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

JOSÉ FERNANDO VILLASEÑOR-GÓMEZ

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 AVE IS INVERNANTES EN SONORA, MEXICO: IMPORTANCIA DE LOS HABITAT 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 2,175 m durante Enero-Febrero de 2004–2006. Detecé 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), 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 km². 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>
<thead>
<tr>
<th>Location</th>
<th>Vegetation sampled</th>
<th>Elevation (m)</th>
<th>Latitude N</th>
<th>Longitude W</th>
<th>N Counts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aconchi – Río Sonora</td>
<td>Riparian cottonwood-mesquite, cottonwoods, cottonwood-willow</td>
<td>588</td>
<td>29°48'14&quot;</td>
<td>110°13'37&quot;</td>
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<td>606</td>
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<td>Agua Caliente Springs</td>
<td>Highland oakslands</td>
<td>1,490</td>
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<td>109°06'10&quot;</td>
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<td>Arribabi – Sierra Alta</td>
<td>Riparian mesquite</td>
<td>188</td>
<td>28°52'04&quot;</td>
<td>110°57'43&quot;</td>
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<tr>
<td>Arroyo La Poza</td>
<td>Riparian cottonwood-willow, willow-mesquite</td>
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<td>28°51'45&quot;</td>
<td>109°10'03&quot;</td>
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<tr>
<td>Baviácora – Río Sonora</td>
<td>Riparian cottonwoods, cottonwood-willow</td>
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<td>Sarcoacalecent scrubland</td>
<td>188</td>
<td>28°34'41&quot;</td>
<td>111°00'43&quot;</td>
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<tr>
<td>Cañón de Onapa, Río Sahuaripa</td>
<td>Riparian mesquite, willow</td>
<td>587</td>
<td>28°44'09&quot;</td>
<td>109°07'59&quot;</td>
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<td>Riparian sycamores</td>
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<td>Cananea – Bacoachi</td>
<td>Oasis (Washingtonia and Ficus)</td>
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<td>28°00'50&quot;</td>
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<td>Coteco</td>
<td>Coastal sarcoacalecent scrubland</td>
<td>22</td>
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<td>Cucurpe – Río San Miguel</td>
<td>Riparian cottonwoods</td>
<td>849</td>
<td>30°19'20&quot;</td>
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<td>Desv. Playa San Nicolás</td>
<td>Coastal sarcoacalecent scrubland</td>
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<td>Ejido Ganadero Puente El Tigre, Guaymas</td>
<td>Sarcoacalecent scrubland</td>
<td>82</td>
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<td>El Carrizo, Rancho San Dario</td>
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<td>730</td>
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<td>El Chiculi, Hornos, Río Yaqui, Sonora</td>
<td>Riparian willow-mesquite-chino</td>
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<td>Agua Prieta-Moctezuma</td>
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<td>29°43'25&quot;</td>
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<tr>
<td>El Llano – Moctezuma</td>
<td>Tropical deciduous forest</td>
<td>654</td>
<td>29°07'57&quot;</td>
<td>109°16'51&quot;</td>
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<td>El Resbalón – Sahuaripa</td>
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<td>27°59'15&quot;</td>
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<td>El Sahuaral, San José de Guaymas</td>
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<td>Estero del Soldado, San Carlos, Nuevo Guaymas</td>
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<td>29°02'21&quot;</td>
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<td>Estero Paraíso – Punta Checa</td>
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<td>Estero Santa Cruz – Kino</td>
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<td>29°51'46&quot;</td>
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<td>109°00'34&quot;</td>
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<td>La Majada, between Moctezuma-Mazocahu</td>
<td>Lowland oakslands</td>
<td>1,011</td>
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<td>La Mesa del Campanero</td>
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<td>Location</td>
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<td>Latitude N</td>
<td>Longitude W</td>
<td>N Counts</td>
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<td>Magdalena, road</td>
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<td>Magdalena-Imuris</td>
<td>Sarcoclasia caulescent scrubland</td>
<td>784</td>
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<td>110°57'37&quot;</td>
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<tr>
<td>Mazatán, ca. 10 km W</td>
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<td>517</td>
<td>29°00'00&quot;</td>
<td>110°13'45&quot;</td>
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<td>Mesa del Toro-Ejido</td>
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<tr>
<td>Ignacio Zaragoza, Cananea</td>
<td>Grasslands</td>
<td>1,556</td>
<td>31°03'38&quot;</td>
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<td>Sierra Pinacate (between Elegante and Tecolete)</td>
<td>Vegetation of sandy deserts</td>
<td>219</td>
