POPULATION TRENDS AND ECOLOGY
OF RIPARIAN AND WETLAND BIRDS

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Studies in Avian Biology No. 37:53–68

HABITAT USE OF WINTERING BIRD COMMUNITIES IN SONORA, MEXICO: THE IMPORTANCE OF RIPARIAN HABITATS

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Abstract. Riparian systems are dynamic and diverse despite their limited areal extent. They are especially important for breeding bird communities in southwestern US and are highly used as migratory corridors; however, their importance for wintering birds has not been assessed systematically. Information from 1,816 standard 10-min point counts was gathered at 85 locations in the State of Sonora, Mexico from sea level to 2,175 m during January and February 2004–2006. I detected 253 bird species across 14 vegetation types, including nine categories of riparian vegetation. Eighty percent of total species were detected in riparian habitats, and 72% were detected in non-riparian habitats. The mean number of species and individuals detected per count were significantly higher in riparian habitats than in non-riparian habitats for migratory species, but not for residents. A hierarchical classification analysis showed that riparian bird communities are different from those in non-riparian communities, and they contribute 22% of the species that comprise the regional avifauna, which is more than any other habitat type.

Key Words: habitat use, Mexico, neotropical migrant birds, riparian, Sonora, wintering.

USO DE HABITAT DE COMUNIDADES DE AVES INVERNANTES EN SONORA, MEXICO: IMPORTANCIA DE LOS HABITATS RIPARIOS

Resumen. Los sistemas riparios son dinámicos y diversos a pesar de su limitada cobertura espacial. Son especialmente importantes para las comunidades de aves que se reproducen en el Suroeste de los Estados Unidos y son usados extensamente como corredores migratorios; sin embargo, su importancia para las aves invernantes no se ha determinado de forma sistemática. Información de 1,816 conteos estándar de 10-minutos se obtuvo en 85 localidades en el Estado de Sonora, México, desde el nivel del mar hasta 2,175m durante Enero-Febrero de 2004–2006. Detecté 243 especies en 14 tipos de vegetación, incluyendo nueve categorías de vegetación riparia. Ochenta por ciento de las especies fueron registradas en hábitats riparios y 72% en hábitats no-riparios. El número promedio de especies e individuos detectados por conteo fue significativamente mayor en hábitats riparios que en no-riparios para las especies migratorias, pero no para las residentes. Un análisis de clasificación jerárquica mostró que las comunidades de aves riparias son diferentes a las comunidades de sitios no-riparios, y contribuyen con 22% de las especies que conforman la avifauna regional, la mayor contribución entre los hábitats estudiados.

Riparian habitats are dynamic and generally more biologically diverse than surrounding uplands, especially in arid regions (Hunt 1985). This faunal diversity is due to the presence of water, high productivity, and abundance of habitat edge, which is maximized by the linear shape of riparian habitats (Gregory et al. 1991). In the arid Southwest, riparian systems support at least 80% of all wildlife species (Hunt 1985, USDI Bureau of Land Management 1998). They support the highest densities of small mammals (Andersen 1994) and richest communities of butterflies (Fleishman et al. 1999, Nelson and Anderson 1999). Riparian habitats support some of the highest densities and most species-rich avian communities in the US (Knopf et al. 1988) and western Mexico (Hutto 1995), and influence the ecological dynamics of adjacent upland habitats (Strong and Bock 1990, Farley et al. 1994a, Skagen et al. 1998, Powell and Steidl 2000). In addition, many riparian bird species are riparian obligates, which is significant in light of the very small percentage (generally <1%) of land area composed of riparian habitat (Mosconi and Hutto 1982, Knopf 1985, Schmitt 1976, Hubbard 1971).

The importance of riparian systems during periods of migratory passage and as wintering habitats has begun to receive more attention, and we know these periods may be equally or more important than the breeding season in terms of population regulation (Fretwell 1972, Sherry and Holmes 1995, Hutto 1998). During the energetically demanding migration period, landbirds have to make important choices about which stopover habitats will provide enough food, cover, and water to enable a rapid and safe replenishment of fuels (Moore and Simons 1992). Mortality rates may be considerable (especially for young birds) as migrants compete for resources while avoiding potential predators in unfamiliar locations. We currently know little about the specific habitat needs of migrants. Studies have shown, however, that landbirds use riparian habitats disproportionately more frequently during migration. This is especially the case during spring migration, when the productivity of riparian habitats is higher than that of the surrounding uplands (Skagen et al. 1998, Finch and Yong 2000, Skagen et al. 2005, Kelly and Hutto 2005). Understanding migration ecology is now considered key to the conservation of migrant landbird populations (Moore et al. 1995, Hutto 2000, Heglund and Skagen 2005).

Information on the importance of riparian systems compared to other habitat types for wintering birds is also scant and is based largely on occasional species- and site-specific records (Russell and Lamm 1978, Terrill 1981, Rosenberg et al. 1991, USDI Bureau of Land Management 1996), Christmas Bird Counts, and studies that happen to include the complete annual cycle of riparian birds (Anderson and Ohmart 1977, Wells et al. 1979, Strong and Bock 1990, Farley et al. 1994a). In the only published studies focused on wintering bird distribution among a variety of vegetation types in western Mexico, the abundance of Neotropical migrants in riparian habitats and gallery forests are among the highest recorded (Hutto 1980, 1995), thus suggesting that riparian corridors are important for wintering birds. During winter, riparian habitats may be especially important in the Sonoran Desert, which lies at the northern edge of the wintering range of many western North American migratory bird species, and which represents the primary wintering area for short-distant migrant species from the central and western US. In lowland Sonora, the only other habitats for wintering birds are drier, hotter, and structurally less diverse.

Riparian zones are known to be habitats of critical conservation concern worldwide, including the southwestern US and northwestern Mexico. These habitats, which have always constituted a small component of arid landscapes, have been reduced drastically and are now fragmented and modified by desiccation, dam construction, water diversion, invasion of exotic species, overgrazing, and other factors.

In this study I sought to determine how significant riparian areas are for wintering bird communities in the state of Sonora, Mexico. Specifically, I addressed two main questions: (1) are wintering bird communities associated with riparian habitats significantly different from those associated with upland habitat types in the State of Sonora, and; (2) are the riparian habitats important in terms of their contribution to regional diversity? In order to answer these questions, I examined the community composition and species abundance patterns of wintering birds across the complete array of extant vegetation types in the state, and determined the value of each vegetation type in terms of its contribution to regional avifaunal diversity.

METHODS

STUDY AREA

Sonora is the second largest state in Mexico, covering 179,156 km^2. It is located at the northwestern corner of mainland Mexico between 26°18′ and 32°29′N, and 108°25′ and 115°03′W. The geographical features of the state make it rich and biologically diverse. Sonora is located at the latitude where the tropics meet the southern limit of the temperate region, and includes elements from both regions. It is composed of a complex mix of landscapes with elevations from sea level to 2,630 m. The lowland plains are vegetated primarily by desert and xeric shrubs. At middle elevations the northernmost extensions of tropical deciduous forest are found in the south and southeastern part of the state. In the highlands a diversity of oak woodlands and mixed coniferous forest along the eastern section border the state of Chihuahua. Riparian communities composed mainly of associations of cottonwood (*Populus* spp.) and willows (*Salix* spp.) are present discontinuously along the river courses, and mangroves (*Avicennia, Conocarpus, Laguncularia,* and *Rhizophora*) are distributed in isolated patches along the coast of the Sea of Cortés (INEGI 2000). Because of these characteristics and its location, Sonora supports a diverse community of breeding, migrating, and wintering landbirds of western North America (Kelly and Hutto 2005)

Rivers and subsurface water continue to play an important role in the economy of the state. Most rivers originate in the Sierra Madre Occidental and run to the coastal plains and into the Sea of Cortés. The most important permanent flows are from north to south and east to west, and include the Colorado, Sonoyta, Altar, Magdalena, San Miguel, Sonora, Moctezuma, Bavispe, Mátape, Sahuaripa, Yaqui, Cedros, and Mayo Rivers (Bojórquez-Tapia et al. 1985). Several large dams create important impoundments to supply water for the irrigation of extensive agricultural fields in the lowlands. Sonora is also one of Mexico's main producers of high quality beef cattle; fifteen million hectares, including pasturelands, woodlands, shrublands, and prairies with buffelgrass (*Pennisetum ciliare*) are used for raising and breeding beef cattle, having potential negative impacts, especially on the composition and structure of riparian habitats due to overgrazing (Saab et al. 1995).

