approximately 0.8% of the area of the 10,000-km^2 region that corresponds with our study sites. Riparian cottonwood-willow and mixed broadleaf habitats alone totaled 3272 ha or about 0.3% of the land area. Approximately 68% of the cottonwood-willow habitat was located along the San Pedro River and 32% in isolated oases and sites of intermediate size and connectivity. Along the San Pedro River, the southern half had 88.8% of the 2053 ha of cottonwood-willow stands within our delineated region, whereas the northern half contained 83.7% of 1359 ha of tamarisk stands. North of the Cascabel sites and beyond our delineated region, cottonwood-willow was relatively sparse along the San Pedro River, covering only 82 ha in the 60 km of river between the Cascabel sites and Dudleyville. Between Dudleyville and the confluence of the San Pedro River with the Gila River there were only 111 ha of cottonwood-willow in about 15 km of river.

Discussion

Importance of Continuous Tracts of Riparian Vegetation and Oases

We tested four predictions related to the hypothesis that extensive river corridors are more important than smaller, isolated patches to en route migrants. We found little support for this hypothesis for most birds migrating across southeastern Arizona. First, the corridor sites did not host more species than oases; rather, the species richness of migrants tended to be greater in oases than in corridor sites. Second, abundant species in migration categories 4 and 5, such as Chipping Sparrows, White-crowned Sparrows, and Wilson's Warblers, showed no preference for corridor sites; instead, three species in these migration categories were associated with oases in 1 of 4 years. Other abundant migrants, such as Yellow Warblers (89% estimated migrants) and Yellow-rumped Warblers, used riparian sites regardless of size-connectivity. But three migration category 3 species with large components of migrants—Yellow-breasted Chats (65% estimated migrants), Summer Tanagers (21% estimated migrants), and Northern Rough-winged Swallows (breeding range extends north of 50°N) were consistently associated with corridor sites. Migrants of these three species probably account for fewer than 10% of the individuals migrating through the area.

Third, few differences in between-year variability of abundances of migrating birds were apparent among corridor and oasis sites. Both measures of between-year variability were greater in oases than corridor sites for four of the 33 species evaluated; three of these species had migrating as well as breeding components—Yellow-breasted Chats, Song Sparrows (79% estimated migrants) and Cedar Waxwings (breeding range extends north of 50°N). Variability is more closely tied to rarity of a species than to isolation of a site. Species that primarily breed far north of the study area were less abundant and more variable than species that breed closer to the study area.

There were no suggestions of differences in general resource abundance, as reflected in aerial insect biomass, between corridor and oasis sites. We acknowledge, however, that the abundances of foliage and bark insects, which are primary food sources of insectivorous songbirds, were not measured in this study. Finally, there were no differences in the body condition of birds captured along the San Pedro River, an oasis, and an intermediate site. We believed that the body condition methodology was powerful enough to detect differences if they existed because we were able to find patterns in body condition relative to migration distance and time of day.

Our study does not indicate that riparian sites along the San Pedro River are preferred over isolated oases by most migrating birds. Most long-distance migrants travel at night and follow paths that are strongly influenced by variable wind patterns. The use of the oases and intermediate sites as well as the river corridor by many migrating birds is consistent with the passage of migrants in broad fronts rather than along north-south corridors. The spatial arrangement of habitat patches and other landscape-level features may not be of major importance to birds that travel long distances (Fahrig & Paloheimo 1988). Similarly, transient passerines use oases in the Sa-

hara as "stepping stones" as they cross the desert (Bairlein 1988, 1992; Biebach 1990).

Oasis sites were higher in elevation and had less vegetation than riparian sites. In spite of these confounding factors, the patterns of species presence and abundance relative to size-connectivity were clear. More species occurred in oases even though shrub and canopy foliage volumes were smaller there, and the abundance of most migrating species did not differ between sites regardless of differences in foliage volume.