<td>31°51'21&quot;</td>
<td>113°21'28&quot;</td>
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<td>Sierra Pinacate Crater</td>
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<tr>
<td>Cerro Colorado</td>
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<td>185</td>
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<td>Puerto Peñasco</td>
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<td>16</td>
<td>31°21'36&quot;</td>
<td>113°27'41&quot;</td>
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<tr>
<td>Rancho Monte Alto-road to Puerto Libertad</td>
<td>Coastal sarcoclasia caulescent scrubland</td>
<td>131</td>
<td>29°18'38&quot;</td>
<td>111°51'26&quot;</td>
<td>31</td>
</tr>
<tr>
<td>Rancho El 44, between Cobachi and Road to Yécora</td>
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<td>431</td>
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<tr>
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<tr>
<td>Rancho La Cuesta, km 94 road to Yécora</td>
<td>Subtropical scrub</td>
<td>391</td>
<td>28°35'44&quot;</td>
<td>110°01'00&quot;</td>
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<tr>
<td>Rancho La Noria, N</td>
<td>Sarcolescent scrubland</td>
<td>352</td>
<td>29°03'01&quot;</td>
<td>110°37'56&quot;</td>
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<tr>
<td>Rancho Los Cuervos, N El Carrizo</td>
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<td>111°12'37&quot;</td>
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<td>(Carretera Minera Nyco)</td>
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<td>Río Altar, Tubutama</td>
<td>Riparian cottonwoods</td>
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<tr>
<td>Río Cuchujqui</td>
<td>Riparian baldcypress-willow</td>
<td>239</td>
<td>26°56'29&quot;</td>
<td>108°53'05&quot;</td>
<td>21</td>
</tr>
<tr>
<td>Río Cocóspera-Rancho</td>
<td>Riparian cottonwood-willow</td>
<td></td>
<td></td>
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<tr>
<td>Arribabi</td>
<td>Cottonwood-mesquite, cottonwoods</td>
<td>974</td>
<td>30°51'15&quot;</td>
<td>110°39'51&quot;</td>
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<tr>
<td>Río Cuchujqui at El Mentidero</td>
<td>Riparian baldcypress-willow</td>
<td>227</td>
<td>26°54'44&quot;</td>
<td>108°54'46&quot;</td>
<td>9</td>
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<tr>
<td>Río Cuchujqui at La Isleta</td>
<td>Riparian baldcypress-willow</td>
<td>224</td>
<td>26°54'38&quot;</td>
<td>108°54'51&quot;</td>
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<tr>
<td>Río Matape—San José de Pimas</td>
<td>Riparian mesquite, willow</td>
<td>350</td>
<td>28°43'02&quot;</td>
<td>110°20'50&quot;</td>
<td>35</td>
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<tr>
<td>Río Mayo—Presa Mocúzari</td>
<td>Riparian willow-mesquite-chino</td>
<td>98</td>
<td>27°12'57&quot;</td>
<td>109°06'47&quot;</td>
<td>20</td>
</tr>
<tr>
<td>Río Mayo—Tetapeche</td>
<td>Riparian willow-mesquite-chino</td>
<td>49</td>
<td>27°12'23&quot;</td>
<td>109°21'35&quot;</td>
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<td>Río San Miguel</td>
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<tr>
<td>Rancho San Esteban</td>
<td>Riparian mesquite</td>
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<td>29°17'13&quot;</td>
<td>110°52'02&quot;</td>
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<td>Río Santa Cruz, San Lázaro</td>
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<td>1,284</td>
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<td>Riparian willow-mesquite</td>
<td>203</td>
<td>28°47'45&quot;</td>
<td>109°38'41&quot;</td>
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<tr>
<td>Location</td>
<td>Vegetation sampled</td>
<td>Elevation (m)</td>
<td>Latitude N</td>
<td>Longitude W</td>
<td>N  Counts</td>
</tr>
<tr>
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<td>-------------------------------------</td>
<td>--------------</td>
<td>---------------------</td>
<td>----------------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Río Yaqui, San Antonio de la Huerta</td>
<td>Riparian willow-mesquite</td>
<td>187</td>
<td>28°37'44&quot;</td>
<td>109°36'27&quot;</td>
<td>1</td>
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<tr>
<td>Río Yaqui, Tónichi</td>
<td>Riparian willow-mesquite</td>
<td>166</td>
<td>28°35'37&quot;</td>
<td>109°34'08&quot;</td>
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<tr>
<td>Río Yaqui, S El Novillo</td>
<td>Riparian willow-mesquite</td>
<td>214</td>
<td>28°49'43&quot;</td>
<td>109°37'46&quot;</td>
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<td>Río Yaqui, Soyopa</td>
<td>Riparian willow-mesquite, mesquite</td>
<td>188</td>
<td>28°45'02&quot;</td>
<td>109°37'32&quot;</td>
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<tr>
<td>San Carlos—ca.</td>
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<td></td>
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<tr>
<td>Cañón de Nacapule</td>
<td>Sarcocalescent scrubland</td>
<td>47</td>
<td>27°58'58&quot;</td>
<td>111°02'24&quot;</td>
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<tr>
<td>San Ignacio—Terrenate</td>
<td>Riparian cottonwoods</td>
<td>784</td>
<td>30°42'51&quot;</td>
<td>110°55'27&quot;</td>
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<tr>
<td>San Javier</td>
<td>Tropical deciduous forest</td>
<td>813</td>
<td>28°34'58&quot;</td>
<td>109°44'51&quot;</td>
<td>32</td>
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<tr>