Survey Protocols

During January and February of 2004, 2005, and 2006, avian surveys were conducted at 85 locations in 14 vegetation types following INEGI (2000) and nine riparian associations throughout Sonora, ranging from sea level to elevations over 2,000 m (Table 1). Non-repeated and randomly selected standard 10-min point counts with unlimited radius were conducted between 0700 and 1100 H. Most aquatic species and birds flying over were recorded but not used in any of the analysis. Raptors, swallows, and other aerial species were recorded only if they were perched on the vegetation or the ground within the point count area (Hutto et al. 1986, Ralph et al. 1993). Unidentified species, such as hummingbirds and *Empidonax* species, were grouped and included on the list as unknown hummingbird and *Empidonax* sp., respectively. The location and distance from the observer to each detected bird were mapped; the information gathered was entered into Excel and was managed for the analysis with SPSS 11.5.1 software package (SPSS 2002). Only the detections within a radius of 25 m from the observer were used in the analyses. Although much information was unused by restricting the data in this way, and rarer and shy or cryptic species may have been missed as a result, it was done to decrease the potential error caused by the inclusion of individuals detected in an adjacent but different habitat type and to decrease bias due to inherent differences in detectability of birds among habitats.

Analyses

Species were assigned to one of three residency status categories—residents, migrants, and partial migrants. Residents are those species that remain in the same area year-round. Migrants are those species that move far from their breeding areas and occupy a completely different geographical region to the south during the winter, with no overlapping populations (all long-distance migrant species). Partial migrants are those species that move seasonally but not for distances of such magnitude. As a consequence, in the southern portions of some species' distributions, populations of resident, transient, and wintering individuals could overlap during migration and winter. The species were assigned to one of these residency status categories based on published information (van Rossem 1945, Howell and Webb 1995, Russell and Monson 1998), and personal experience (Appendix 1).

The total number of species and individuals detected, the mean number of species and individuals per count, and the percentage of resident, partial migrants, and migrant species were computed for each vegetation type and riparian association. ANOVA was performed to compare the mean number of species and individuals detected in point counts (25-m radius) by residency status, as well as the number of individuals detected for each species to determine the ones showing significant differences between non-riparian and riparian habitats. A chi-square test was performed to examine differences in the mean percentage of species recorded belonging to the residency status groups between riparian and non-riparian habitats. I also used a contingency analysis of species richness to look for differences in the expected proportions of species with preferences for non-riparian and riparian habitats, as well as those with no preferences for either habitat.

To determine if wintering bird communities associated with riparian habitats were significantly different from those associated with other habitat types, I used two classification methods. A hierarchical classification method (cluster analysis; Manly 2004) was used to compare similarities among bird communities in each habitat type, producing a dendrogram (based on presence-absence data and using complete linkage and the Ochiai measure). Secondly, a two-way indicator species analysis (TWINSPAN; McCune and Mefford 1997) was used, based on the concept that samples which constitute a group will have a corresponding set of species that characterize that group (indicator species). TWINSPAN finds the relationships between species and samples through correspondence analysis ordination. It initially classifies the samples into two groups and then refines the classification through detrended correspondence analysis (DCA), finding the indicator and associated species for the resulting groups, and based on those species, regroups iteratively within the groups into smaller clusters until a limit is met. An indicator species is the species (or the group of species) present in all of the clustered vegetation types; an associated species is present primarily in a given group although it could also be present in other vegetation types or associations. With TWINSPAN I defined the species that characterize the general vegetation groups identified by the dendrogram produced in the clustering technique. In order to perform these analyses, I used the software PC-ORD for Windows, version 3.17 (McCune and Mefford 1997).

TABLE 1. LOCATIONS AND VEGETATION TYPES SAMPLED IN SONORA, MEXICO, DURING JANUARY AND FEBRUARY (2004, 2005, AND 2006).

Location	Vegetation sampled	Elevation (m)	Latitude N	Longitude W	N Counts
Aconchi—Río Sonora	Riparian cottonwood-mesquite, cottonwoods, cottonwood-willow	588	29°48′14″	110°13′37″	72
Aconchi, Río Sonora, Agua Caliente Springs	Riparian mesquite	606	29°50′26″	110°16′33″	1
Aribabi—Sierra Alta	Highland oaklands	1,490	30°03′25″	109°06′10″	30
Arroyo La Poza	Riparian mesquite	188	28°52′04″	110°57′43″	15
Bámori—Río Sahuaripa	Riparian cottonwood-willow, willow, willow-mesquite	516	28°51′45″	109°10′03″	76
Baviácora—Río Sonora	Riparian cottonwoods, cottonwood-willow	554	29°43′27″	110°10′29″	69
Cerro La Pintada—Tetabejo	Sarcocaulescent scrubland	188	28°34′41″	111°00′43″	20
Caborca	Sarcocrassicaulescent scrubland	324	30°47′35″	112°13′25″	30
Cajón de Onapa, Río Sahuaripa	Riparian mesquite, willow Willow-mesquite	587	28°44′09″	109°07′59″	61
Camino a San Lázaro-San Antonio	Thornscrub	1,189	31°03′00″	110°38′32″	5
Camino a San Marcial	Grasslands	326	28°34′53″	110°15′18″	20
Cañón de Evans, road Cananea—Bacoachi	Riparian sycamores	1,372	30°56′34″	110°07′37″	22
Cañón de Nacapule, San Carlos, Nuevo Guaymas	Oasis (*Washingtonia* and *Ficus*)	111	28°00′50″	111°02′57″	21
Coteco	Coastal sarcocaulescent scrubland	22	26°34′35″	109°18′11″	28
Cucurpe—Río San Miguel	Riparian cottonwoods	849	30°19′20″	110°42′35″	14
Desv. Playa San Nicolás	Coastal sarcocaulescent scrubland	5	28°49′43″	111°48′19″	37
Ejido Ganadero Puente El Tigre, Guaymas	Sarcocaulescent scrubland	82	28°06′22″	110°59′27″	22
El Carrizo, Rancho San Darío	Grasslands, subtropical scrub	730	30°02′59″	111°12′19″	3
El Chiculi, Hornos, Río Yaqui, Sonora	Riparian willow-mesquite-chino	57	27°46′26″	109°53′52″	20
El Cochito—km. 179, road Agua Prieta-Moctezuma	Microphyllous scrubland	1,164	31°10′52″	109°33′53″	30
El Llano—Moctezuma	Thornscrub	638	29°43′25″	109°39′04″	9
El Resbalón—Sahuaripa	Tropical deciduous forest	654	29°07′57″	109°16′51″	33
El Sahuaral, San José de Guaymas	Coastal sarcocaulescent scrubland	5	27°59′15″	110°50′30″	22
Estero del Soldado, San Carlos, Nuevo Guaymas	Mangroves	0	27°57′23″	110°58′53″	17
Estero Paraíso—Punta Checa	Mangroves	0	29°02′21″	112°09′59″	6
Estero Santa Cruz—Kino	Mangroves	1	28°47′49″	111°52′34″	16
Estero Santa Rosa—Punta Chueca	Mangroves	0	28°58′37″	112°09′48″	16
Granados—Río Bavispe	Riparian cottonwood-willow	540	29°51′46″	109°18′01″	20
Huásabas—Río Bavispe	Riparian cottonwood-willow	554	29°55′13″	109°17′31″	10
Jécori—Río Moctezuma	Riparian cottonwoods	716	29°58′01″	109°45′39″	67
La Aduana	Tropical deciduous forest	602	27°01′53″	109°00′34″	15
La Majada, between Moctezuma-Mazocahui	Lowland oaklands	1,011	29°42′57″	109°50′45″	31
La Mesa del Campanero	Highland coniferous forest	2,139	28°22′12″	109°01′50″	19

TABLE 1. CONTINUED.