Exceptions to the Pattern

Although the continuous band of riparian vegetation along the San Pedro did not appear to function as a migration conduit for most species, it may for a few—namely Yellow-breasted Chats, Summer Tanagers, and Northern Rough-winged Swallows. Evidence is inconsistent for Song Sparrows—more variable in oases but more abundant in corridor sites in only 1 year—and weakly suggestive for Bullock's Orioles (89% estimated migrants)—more abundant in corridor sites for 2 years. It is possible that breeding birds prefer the river sites with greater foliage volumes, whereas migrating birds disperse among the different sites irrespective of size-connectivity and vegetation structure. Our study did not permit us to detect patterns for en route migrants in these species separately from the breeding components of the populations. Studies that incorporate radio telemetry to determine the residency periods of individual birds, thereby separating migrant from breeding components, would be useful in answering this question.

High Densities of Migrating Birds

The estimated densities of some species far exceed the breeding and migration densities reported elsewhere. The peak densities of Yellow Warblers (48.0 birds/ha) were much greater than reported breeding densities in southwestern riparian areas (San Pedro River, Arizona, peak of 5.7 birds/ha [Krueper 1992]; Rio Grande River, New Mexico, 3.3 birds/ha [Stahlecker et al. 1989] and 0.6 birds/ha [V. C. Hink & R. D. Ohmart, unpublished manuscript]; and at 2500 m in Colorado, 2.5 birds/ha [Knopf et al. 1988]), verifying that these stopover sites provide habitat for a great number of northbound migrants. Peak densities of Yellow Warblers, Wilson's Warblers (33.7 birds/ha), and Yellow-rumped Warblers (30.1 birds/ha) in this study also surpass estimates of densities during spring and fall migration along the Rio Grande (Yellow Warblers, <0.5 birds/ha in spring; Wilson's Warblers, 1.3 birds/ha in spring and 2.5 birds/ha in fall; Yellow-rumped Warblers, 5.1 birds/ha in spring and 22.1 birds/ha in fall; V. C. Hink and R. D. Ohmart, unpublished manuscript) and in a variety of habitats in the Chiricahua Mountains of southeastern Arizona (Yellow Warblers, 0.36 birds/ha in fall; Wilson's Warblers, 0.5 birds/ha in spring and 2.0 birds/ha in fall; Yellow-rumped Warblers, 3.0 birds/ha in spring and 1.1 birds/ha in fall; Hutto 1985*b*).

The stopover sites that host these great densities of spring migrants in southeastern Arizona may be limited. Less than 1% of the land area within the designated 10,000 km^2 is primarily cottonwood-willow vegetation, of which one-third is in oases and intermediate sites. All of the sites we surveyed may have been important to migrating birds, because suitable stopover habitat here is limited. We acknowledge that the patterns detected here may not hold in regions with more extensive cottonwood-willow riparian vegetation or fewer en route migrants.

Implications for Conservation and Management

We propose that all riparian areas in southeast Arizona, regardless of size-connectivity and vegetation structure, are important to en route migrants. In southeastern Arizona, riparian habitats make up a small fraction of the desert landscape. Here, all suitable stopover sites are important, regardless of the degree of isolation or connectivity. Traditional insights from habitat fragmentation studies defend the importance of large, continuous habitat patches but not of small, isolated patches. These insights are based on landscapes in which vast expanses of contiguous habitat have been fragmented by human influence. Our study presents an example of a system in which these traditional insights may not apply. Riparian vegetation in the southwestern United States is naturally disjunct compared with that of eastern deciduous forests, although habitat loss has unquestionably occurred (Minckley & Brown 1982). The riverine vegetation represents a small proportion of the landscape and is connected only along narrow ribbon-like bands; desert oases are often isolated from similar vegetation patches. Migrating birds in need of refueling resources are opportunistic, finding and using small, disjunct patches as well as larger more continuous patches.