<td>San José de Pimas</td>
<td>Thornscrub</td>
<td>384</td>
<td>28°43'54&quot;</td>
<td>110°21'49&quot;</td>
<td>21</td>
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<td>San Lázaro, S</td>
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<td>San Miguel, road to</td>
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<td>28°57'51&quot;</td>
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<td>Santa Cruz</td>
<td>Graslands, highland oaklands</td>
<td>1,417</td>
<td>31°19'56&quot;</td>
<td>110°36'30&quot;</td>
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<td>Sáric — Río Altar</td>
<td>Riparian cottonwood-mesquite,</td>
<td>786</td>
<td>31°09'25&quot;</td>
<td>111°21'11&quot;</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>cottonwoods, mesquite, willow,</td>
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<td></td>
<td></td>
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<tr>
<td></td>
<td>cottonwood-willow</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Sierra La Elenita, Cananea</td>
<td>Highland coniferous forest</td>
<td>1,920</td>
<td>31°00'30&quot;</td>
<td>110°23'06&quot;</td>
<td>30</td>
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<tr>
<td>Sierra Ladrilleros-El Pinacate</td>
<td>Sarcocalescent scrubland</td>
<td>154</td>
<td>31°44'28&quot;</td>
<td>113°18'23&quot;</td>
<td>30</td>
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<tr>
<td>Sierra Mazatán</td>
<td>Lowland oaklands</td>
<td>1,357</td>
<td>29°05'38&quot;</td>
<td>110°12'54&quot;</td>
<td>9</td>
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<tr>
<td>Sierra Mazatán, NE Presa Teópari</td>
<td>Riparian mesquite</td>
<td>663</td>
<td>29°13'15&quot;</td>
<td>110°04'44&quot;</td>
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<tr>
<td>Terapa — Río Moctezuma</td>
<td>Riparian cottonwood-mesquite,</td>
<td>565</td>
<td>29°40'41&quot;</td>
<td>109°39'04&quot;</td>
<td>88</td>
</tr>
<tr>
<td></td>
<td>cottonwood-willow, mesquite,</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>cottonwoods</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Tónichi</td>
<td>Riparian willow-mesquite</td>
<td>186</td>
<td>28°35'42&quot;</td>
<td>109°34'05&quot;</td>
<td>31</td>
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<td>Tubutama - Río Altar</td>
<td>Riparian cottonwoods,</td>
<td>684</td>
<td>30°53'17&quot;</td>
<td>111°27'21&quot;</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>cottonwood-willow</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Unamichi — Río Sonora</td>
<td>Riparian cottonwood-willow</td>
<td>1,048</td>
<td>30°39'39&quot;</td>
<td>109°58'58&quot;</td>
<td>20</td>
</tr>
<tr>
<td>Yécora</td>
<td>Highland coniferous forest</td>
<td>1,538</td>
<td>28°22'54&quot;</td>
<td>108°54'39&quot;</td>
<td>11</td>
</tr>
<tr>
<td>Yecora — La Palmita</td>
<td>Highland oaklands</td>
<td>1,462</td>
<td>28°22'19&quot;</td>
<td>109°03'59&quot;</td>
<td>21</td>
</tr>
</tbody>
</table>
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 ($\chi^2 = 4.105, \text{df} = 2, P = 0.128$; 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 ($\chi^2 = 4.083, \text{df} = 1, P = 0.03$; 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>
<thead>
<tr>
<th>Vegetation Type</th>
<th>Counts/species</th>
<th>Elevation range (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-riparian vegetation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mangroves</td>
<td>54/53</td>
<td>Sea level (0)</td>
</tr>
<tr>
<td>Coastal sarcocaulcecent scrubland</td>
<td>138/58</td>
<td>(0–234)</td>
</tr>
<tr>
<td>Vegetation of sandy deserts</td>
<td>70/17</td>
<td>(3–231)</td>
</tr>
<tr>
<td>Microphyllous scrubland</td>
<td>30/17</td>
<td>(1,159–1,217)</td>
</tr>
<tr>
<td>Tropical deciduous forest</td>
<td>79/61</td>
<td>(102–983)</td>
</tr>
<tr>
<td>Sarcocaulcecent scrubland</td>
<td>58/20</td>
<td>(307–824)</td>
</tr>
<tr>
<td>Thornscrub</td>
<td>45/37</td>
<td>(184–1,189)</td>
</tr>
<tr>
<td>Subtropical scrub</td>
<td>25/43</td>
<td>(391–878)</td>
</tr>
<tr>
<td>Sarcocaulcecent scrubland</td>
<td>152/47</td>
<td>(13–551)</td>
</tr>
<tr>
<td>Grasslands</td>
<td>83/14</td>
<td>(316–1,592)</td>
</tr>
<tr>
<td>Low oaklands</td>
<td>54/41</td>
<td>(970–1,250)</td>
</tr>
<tr>
<td>High oaklands</td>
<td>75/61</td>
<td>(1,400–2,010)</td>
</tr>
<tr>
<td>Highland coniferous forest</td>
<td>60/37</td>
<td>(1,525–2,175)</td>
</tr>
<tr>
<td>Oases</td>
<td>21/37</td>
<td>(50–233)</td>
</tr>
<tr>
<td>Non-riparian vegetation (general)</td>
<td>944/183</td>
<td>(Sea level–2,175)</td>
</tr>
<tr>
<td>Riparian vegetation</td>
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<td></td>
</tr>
<tr>
<td>Willow–mesquite-chino</td>
<td>57/96</td>
<td>(36–102)</td>
</tr>
<tr>
<td>Mesquite desert riparian</td>
<td>89/108</td>
<td>(117–823)</td>
</tr>
<tr>
<td>Willow–mesquite</td>
<td>91/96</td>
<td>(166–823)</td>
</tr>
<tr>
<td>Willow</td>
<td>104/96</td>
<td>(348–840)</td>
</tr>
<tr>
<td>Willow–baldercypress (Salix-Taxodium)</td>
<td>31/75</td>
<td>(222–277)</td>
</tr>
<tr>
<td>Cottonwood–willow</td>
<td>230/125</td>
<td>(527–1,282)</td>
</tr>
<tr>
<td>Cottonwood–mesquite</td>
<td>25/45</td>
<td>(555–1,305)</td>
</tr>
<tr>
<td>Cottonwood–sycamore (Platanus)</td>
<td>214/125</td>
<td>(505–1,388)</td>
</tr>
<tr>
<td>Sycamores (Platanus)</td>
<td>33/40</td>
<td>(1,322–1,402)</td>
</tr>
<tr>
<td>Riparian sites (general)</td>
<td>872/203</td>
<td>(33–1,402)</td>
</tr>
</tbody>
</table>
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