Location	Vegetation sampled	Elevation (m)	Latitude N	Longitude W	N Counts
Los Alisos	Highland oaklands, Riparian sycamores	1,358	30°33′09″	109°39′21″	35
Los Torreones	Subtropical scrub	857	29°17′23″	109°54′12″	5
Magdalena, road Magdalena-Imuris	Sarcocrassicaulescent scrubland	784	30°36′18″	110°57′37″	28
Mazatán, ca. 10 km W	Subtropical scrub	517	29°00′00″	110°13′45″	1
Mesa del Toro-Ejido Ignacio Zaragoza, Cananea	Grasslands	1,556	31°03′38″	110°03′53″	30
Sierra Pinacate (between Elegante and Tecolote)	Vegetation of sandy deserts	219	31°51′21″	113°21′28″	10
Sierra Pinacate Crater Cerro Colorado	Vegetation of sandy deserts	185	31°55′08″	113°18′05″	10
Puerto Peñasco	Vegetation of sandy deserts	16	31°21′36″	113°27′41″	20
Rancho Monte Alto-road to Puerto Libertad	Coastal sarcocaulescent scrubland	131	29°18′38″	111°51′26″	31
Rancho El 44, between Cobachi and Road to Yécora	Subtropical scrub	431	28°47′22″	110°21′28″	1
Rancho El Perú	Subtropical scrub	709	30°20′38″	111°04′39″	10
Rancho La Cuesta, km 94 road to Yécora	Subtropical scrub	391	28°35′44″	110°11′00″	1
Rancho La Noria, N	Sarcocaulescent scrubland	352	29°03′01″	110°37′56″	10
Rancho Los Cuervos, N El Carrizo)	Subtropical scrub	715	30°06′17″	111°12′37″	2
Rancho Piedras Negras (Carretera Minera Nyco)	Sarcocaulescent scrubland	352	29°16′16″	111°05′18″	18
Rancho San Darío ca. Carrizo	Subtropical scrub	724	30°04′18″	111°14′27″	1
Rancho San Fermín, ca. Cobachi	Subtropical scrub	549	28°55′14″	110°07′55″	1
Reserva de la Biosfera Pinacate	Vegetation of sandy deserts	167	31°48′16″	113°17′45″	30
Río Altar, Tubutama	Riparian cottonwoods	634	30°53′09″	111°27′39″	9
Río Cuchujaqui	Riparian baldcypress-willow	239	26°56′29″	108°53′05″	21
Río Cocóspera — Rancho Aribabi	Riparian cottonwood-willow, Cottonwood-mesquite, cottonwoods	974	30°51′15″	110°39′51″	40
Río Cuchujaqui at El Mentidero	Riparian baldcypress-willow	227	26°54′44″	108°54′46″	9
Río Cuchujaqui at La Isleta	Riparian baldcypress-willow	224	26°54′38″	108°54′51″	8
Río Matape — San José de Pimas	Riparian mesquite, willow, willow-mesquite	350	28°43′02″	110°20′50″	35
Río Mayo — Presa Mocúzari	Riparian willow-mesquite-chino, tropical deciduous forest	98	27°12′57″	109°06′47″	20
Río Mayo — Tetapeche	Riparian willow-mesquite-chino	49	27°12′23″	109°21′35″	19
Río San Miguel, Rancho San Esteban	Riparian mesquite	285	29°17′13″	110°52′02″	30
Río Santa Cruz, San Lázaro	Riparian cottonwood-mesquite, cottonwood-willow	1,284	31°09′03″	110°38′33″	19
Río Yaqui, Ónavas	Riparian mesquite	155	28°27′45″	109°32′01″	1
Río Yaqui, Sitio Nochebuena	Riparian willow-mesquite	203	28°47′45″	109°38′41″	1

TABLE 1. CONTINUED.

Location	Vegetation sampled	Elevation (m)	Latitude N	Longitude W	N Counts
Río Yaqui, San Antonio de la Huerta	Riparian willow-mesquite	187	28°37′44″	109°36′27″	1
Río Yaqui, Tónichi	Riparian willow-mesquite	166	28°35′37″	109°34′08″	2
Río Yaqui, S El Novillo	Riparian willow-mesquite	214	28°49′43″	109°37′46″	3
Río Yaqui, Soyopa	Riparian willow-mesquite, mesquite	188	28°45′02″	109°37′32″	4
San Carlos—ca. Cañón de Nacapule	Sarcocaulescent scrubland	47	27°58′58″	111°02′24″	31
San Ignacio—Terrenate	Riparian cottonwoods	784	30°42′51″	110°55′27″	19
San Javier	Tropical deciduous forest	813	28°34′58″	109°44′51″	32
San José de Pimas	Thornscrub	384	28°43′54″	110°21′49″	21
San Lázaro, S	Lowland oaklands	1,279	31°05′49″	110°39′00″	6
San Miguel, road to Punta Chueca	Sarcocaulescent scrubland	177	28°57′51″	112°03′29″	62
Santa Cruz	Grasslands, highland oaklands	1,417	31°19′56″	110°36′30″	6
Sáric—Río Altar	Riparian cottonwood-mesquite, cottonwoods, mesquite, willow, cottonwood-willow	786	31°09′25″	111°21′11″	19
Sierra La Elenita, Cananea	Highland coniferous forest	1,920	31°00′30″	110°23′06″	30
Sierra Ladrilleros-El Pinacate	Sarcocaulescent scrubland	154	31°44′28″	113°18′23″	30
Sierra Mazatán	Lowland oaklands	1,357	29°05′38″	110°12′54″	9
Sierra Mazatán, NE Presa Teópari	Riparian mesquite	663	29°13′15″	110°04′44″	22
Terapa—Río Moctezuma	Riparian cottonwood-mesquite, cottonwood-willow, mesquite, cottonwoods	565	29°40′41″	109°39′04″	88
Tónichi	Riparian willow-mesquite	186	28°35′42″	109°34′05″	31
Tubutama - Río Altar	Riparian cottonwoods, cottonwood-willow	684	30°53′17″	111°27′21″	15
Unámichi—Río Sonora	Riparian cottonwood-willow	1,048	30°39′39″	109°58′58″	20
Yécora	Highland coniferous forest	1,538	28°22′54″	108°54′39″	11
Yecora—La Palmita	Highland oaklands	1,462	28°22′19″	109°03′59″	21

RESULTS

Survey data were gathered on 1,816 standard 10-min point counts (944 in non-riparian and 872 in riparian sites, respectively), at 85 locations from sea level to 2,175 m (Table 1). A total of 32,570 individuals of 253 bird species was recorded across all vegetation types. Eighty percent of total species (203) were recorded in riparian associations, and 72% (183) in all other non-riparian vegetation types.

The number of bird species in riparian vegetation was greater than in any other vegetation type. A tally of species richness by vegetation types shows that species richness in all non-riparian vegetation types was less than 65 species per habitat type, with all but four having less than 50 species per category. In contrast, riparian habitats for the most part were richer, with all but two riparian vegetation types having 75 or more species per type, and all but three having more than 95 species per category (Table 2).

By limiting data analyses to observations within a 25-m radius, a total of 8,237 individuals of 168 species was detected (82 residents, 33 partial migrants, and 53 migrants [see Appendix 1 for the residency status and number of individuals recorded for the most common species]). The mean numbers of species and individuals (all groups combined) detected per count in riparian habitats were significantly higher than in non-riparian habitats (Table 3). The same pattern held for mean number of species and individuals per count within the migrant and partial migrant groups, which also had significantly higher numbers in riparian habitats. In contrast, I found no significant differences in mean number of species or individuals per count between riparian and non-riparian habitats for resident species.

I found no statistically significant differences in the proportions of residents, migrants, and partial migrants in each count between riparian and non-riparian vegetation types ($\chi^2 = 4.105$, df = 2, P = 0.128; Fig. 1a). However, the general pattern suggests that the proportion of total resident species was higher in non-riparian habitats, while the proportions of total partial migrants and migrant species were higher in riparian vegetation types. When partial migrants and migrants were combined into a single migrant group and compared with residents, the difference became significant ($\chi^2 = 4.083$, df = 1, P = 0.03; Fig. 1b), with a greater proportion of resident species in non-riparian habitats and a greater percentage of migrant species in riparian habitats. The contribution

TABLE 2. VEGETATION TYPES, NUMBER OF POINTS SAMPLED, AND NUMBER OF SPECIES RECORDED IN SONORA, MEXICO, DURING JANUARY AND FEBRUARY (2004, 2005, AND 2006).

Vegetation Type	Counts/species	Elevation range (m)
Non-riparian vegetation		
Mangroves	54/53	Sea level (0)
Coastal sarcocaulescent scrubland	138/58	(0–234)
Vegetation of sandy deserts	70/17	(3–231)
Microphyllous scrubland	30/17	(1,159–1,217)
Tropical deciduous forest	79/61	(102–983)
Sarcocrassicaulescent scrubland	58/20	(307–824)
Thornscrub	45/37	(184–1,189)
Subtropical scrub	25/43	(391–878)
Sarcocaulescent scrubland	152/47	(13–551)
Grasslands	83/14	(316–1,592)
Low oaklands	54/41	(970–1,250)
High oaklands	75/61	(1,400–2,010)
Highland coniferous forest	60/37	(1,525–2,175)
Oases	21/37	(50–233)
Non-riparian vegetation (general)	944/183	(Sea level–2,175)
Riparian vegetation		
Willow–mesquite-chino	57/96	(36–102)
Mesquite desert riparian	89/108	(117–823)
Willow-mesquite	91/96	(166–823)
Willow	104/96	(348–840)
Willow-baldcypress (*Salix-Taxodium*)	31/75	(222–277)
Cottonwood-willow	230/125	(527–1,282)
Cottonwood-mesquite	23/45	(555–1,305
Cottonwood	214/125	(505-1,288)
Sycamores (*Platanus*)	33/40	(1,322–1,402)
Riparian sites (general)	872/203	(33–1,402)

TABLE 3. ANOVA RESULTS COMPARING THE MEAN NUMBER OF SPECIES AND INDIVIDUALS DETECTED IN POINT COUNTS (25-M RADIUS) BY RESIDENCY STATUS.