Evidence of such high densities and limited habitat availability during migration accentuates the interdependence of geographic and political regions in providing resource requirements for birds throughout their life cycles. Many western North American migrants pass through or over Arizona. Arizona provides a critical link between breeding and wintering habitats of species that are highly dependent on the presence and condition of stopover sites along their migration routes. Riparian habitats in the southwestern United States have undergone extensive deterioration (Minckley & Brown 1982), invasions by exotic plants (Davis 1977; Ohmart & Anderson 1982), and alterations in hydrology and salinity that further threaten cottonwood-willow associations (Busch & Smith 1995). Further elimination or degradation of ripar-

ian stopover sites could adversely affect the breeding success of northern bird populations. In light of potential habitat limitation during migration and the specific results of this study, the protection of both small, disjunct riparian patches and extensive riverine tracts in western landscapes is imperative.

Acknowledgments

We acknowledge the contributions of K. Castelein, D. Hawksworth, and J. Sedgwick for their assistance in bird surveys and vegetation measurements. B. Allen-Johnson and D. McCullough assisted in insect samplings and in capturing and processing birds; N. Mays, T. Valone, and H. Dinkeloo also assisted in mistnetting birds. R. Waltermire provided expertise in ARC/INFO, and J. Richards provided programing support for density estimation. Housing and logistical support were provided by the Bureau of Land Management, San Pedro Riparian National Conservation Area; we especially thank E. Campbell, D. Krueper, G. Yensevich, and J. Whetsrone. The Nature Conservancy allowed access to their preserves, and housing; we especially thank D. Gori, M. Heitlinger, J. Cooper, and M. Apel. We also thank W. Brophy and Carlos, and B. and B. LaSelle, for access to and lands logistical support. J. and N. Hughes provided access through their land. We thank personnel of Arizona Game and Fish Department for providing the Arizona Statewide Riparian Mapping and Inventory database and two related databases. S. Sferra, D. Krueper, J. Ruth, and D. S. Dobkin provided comments on the manuscript. This work was funded by Grant-in-Aid no. I92071 of the Arizona Game and Fish Heritage Fund, by Grant no. 93-077 of the National Fish and Wildlife Foundation, and by the Biological Resources Division of the United States Geological Survey.

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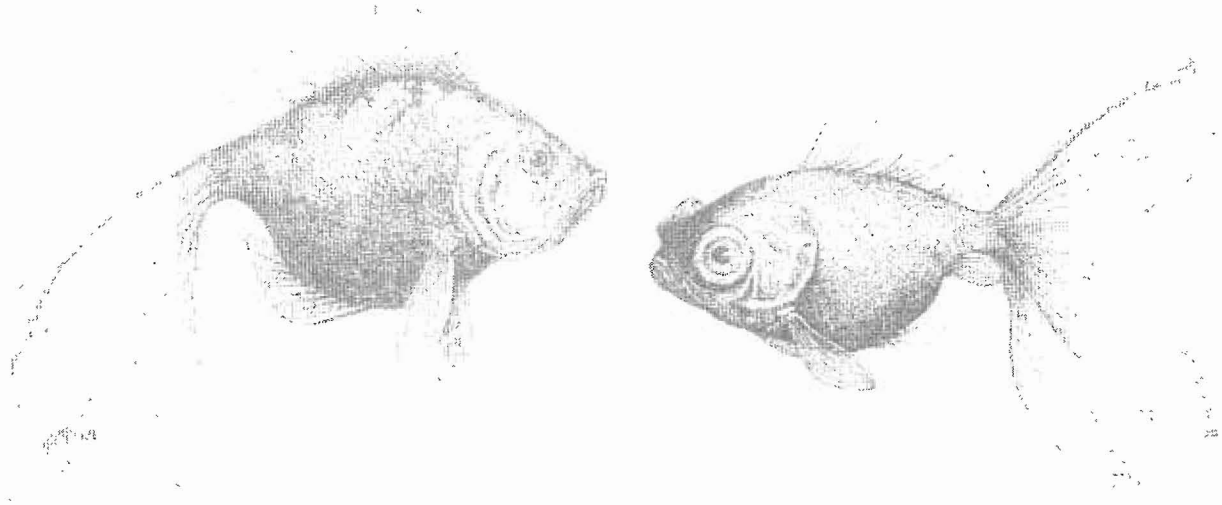
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