### Table 3. ANOVA results comparing the mean number of species and individuals detected in point counts (25-m radius) by residency status.

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

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.
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 sarcocauliscent scrubland, 5 = subtropical scrub, 6 = tropical deciduous forest, 7 = thornscrub, 8 = sarcocauliscent scrubland, 9 = sarcocauliscent 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.)
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, desert scrub 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 vegetation 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

<table>
<thead>
<tr>
<th>Status</th>
<th>All species</th>
<th>Non-riparian species</th>
<th>Riparian species</th>
<th>Total</th>
<th>N significantly different species</th>
<th>N riparian species</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residents</td>
<td>53</td>
<td>15</td>
<td>14</td>
<td>82</td>
<td>18</td>
<td>9</td>
<td>27</td>
</tr>
<tr>
<td>Partial migrants</td>
<td>(53.2)</td>
<td>(15.0)</td>
<td>(14.0)</td>
<td>(82.0)</td>
<td>(18.0)</td>
<td>(9.0)</td>
<td>(27.0)</td>
</tr>
<tr>
<td>Migrants</td>
<td>32</td>
<td>2</td>
<td>19</td>
<td>53</td>
<td>1</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>(34.4)</td>
<td>(5.7)</td>
<td>(12.9)</td>
<td>(53.0)</td>
<td>(1.0)</td>
<td>(0.6)</td>
<td>(13.0)</td>
</tr>
<tr>
<td>Total</td>
<td>109</td>
<td>18</td>
<td>41</td>
<td>168</td>
<td>26</td>
<td>13</td>
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</tbody>
</table>