Residency status	General mean (N = 1,816)	Non-riparian habitats (N = 944)	Riparian habitats (N = 872)	F	P
Species					
All species	2.55	1.93	3.24	164.40	<0.01
Residents	1.32	1.36	1.29	1.15	0.28
Partial migrants	0.59	0.32	0.88	234.99	<0.01
Migrants	0.64	0.25	1.06	424.78	<0.01
Individuals					
All species	4.29	3.34	5.33	58.43	<0.01
Residents	2.06	2.15	1.94	1.92	0.17
Partial migrants	1.12	0.65	1.63	46.14	<0.01
Migrants	1.11	0.53	1.74	106.41	<0.01

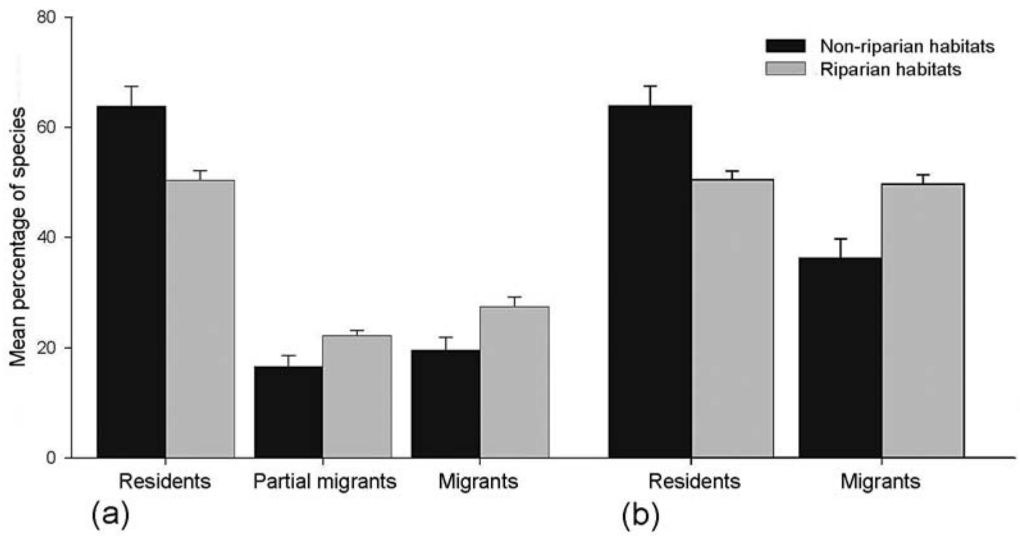

FIGURE 1. Mean percentage of bird species by residency status in riparian and non-riparian habitat groups in Sonora (mean percentage of species recorded for resident, partial migrant, and migrant species per habitat type); (a) considering the three residency status groups; (b) considering partial migrants and migrants together as a single group.

of migrant and partial migrant species and individuals to the avifauna in riparian sites is particularly important, as is the contribution of resident species and individual to non-riparian habitats (Fig. 2 a, b). Numerically speaking, migrants are an important element of the wintering avifauna of riparian environments in the state of Sonora.

However, such generalizations could be misleading because species respond ecologically and behaviorally in different ways, and they have to be assessed individually. Of the 168 species noted above, 59 (35.1%) showed significant differences in their abundances between the riparian and non-riparian habitats; 18 (10.7%) were primarily associated with non-riparian habitats, and 41 (24.4%) with riparian habitats. Considering the community as a whole, the contingency analysis (chi-square test) shows that the residents are overrepresented in the non-riparian habitats and the frequency of the migrants is significantly higher in the riparian environments ($\chi^2 = 13.72$, df = 4, P = 0.008; Table 4). If the analysis is limited to those species with at least 20 detections (66 species) to avoid the influence of those species with low sample sizes, the differences are even more evident ($\chi^2 = 18.35$, df = 4, P = 0.001; Table 4).

The dendrogram resulting from the cluster analysis (Fig. 3) separates the habitats into three main groups. The first, near the bottom of the dendrogram, represents highland habitats, the second clusters desertscrub habitats and mangroves, and the last, at the top of the

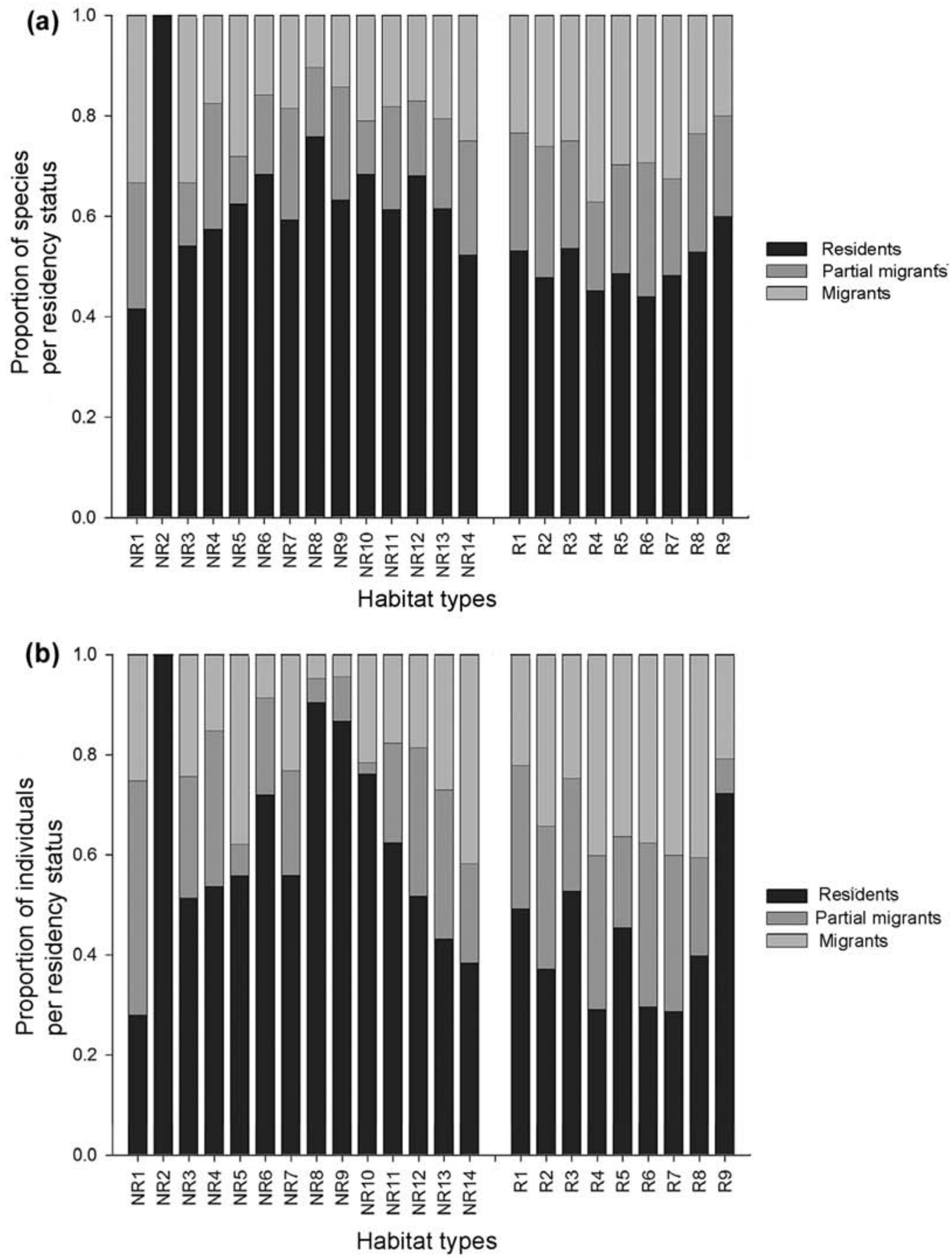

FIGURE 2. Proportional contribution of residents, partial migrants, and migrants to (a) species richness, and (b) total individuals for each riparian and non-riparian habitat (habitat types: NR = non-riparian: 1 = mangroves, 2 = microphyllous scrubland, 3 = oasis, 4= coastal sarcocaulescent scrubland, 5 = subtropical scrub, 6 = tropical deciduous forest, 7 = thornscrub, 8 = sarcocrassicaulescent scrubland, 9 = sarcocaulescent scrubland, 10 = vegetation of sandy deserts, 11 = grasslands, 12 = low elevation oaklands, 13 = high elevation oaklands, 14 = highland coniferous forest; R= riparian: 1= willow-mesquite-chino, 2 = willow-mesquite, 3 = mesquite, 4 = willow, 5 = baldcypress-willow, 6 = cottonwood, 7 = cottonwood-willow, 8 = cottonwood-mesquite, 9 = sycamores.)

TABLE 4. RESULTS OF CONTINGENCY ANALYSIS OF SPECIES RICHNESS: DIFFERENCES BETWEEN NON-RIPARIAN AND RIPARIAN HABITATS.

	All species (N = 168)				Species with at least 20 detections (N = 66)			
Status	N significantly different	Non-riparian species	Riparian species	Total	N significantly different	Non-riparian species	Riparian species	Total
Residents	53 (53.2)	15 (8.8)	14 (20.0)	82 (15.0)	18 (7.5)	11 (5.5)	9	38
Partial migrants	24 (21.4)	1 (3.5)	8 (8.1)	33 (7.1)	7 (2.6)	0 (5.3)	6	13
Migrants	32 (34.4)	2 (5.7)	19 (12.9)	53 (5.9)	1 (3.0)	2 (6.1)	12	15
Total	109	18	41	168	26	13	27	66

Note: Expected frequencies shown in parenthesis.

dendrogram, groups riparian associations (except for the sycamores [*Platanus* sp.] which are grouped within the highland habitats) with tropical deciduous forest and oases. The microphyllous scrub habitat stands by itself and independent of the other groups as a result of its poor avifauna (only six species recorded).

The contribution of these grouped habitat types to regional diversity was assessed by determining the species that were found exclusively in a particular habitat or group of habitats and would not occur if that habitat were not present in the region. Based on these criteria, riparian habitats contributed the most species unique to the regional avifauna, followed in importance by highlands, desertscrub habitats, tropical deciduous forest, oases, and mangroves (Fig. 3).

The two-way indicator species analysis (TWINSPAN) results identified those indicator and associated species that characterize each one of the vegetative clusters produced by the hierarchical analysis. It defined the existence of six groups of bird species: (1) highland vegetation species, (2) microphyllous scrubland, (3) desert scrubby vegetations and grasslands, (4) mangroves, (5) lower elevation riparian associations, and (6) tropical deciduous forest and oases (Table 5).

DISCUSSION

Riparian environments have been identified as a key habitat component of ecological systems through maintenance of dynamic ecological processes along a gradient of landscapes, which links wildlife, vegetation, and soils within terrestrial systems. They are very productive systems and represent the most valuable habitat for wildlife in general, especially in the xeric regions of the world. The results of this study support this concept.

Cottonwood riparian woodlands and their associations have been identified as the most important habitat for birds in the southwestern US (Hubbard 1971, Stamp 1978, Strong and Bock 1990; Farley et al. 1994a, b; Skagen et al. 1998), and in every case they support the highest number of species and/or densities among the studied habitats. Based on the above-cited papers that included a list of the species recorded in riparian habitats, the percentage of those riparian species in the US that were also found wintering in Sonoran cottonwood riparian associations in this study ranged from 63–86%. The differences are due primarily to resident species with distributional ranges restricted to the United States or to species whose distribution does not include the

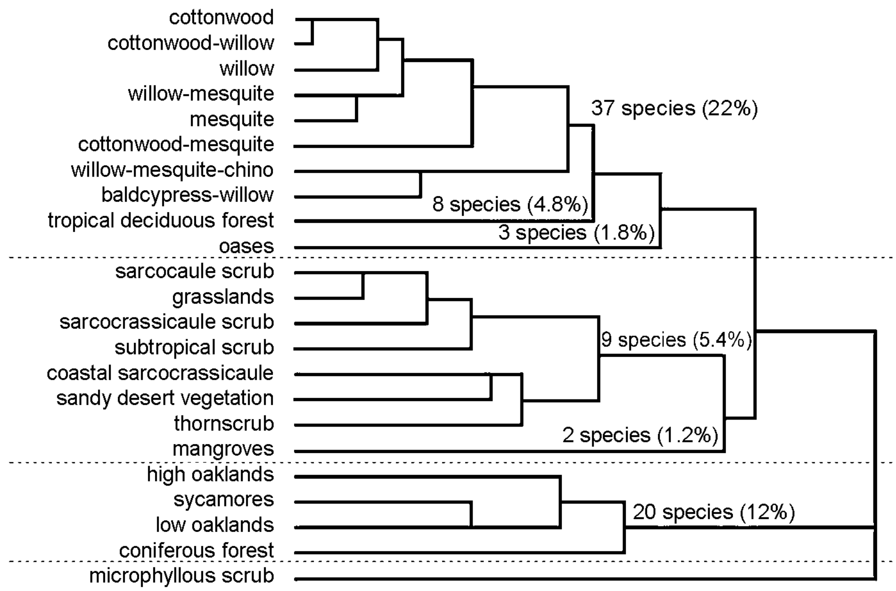

FIGURE 3. Grouping of the vegetation types resulting from a cluster analysis based on the wintering avifauna in Sonora, Mexico, based on presence-absence data. (The number of species and percentages represent the number of species unique to that habitat or cluster of habitats).

US. Although we do not know the details of connectivity among the populations involved here, the high proportion of riparian-breeding species that also use riparian associations (and mostly lowland riparian areas) in the winter in northwestern Mexico indicates the importance of these habitat types for wintering migrants. Knowing that riparian environments are important for wintering birds, an additional question might be asked: how unique are riparian bird communities during the winter in comparison with communities in other habitat types? Are they important in terms of their contribution to regional diversity?

Cluster analysis results show an interesting pattern in the composition of the avian communities—an elevational gradient separates the highland habitats from the low elevation ones, and a gradient of humidity separates dry habitat communities from ones associated with more humid riparian areas. This pattern is in accordance with the TWINSPAN ordination, which in the highlands grouped a set of 19 coniferous forest bird species, a set of 17 species in drier areas such as grasslands and scrubby vegetations, dry forest and oases shared 12 species, and the lower elevation riparian associations were typified by a group of 24 species. Mangroves had a combination of four species that defined its community.

It is important to note that the riparian vegetation in the highlands is represented by limited extensions of sycamores adjacent to oak woodlands, which explains the composition of their bird community and the affinity with this group of habitats. Tropical deciduous forest and the oases clustered near the riparian associations; they share a good number of species, maybe as a result of the extension of tropical dry forest tree species farther north along the riparian corridors, as well as the effect of the elevational gradient previously mentioned.

My approach to assessing the contribution of riparian habitats to regional diversity is similar to an approach advocated by Hylander (2006). My results indicate that riparian habitats contribute substantially to regional diversity (22% of species) in Sonora, Mexico, and are consistent in general with Sabo and Soykan's (2006) findings which state that on average, the percentage of unique riparian species is 24%, and that riparian zones increase regional richness by 38%. My results indicate that wintering bird communities in riparian habitats are richer in comparison to adjacent uplands, and of the 134 species recorded in our counts, 37 were exclusive to riparian habitats. These differences are due mostly to the increased number of migrant and partial migrant species and individuals detected in riparian habitats.

Several important factors may explain the importance of riparian habitats to winter avian diversity in Sonora. Riparian habitats provide structural complexity, which is important for

TABLE 5. RESULTS OF A TWO-WAY INDICATOR SPECIES ANALYSIS (TWINSPAN) TO IDENTIFY INDICATOR AND ASSOCIATED SPECIES CHARACTERIZING THE HABITAT CLUSTERS PRODUCED BY THE HIERARCHICAL ANALYSIS.