Note: Expected frequencies shown in parentheses.
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 vegetation, 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 (TWINSPLAN) 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)*
- White-eared Hummingbird (Hylocharis leucotis)
- Hairy Woodpecker (Picoides villosus)
- Williamson’s Sapsucker (Sphyrapicus thyroideus) b
- Hutton’s Vireo (Vireo huttonii)
- Mexican Chickadee (Poecile sclateri)
- Eastern Bluebird (Sialia sialis)
- American Robin (Turdus migratorius)
- Olive Warbler (Procedramus taudtis)
- Crescent-crowned Warbler (Parula superciliosa)
- Townsend’s Warbler (Dendroica townsendi)
- Hermit Warbler (Dendroica occidentalis) a
- Grasshopper Sparrow* (Ammodramus savanum)
- 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) *
- Costa’s Hummingbird (Calypte costae) *
- Say’s Phoebe (Sayornis saya)
- Black-capped Flycatcher (Myciarchus tyrannulus)
- Vermilion Flycatcher (Pyrocephalus rubinus)
- Loggerhead Shrike (Lanita ludoviciana) b c
- Horned Lark (Eremophila alpestris)
- Black-capped Gnatchatcher (Polioptila nigriceps) *
- Bendire’s Thrasher (Toxostoma bendirei) a b c
- Phainopepla (Phainopepla nitens)
- Vesper Sparrow (Poecetes 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 violacea)
- Green Kingfisher (Chloroceryle americana)
- Sinaloa Wren (Thryothorus sinaloa)

**Associated species:**
- Elegant Quail (Callipepla douglasii)
- Cooper’s Hawk (Accipiter cooperii)
- Wilson Snipe (Callinago delacate)
- Plain-capped Starthroat (Helisoma constatitii)
- Belted Kingfisher (Ceryle alcyon)
- Pacific-slope Flycatcher (Empidonax difficilis)
- Nutting’s Flycatcher (Myciarchus nuttingii)
- Cassin’s Vireo (Vireo cassinii)
- Plumbeous Vireo (Vireo plumbeus)
- Warbling Vireo (Vireo gilvus)
- Happy Wren (Thryothorus feliz)
- American Pipit (Anthus rubescens)
- Lucy’s Warbler (Vermivora luciae) *
- 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) * c
- Red-winged Blackbird (Agelaius phoeniceus)
- Lawrence’s Goldfinch (Carduelis laurencis) * b

#### TROPICAL DECIDUOUS FOREST AND OASES
**Indicator species:**
- none

**Associated species:**
- White-tipped Dove (Leptotila verreauxi)
- Northern Beardless-Tyrannulet (Camptostoma imberbe) *
- Nutting’s Flycatcher (Myciarchus nuttingii)
- Ash-throated Flycatcher (Myciarchus cinereus)
- Canyon Wren (Catherpes mexicanus)
- Five-striped Sparrow (Amphilea quinquestrata)
- Rock Wren (Salpinctes obsoletus)
- Black-and-white Warbler (Mniotilta varia)
- Wilson’s Warbler (Wilsonia pusilla)
- Rufous-capped Warbler (Basileuterus rufifrons)
- Rufous-crowned Sparrow (Amphilea ruficeps)
- Streak-backed Oriole (Icterus pustulatus)

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* PII Watch List.
* b USFWS birds of conservation concern national level.
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 pastures 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 deserts 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

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<table>
<thead>
<tr>
<th>Species</th>
<th>Status</th>
<th>N</th>
<th>Overall (N = 1,816) Mean (SE)</th>
<th>Non-riparian (N = 944) Mean (SE)</th>
<th>Riparian (N = 872) Mean (SE)</th>
<th>P</th>
<th>Habitat preference</th>
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<td>Gambel’s Quail (Callipepla gambelii)</td>
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<td>48.81 (&lt;0.01)</td>
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## APPENDIX 1. CONTINUED.

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

\(^a\) 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.
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