HIGHLAND VEGETATION CLUSTER
- **Indicator species:**
  - Acorn Woodpecker (*Melanerpes formicivorus*)
- **Associated species:**
  - Sharp-shinned Hawk (*Accipiter striatus*)
  - Band-tailed Pigeon (*Patagioenas fasciata*)[a]
  - White-eared Hummingbird (*Hylocharis leucotis*)
  - Hairy Woodpecker (*Picoides villosus*)
  - Williamson's Sapsucker (*Sphyrapicus thyroideus*) [b]
  - Hutton's Vireo (*Vireo huttoni*)
  - Mexican Chickadee (*Poecile sclateri*)
  - Eastern Bluebird (*Sialia sialis*)
  - American Robin (*Turdus migratorius*)
  - Brown Creeper (*Certhia americana*)
  - Olive Warbler (*Peucedramus taeniatus*)
  - Crescent-chested Warbler (*Parula superciliosa*)
  - Townsend's Warbler (*Dendroica townsendi*)
  - Hermit Warbler (*Dendroica occidentalis*) [a]
  - Grasshopper Sparrow[b] (*Ammodramus savannarum*)
  - Yellow-eyed Junco (*Junco phaeonotus*)
  - Pine Siskin (*Carduelis pinus*)
  - Scott's Oriole (*Icterus parisorum*)

MICROPHYLLOUS SCRUBLAND
- **Indicator species**:
  - Rock Wren (*Salpinctes obsoletus*)
- **Associated species**: none

DESERT SCRUBBY VEGETATION AND GRASSLANDS
- **Indicator species**:
  - Green-tailed Towhee (*Pipilo chlorurus*)
- **Associated species:**
  - Gambel's Quail (*Callipepla gambelii*)
  - American Kestrel (*Falco sparverius*)
  - Common Ground-Dove (*Columbina passerina*)
  - Broad-billed Hummingbird (*Cynanthus latirostris*) [c]
  - Costa's Hummingbird (*Calypte costae*) [a]
  - Say's Phoebe (*Sayornis saya*)
  - Brown-crested Flycatcher (*Myiarchus tyrannulus*)
  - Vermilion Flycatcher (*Pyrocephalus rubinus*)
  - Loggerhead Shrike (*Lanius ludovicianus*) [b c]
  - Horned Lark (*Eremophila alpestris*)
  - Black-capped Gnatcatcher (*Polioptila nigriceps*) [a]
  - Bendire's Thrasher (*Toxostoma bendirei*) [a b c]
  - Phainopepla (*Phainoepla nitens*)
  - Vesper Sparrow (*Pooecetes gramineus*)
  - White-crowned Sparrow (*Zonotrichia leucophrys*)
  - Pyrrhuloxia (*Cardinalis sinuatus*)

MANGROVES
- **Indicator species:**
  - American Redstart (*Setophaga ruticilla*)
- **Associated species:**
  - Yellow Warbler (*Dendroica petechia*)
  - Northern Waterthrush (*Seiurus noveboracensis*)
  - Lincoln's Sparrow (*Melospiza lincolnii*)

LOWER ELEVATION RIPARIAN ASSOCIATIONS
- **Indicator species:**
  - Violet-crowned Hummingbird (*Amazilia violiceps*)
  - Green Kingfisher (*Chloroceryle americana*)
  - Sinaloa Wren (*Thryothorus sinaloa*)
- **Associated species:**
  - Elegant Quail (*Callipepla douglasii*)
  - Cooper's Hawk (*Accipiter cooperii*)
  - Wilson Snipe (*Gallinago delicata*)
  - Plain-capped Starthroat (*Heliomaster constantii*)
  - Belted Kingfisher (*Ceryle alcyon*)
  - Pacific-slope Flycatcher (*Empidonax difficilis*)
  - Nutting's Flycatcher (*Myiarchus nuttingi*)
  - Cassin's Vireo (*Vireo cassinii*)
  - Plumbeous Vireo (*Vireo plumbeus*)
  - Warbling Vireo (*Vireo gilvus*)
  - Happy Wren (*Thryothorus felix*)
  - American Pipit (*Anthus rubescens*)
  - Lucy's Warbler (*Vermivora luciae*) [a]
  - MacGillivray's Warbler (*Oporornis tolmiei*)
  - Black-and-white Warbler (*Mniotilta varia*)
  - Painted Redstart (*Myioborus pictus*)
  - Hepatic Tanager (*Piranga flava*)
  - Lazuli Bunting (*Passerina amoena*)
  - Varied Bunting (*Passerina versicolor*) [a c]
  - Red-winged Blackbird (*Agelaius phoeniceus*)
  - Lawrence's Goldfinch (*Carduelis lawrencei*) [a b]

TROPICAL DECIDUOUS FOREST AND OASES
- **Indicator species:** none
- **Associated species:**
  - White-tipped Dove (*Leptotila verreauxi)*
  - Northern Beardless-Tyrannulet (*Camptostoma imberbe*) [c]
  - Nutting's Flycatcher (*Myiarchus nuttingi*)
  - Ash-throated Flycatcher (*Myiarchus cinerascens*)
  - Canyon Wren (*Catherpes mexicanus*)
  - Five-striped Sparrow (*Aimophila quinquestriata*)
  - Rock Wren (*Salpinctes obsoletus*)
  - Black-and-white Warbler (*Mniotilta varia*)
  - Wilson's Warbler (*Wilsonia pusilla*)
  - Rufous-capped Warbler (*Basileuterus rufifrons*)
  - Rufous-crowned Sparrow (*Aimophila ruficeps*)
  - Streak-backed Oriole (*Icterus pustuatus*)

[a] PIF Watch List.
[b] USFWS birds of conservation concern national level.
[c] USFWS birds of conservation concern regional level [Southwestern Region] USDI Fish and Wildlife Service 2002, Rich et al. 2004).

breeding and wintering birds (MacArthur 1964, Anderson et al. 1983, Farley et al. 1994a, Sanders and Edge 1998, McComb et al. 2005). Wintering migrants were found to be more abundant in *Acacia* sp. patches with relatively high tree density and understory height in managed pasturelands in eastern Chiapas, Mexico (Greenberg et al. 1997). Compared with surrounding uplands, riparian habitats have a more complex vertical and horizontal structure, higher plant diversity, and more woody vegetation, especially in arid landscapes like Sonora.

Another possible factor is that vegetative productivity, which is higher in riparian ecosystems in general due to higher humidity and available water, and translates into a more abundant and diverse array of food items available to birds during all times of year. If this were the case, one might expect resident species to be equally or more abundant than migrants in riparian environments. However, according to my results this is not so; therefore, how can we explain the higher numbers of migrant species and individuals detected during winter in riparian environments?

The integration of migrant and resident species in the tropics and related wintering grounds can be described as a paradox; ecosystem productivity (and especially the abundance of arthropods) is low when bird abundances reach their annual high during winter. Numerous hypotheses have been proposed to explain this paradox. Greenberg (1995) proposed that a seasonal abundance of large, protein-rich insects supports the breeding productivity (feeding of young) of resident populations, while small arthropods are available year-round in sufficient biomass to support self-maintenance of adults, both resident and migrant. In Jamaica, Johnson et al. (2005) found some supporting evidence for one of Greenberg's predictions. They found more wintering migrants using habitats that provided less breeding season food resources for residents, and total abundance of birds was correlated with total arthropod biomass in winter. Johnson et al. (2005), however, suggest that other ecological factors act in synergy with food availability to affect migrant-to-resident ratios.

One of these other ecological factors could be predation. Hutto (1980) suggested that disturbed habitats supported higher abundances of wintering migrants because these habitats were underutilized by residents looking for nesting sites safe from predation, leaving them available for wintering species. This pattern has been found in habitats with edges and those that form habitat corridors (Kricher and Davis 1992, Hutto 1995, Villaseñor-Gómez and Hutto 1995, Warkentin et al. 1995). Johnson et al. (2006) explored the ties between food resources and predation. They suggest that the availability of food resources while feeding young affects the risk of nest predation; where fewer food resources exist parents have to increase the number of feeding trips, attracting predators and reducing nest guarding time, therefore increasing the likelihood of nest predation.

To my knowledge, in western Mexico no studies have addressed these possible explanations (diet composition and seasonality, predation, and habitat disturbance), and it was beyond the scope of this study. Because of their importance to resident and migrant bird species, and because they experience impacts on and variation in the ecological factors of interest, riparian corridors in Sonora provide a good opportunity to assess these concepts and hypotheses. However, caution should be used in designing such studies. Avian assemblages on riparian tracts and adjoining uplands are not independent (Strong and Bock 1990, Knopf and Samson 1994, Saab 1999, Martin et al. 2006), and it is complicated to define the effects these habitats exert on each other. Birds can move along the riparian corridor, as well as back and forth between adjacent vegetation types. In this study, I made the practical assumption that by limiting the analyses to detections within a 25-m radius I avoided most of these effects.

During this study I did not detect any territorial behavior in insectivorous migrants, but did find that individuals of several species stayed in the same areas during the winter and showed a certain degree of site fidelity (individuals banded in November were recaptured in the same sites, and even in the same nets in February of the next year, and even after two consecutive years). Additional, research would be valuable to increase our understanding of the importance of food abundance, water, and structural complexity of riparian areas in comparison with non-riparian habitats, and the way numerous birds fleeing the cold, harsh northern winters make use of these environments, as well as deeper insights on riparian winter site fidelity and the extent to which wintering birds move about and make use of adjoining vegetation.

Management Implications

The Sonoran habitats included in this study fall with the Southwest Avifaunal Biome described in Rich et al.(2004). More particularly, they are located within two bird conservation regions (BCR): the Sonoran and Mojave Desert BCR and the Sierra Madre Occidental BCR. The southwest avifaunal biome includes more than half of the landbird Species of continental importance identified in this plan and many of the species have small population sizes, restricted ranges, high threats, and/or declining population trends. Of the primary habitats within this biome, riparian woodlands support the highest diversity of landbird species (Rich et al. 2004); according to my results, among the species associated to riparian environments, three are included in the Partners in Flight Watch List: Lucy´s Warbler (*Vermivora luciae*), Varied Bunting (*Passerina versicolor*), and Lawrence´s Goldfinch (*Carduelis lawrencei*); the Varied Bunting is also included by the USDI Fish and Wildlife Service as a species of conservation concern for the Southwestern Region (Region 2), and the Lawrence´s Goldfinch as a species of conservation concern at the national level (USDI Fish and Wildlife Service 2002). Human settlements and activities are often closely associated with and dependent on riparian ecosystems, imposing ecological pressures on riparian environments. Rich et al. (2004) also identifies agricultural and suburban development, grazing management, and habitat fragmentation as conservation issues or threats to this biome.

Due to the restricted areal extent of riparian habitats in comparison to desertscrub and highland forests habitats in Sonora and elsewhere in the Southwest, lowland riparian habitats contribute significantly to regional species richness, supporting 22% of the total avifauna in the state of Sonora. In addition to the importance of Sonoran riparian areas as habitat for wintering birds, as documented in this study, they also act as corridors that permit the northward expansion of tropical species and faunal mixture on a broader scale, and support high densities of spring migrating birds (Kelly and Hutto 2005). For these reasons, riparian areas in northwestern Mexico and southwestern US are unique and essential habitats for the wintering and migrating bird species of western North America as well as resident species, many of them of conservation concern.

ACKNOWLEDGEMENTS

This research was part of the Western North American Land Bird Project: Wintering Habitats in Sonora, a project funded by the Neotropical Migratory Bird Conservation Act (USDI Fish and Wildlife Service Agreement No. 201814J856), the Sonoran Joint Venture, the University of Montana, and Instituto de Medio Ambiente y Desarrollo Sustentable de Sonora (IMADES). I appreciate the support of Robert Mesta, Mike Scott, Dick Hutto, Rob Hazlewood, and Carol Beardmore. I was also supported by PROMEP through the Universidad Michoacana de San Nicolás de Hidalgo. Field activities were possible thanks to the hard work and great spirit of Rita Guadalupe Dávila Vindiola, Eduardo Gómez Limón, Juan José Rivera Díaz, Leonardo Villaseñor Gómez, Fátima Méndez, Philip J. Micheal, Denise Avila Jiménez, Sahira Aracely Leyva Briseño, and Rosalío León Carrasco; I am deeply indebted to them. I express my deep gratitude to Creagh Breuner, Lisa Eby, Erick Greene, Chris Guglielmo, Don Jenni, and especially Dick Hutto, for their guidance, support and important suggestions in all phases of this research. I also thank David Krueper, Janet M. Ruth, and two anonymous reviewers who provided an impressive review; their suggestions improved this manuscript enormously.

APPENDIX 1. ANOVA results comparing the number of individuals per count (25-m radius) for the most common species with >15 detections in non-riparian and riparian vegetations in Sonora (January–February 2004–2006).

Species	Status [a]	N [b]	Overall (N = 1,816) Mean (SE)	Non-riparian (N = 944) Mean (SE)	Riparian (N = 872) Mean (SE)	P [c]	Habitat preference [d]
Gambel's Quail (*Callipepla gambelii*)	R	79	0.04 (0.01)	0.06 (0.02)	0.02 (0.01)	3.46 (0.06)	
Black Vulture (*Coragyps atratus*)	R	70	0.04 (0.01)	0.06 (0.03)	0.01 (0.01)	3.05 (0.08)	
Turkey Vulture (*Cathartes aura*)	R	31	0.02 (0.001)	0.03 (0.01)	0.01 (0.003)	4.50 (0.03)	Nrip
Killdeer (*Charadrius vociferus*)	R	25	0.01 (0.004)	0.004 (0.002)	0.02 (0.01)	5.40 (0.02)	Rip
Spotted Sandpiper (*Actitis macularius*)	M	49	0.03 (0.004)	0.001 (0.001)	0.05 (0.01)	47.85 (<0.01)	Rip
White-winged Dove (*Zenida asiatica*)	R	113	0.06 (0.01)	0.04 (0.01)	0.09 (0.03)	2.57 (0.11)	
Mourning Dove (*Zenaida macroura*)	R	173	0.09 (0.02)	0.11 (0.04)	0.08 (0.02)	0.39 (0.53)	
Inca Dove (*Columbina inca*)	R	34	0.02 (0.01)	0.01 (0.01)	0.02 (0.01)	0.37 (0.54)	
Common Ground-Dove (*Columbina passerina*)	R	24	0.013 (0.01)	0.001 (0.001)	0.03 (0.01)	3.65 (0.06)	
Broad-billed Hummingbird (*Cynanthus latirostris*)	R	107	0.06 (0.01)	0.07 (0.01)	0.04 (0.01)	5.40 (0.02)	Nrip
Violet-crowned Hummingbird (*Amazilia violiceps*)	R	16	0.01 (0.002)	0.001 (0.001)	0.02 (0.004)	13.69 (<0.01)	Rip
Costa's Hummingbird (*Calypte costae*)	R	2	0.03 (0.004)	0.04 (0.01)	0.02 (0.01)	3.16 (0.08)	
Unknown hummingbird	PM	17	0.01 (0.003)	0.002 (0.001)	0.02 (0.01)	9.08 (<0.01)	Rip
Green Kingfisher (*Chloroceryle americana*)	R	56	0.03 (0.004)	0.00 (0.00)	0.06 (0.01)	56.44 (<0.01)	Rip
Acorn Woodpecker (*Melanerpes formicivorus*)	R	19	0.01 (0.004)	0.02 (0.01)	0.003 (0.003)	3.48 (0.06)	
Gila Woodpecker (*Melanerpes uropygials*)	R	215	0.12 (0.01)	0.10 (0.01)	0.13 (0.01)	1.80 (0.18)	
Red-naped Sapsucker (*Sphyrapicus nuchalis*)	M	17	0.01 (0.002)	0.004 (0.002)	0.01 (0.004)	5.63 (0.02)	Rip
Ladder-backed Woodpecker (*Picoides scalaris*)	R	64	0.03 (0.01)	0.03 (0.01)	0.04 (0.01)	2.32 (0.13)	
Northern Flicker (*Colaptes auratus*)	R	21	0.01 (0.003)	0.02 (0.004)	0.01 (0.003)	3.18 (0.08)	
Gilded Flicker (*Colaptes chrysoides*)	R	25	0.01 (0.003)	0.03 (0.01)	0.00 (0.00)	15.79 (<0.01)	Nrip
Gray Flycatcher (*Empidonax wrightii*)	M	29	0.02 (0.003)	0.01 (0.003)	0.02 (0.01)	7.12 (<0.01)	Rip
Unknown Empidonax (*Empidonax* sp.)	M	148	0.08 (0.01)	0.01 (0.004)	0.16 (0.01)	116.42 (<0.01)	Rip
Black Phoebe (*Sayornis nigricans*)	R	222	0.12 (0.01)	0.004 (0.002)	0.25 (0.02)	177.40 (<0.01)	Rip
Say's Phoebe (*Sayornis saya*)	PM	29	0.02 (0.003)	0.01 (0.003)	0.02 (0.01)	5.56 (0.02)	Rip
Vermilion Flycatcher (*Pyrocephalus rubinus*)	R	50	0.03 (0.004)	0.001 (0.001)	0.06 (0.01)	38.52 (<0.01)	Rip
Dusky-capped Flycatcher (*Myiarchus tuberulifer*)	R	18	0.01 (0.003)	0.01 (0.002)	0.01 (0.01)	3.53 (0.06)	
Ash-throated Flycatcher (*Myiarchus cinerascens*)	R	83	0.05 (0.01)	0.08 (0.01)	0.01 (0.004)	27.70 (<0.01)	Nrip
Loggerhead Shrike (*Lanius ludovicianus*)	PM	24	0.01 (0.003)	0.02 (0.004)	0.01 (0.003)	2.06 (0.15)	
Mexican Jay (*Aphelocoma ultramarina*)	R	16	0.01 (0.004)	0.01 (0.01)	0.01 (0.004)	1.08 (0.30)	
Common Raven (*Corvus corax*)	R	26	0.01 (0.004)	0.02 (0.01)	0.01 (0.003)	3.11 (0.08)	
Violet-green Swallow (*Tachycineta thalassina*)	PM	39	0.021 (0.01)	0.04 (0.02)	0.00 (0.00)	3.04 (0.08)	
Bridled Titmouse (*Baeolophus wollweberi*)	R	51	0.03 (0.01)	0.03 (0.01)	0.02 (0.01)	0.63 (0.43)	
Verdin (*Auriparus flaviceps*)	R	405	0.22 (0.01)	0.31 (0.02)	0.12 (0.01)	47.32 (<0.01)	Nrip
Bushtit (*Psaltriparus minimus*)	R	17	0.01 (0.01)	0.002 (0.002)	0.02 (0.01)	1.20 (0.27)	
Cactus Wren (*Campylorhynchus brunneicapillus*)	R	153	0.08 (0.01)	0.14 (0.02)	0.02 (0.01)	48.81 (<0.01)	Nrip
Rock Wren (*Salpinctes obsoletus*)	R	16	0.01 (0.002)	0.02 (0.004)	0.001 (0.001)	10.0 (<0.01)	Nrip
Sinaloa Wren (*Thryothorus sinaloa*)	R	19	0.01 (0.003)	0.004 (0.003)	0.02 (0.01)	5.64 (0.02)	Rip
Bewick's Wren (*Thryomanes bewickii*)	R	43	0.02 (0.004)	0.02 (0.01)	0.03 (0.01)	0.45 (0.50)	
House Wren (*Troglodytes aedon*)	PM	73	0.04 (0.01)	0.01 (0.003)	0.07 (0.01)	37.60 (<0.01)	Rip

APPENDIX 1. CONTINUED.

Species	Status[a]	N[b]	Overall (N = 1,816) Mean (SE)	Non-riparian (N = 944) Mean (SE)	Riparian (N = 872) Mean (SE)	P[c]	Habitat preference[d]
Ruby-crowned Kinglet (*Regulus calendula*)	M	506	0.28 (0.02)	0.06 (0.01)	0.51 (0.030)	209.68 (<0.01)	Rip
Blue-gray Gnatcatcher (*Polioptila caerulea*)	PM	440	0.24 (0.01)	0.13 (0.02)	0.36 (0.02)	65.25 (<0.01)	Rip
Black-tailed Gnatcatcher (*Polioptila melanura*)	R	217	0.12 (0.0)	0.16 (0.02)	0.07 (0.01)	17.59 (<0.01)	Nrip
Black-capped Gnatcatcher (*Polioptila nigriceps*)	R	84	0.05 (0.01)	0.02 (0.01)	0.07 (0.01)	14.73 (<0.01)	Rip
American Robin (*Turdus migratorius)*	PM	22	0.01 (0.01)	0.02 (0.02)	0.00 (0.00)	1.35 (0.25)	
Northern Mockingbird (*Mimus polyglottos*)	PM	180	0.10 (0.03)	0.15 (0.07)	0.05 (0.01)	2.06 (0.15)	
Curve-billed Thrasher (*Toxostoma curvirostre*)	R	85	0.05 (0.01)	0.07 (0.01)	0.02 (0.01)	6.79 (<0.01)	Nrip
Phainopepla (*Phainoepla nitens*)	R	47	0.03 (0.01)	0.04 (0.01)	0.01 (0.003)	12.79 (<0.01)	
Orange-crowned Warbler (*Vermivora celata*)	M	145	0.08 (0.01)	0.06 (0.01)	0.11 (0.01)	9.17 (<0.01)	Rip
Yellow-rumped Warbler (*Dendroica coronata*)	M	436	0.24 (0.02)	0.06 (0.02)	0.43 (0.03)	116.18 (<0.01)	Rip
Black-throat. Gray Warbler (*Dendroica nigrescens*)	M	36	0.02 (0.004)	0.01 (0.003)	0.03 (0.01)	10.77 (<0.01)	Rip
Common Yellowthroat (*Geothlypis trichas*)	PM	170	0.09 (0.01)	0.031 (0.01)	0.16 (0.01)	66.33 (<0.01)	Rip
Wilson's Warbler (*Wilsonia pusilla*)	M	68	0.04 (0.01)	0.001 (0.001)	0.08 (0.01)	55.95 (<0.01)	Rip
Green-tailed Towhee (*Pipilo chlorurus*)	M	174	0.10 (0.01)	0.03 (0.01)	0.16 (0.02)	53.29 (<0.01)	Rip
Spotted Towhee (*Pipilo maculatus*)	PM	17	0.01 (0.003)	0.01 (0.01)	0.01 (0.002)	2.56 (0.11)	
Canyon Towhee (*Pipilo fuscus*)	R	56	0.03 (0.01)	0.04 (0.01)	0.01 (0.01)	9.57 (<0.01)	Nrip
Rufous-winged Sparrow (*Aimophila carpalis*)	R	74	0.04 (0.01)	0.05 (0.01)	0.03 (0.02)	1.59 (0.21)	
Rufous-crowned Sparrow (*Aimophila ruficeps*)	R	50	0.03 (0.01)	0.04 (0.01)	0.01 (0.01)	2.55 (0.11)	
Chipping Sparrow (*Spizella passerina*)	PM	515	0.28 (0.053)	0.14 (0.04)	0.44 (0.10)	8.32 (<0.01)	Rip
Clay-colored Sparrow (*Spizella pallida*)	M	39	0.02 (0.01)	0.04 (0.02)	0.00 (0.00)	3.88 (<0.05)	Nrip
Brewer's Sparrow (*Spizella breweri*)	M	127	0.07 (0.02)	0.09 (0.03)	0.05 (0.03)	0.67 (0.41)	
Lark Sparrow (*Chondestes grammacus*)	M	255	0.14 (0.03)	0.07 (0.02)	0.21 (0.07)	4.33 (0.04)	Rip
Black-throated Sparrow (*Amphispiza bilineata*)	R	46	0.02 (0.01)	0.04 (0.01)	0.01 (0.01)	3.41 (0.07)	
Savannah Sparrow (*Passerculus sandwichensis*)	PM	26	0.01 (0.01)	0.02 (0.01)	0.00 (0.00)	3.62 (0.06)	
Song Sparrow (*Melospiza melodia*)	PM	351	0.19 (0.01)	0.001 (0.001)	0.401 (0.03)	247.84 (<0.01)	Rip
Lincoln's Sparrow (*Melospiza lincolnii*)	M	47	0.03 (0.01)	0.004 (0.003)	0.05 (0.01)	16.67 (<0.01)	Rip
White-crowned Sparrow (*Zonotrichia leucophrys*)	M	172	0.09 (0.02)	0.04 (0.02)	0.15 (0.04)	8.40 (<0.01)	Rip
Dark-eyed Junco (*Junco hyemalis*)	M	60	0.03 (0.01)	0.06 (0.02)	0.001 (0.001)	7.65 (<0.01)	Nrip
Yellow-eyed Junco (*Junco phaeonotus*)	R	21	0.01 (0.01)	0.02 (0.01)	0.00 (0.00)	5.58 (0.02)	Nrip
Northern Cardinal (*Cardinalis cardinalis*)	R	134	0.07 (0.01)	0.05 (0.01)	0.10 (0.01)	9.78 (<0.01)	Rip
Pyrrhuloxia (*Cardinalis sinuatus*)	R	41	0.02 (0.01)	0.01 (0.004)	0.03 (0.01)	5.48 (0.02)	Rip
Red-winged Blackbird (*Agelaius phoeniceus*)	PM	32	0.02 (0.01)	0.00 (0.00)	0.04 (0.02)	2.57 (0.11)	
Western Meadowlark (*Sturnella neglecta*)	PM	21	0.01 (0.01)	0.02 (0.02)	0.001 (0.001)	0.82 (0.37)	
Great-tailed Grackle (*Quiscalus mexicanus*)	R	21	0.01 (0.01)	0.01 (0.001)	0.01 (0.01)	0.09 (0.76)	
Streak-backed Oriole (*Icterus pustuatus*)	R	34	0.02 (0.003)	0.001 (0.001)	0.04 (0.01)	28.87 (<0.01)	Rip
House Finch (*Carpodacus mexicanus*)	R	222	0.12 (0.01)	0.13 (0.02)	0.11 (0.02)	0.76 (0.38)	
Lesser Goldfinch (*Carduelis psaltria*)	R	124	0.07 (0.01)	0.02 (0.01)	0.12 (0.03)	15.48 (<0.01)	Rip

[a] Status: R = resident, PM = partial migrant, M = migrant.
[b] Number of individuals detected.
[c] ANOVA (P) analysis.
[d] Rip = preference for riparian and Nrip = preference for non-riparian habitats.