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DENSITIES, SPECIES RICHNESS AND HABITAT RELATIONSHIPS OF THE AVIAN COMMUNITY IN THE COLORADO RIVER, MEXICO

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Abstract. We determined the spatial and temporal patterns of avian species richness and density and explored their relationships with habitat features in the floodplain of the Colorado River in Mexico, which was subject to regeneration through pulse-floods in the last 20 yr. Our work included monthly point counts at 30 transects (240 points) from May 2002–July 2003. The average abundance per point was 29.2 individuals with an average richness of 8.6 species, and an average density of 47.7 birds per ha. The most common species were Mourning Dove (*Zenaida macroura*), Red-winged Blackbird (*Agelaius phoeniceus*), and Brown-headed Cowbird (*Molothrus ater*), but another 64 species were commonly found, including Verdin (*Auriparus flaviceps*), Song Sparrow (*Melospiza melodia*), and Abert's Towhee (*Pipilo aberti*). Surface water was the most important habitat feature related to avian richness and density regardless of vegetation type or land cover. During summer, species richness was explained by variations in water and the cover of cottonwoods (*Populus fremontii*), and the variation in bird densities was explained by variations in water and the cover of willows (*Salix gooddingii*). The dedication of instream flows and pulse floods, the maintenance of vegetation cover and structural diversity, and an increase of older riparian stands will secure the viability of existing bird populations and will increase the probability of recovery of the species that are still extirpated from the floodplain of the Colorado River in Mexico.

Key words: birds, Colorado River delta, cottonwood, floodplain, riparian, water, willow.

DENSIDADES, RIQUEZA DE ESPECIES Y RELACIONES DE HÁBITAT DE LA COMUNIDAD DE AVES EN EL RÍO COLORADO, MÉXICO

Resumen. Determinamos los patrones espaciales y temporales de la riqueza y densidad de aves y exploramos sus relaciones con las características de hábitat en la planicie de inundación del delta del Río Colorado, México, la cual se regeneró por recibir pulsos de inundación en los últimos 20 años. Nuestro trabajo incluyó conteos por puntos mensuales en 30 transectos (240 puntos) de Mayo 2002 a Julio 2003. El promedio de abundancia por punto fue de 29.2 individuos, con una riqueza promedio de 9.6 especies, y una densidad promedio de 47.7 aves por ha. Las especies más comunes fueron *Zenaida macroura*, *Agelaius phoeniceus*, y *Molothrus ater*, pero encontramos comúnmente a otras 64 especies, incluyendo a *Auriparus flaviceps*, *Melospiza melodia*, y *Pipilo aberti*. El agua superficial fue la característica del hábitat más importante en relación a la riqueza y densidad de aves, independientemente del tipo de vegetación o cobertura del suelo. Durante el verano, la riqueza de aves fue explicada por variaciones en la cobertura de agua y álamos (*Populus fremontii*), y la densidad fue explicada por variaciones en la cobertura de agua y sauces (*Salix gooddingii*). La asignación de flujos de mantenimiento e inundación, el mantenimiento de la cobertura y diversidad estructural de la vegetación, y el incremento de zonas de bosque ripario maduro permitirán asegurar la viabilidad de las poblaciones existentes de aves e incrementarán la probabilidad de recuperación de las especies que aún se encuentran extirpadas de la planicie del Río Colorado en México.

In western North America, about 95% of riparian areas have been destroyed, altered, or degraded by human activities (Ohmart 1994). However, riparian ecosystems maintain the highest diversity and abundance of birds in the region (Knopf et al. 1988, Rosenberg et al. 1991), and provide critical breeding, wintering, and migratory habitats (Knopf and Samson 1994, Skagen et al. 2005). The cumulative effects of habitat loss and degradation in riparian areas through the life cycle of birds is one of the most important factors associated with land bird population declines (DeSante and George 1994, Hutto 2000, Norris et al. 2004). Thus, documenting the composition and status of riparian bird communities and understanding how they are associated with important biotic and abiotic components of their habitats are crucial to any conservation planning effort.

Studies of riparian ecosystem dynamics have documented the importance of base flows and pulse-flood regimes, dynamic geomorphologic processes in the floodplains, and a diverse mosaic of habitat structures to the biotic community (Richter and Richter 2000, Glenn et al. 2001, Stromberg and Chew 2002). Avian diversity and abundance show a positive response to increases in Freemont cottonwood (*Populus* *fremontii*) and Gooding willow (*Salix gooddingii*) cover, as well as the structural complexity of vegetation (Krueper et al. 2003, Scott et al. 2003, Anderson et al. 2004). All of these associations are important in understanding avian community response to habitat change and in considering methods for restoring habitat and functions.

However, the success of revegetation efforts in restoring riparian ecosystem function and the native avifauna has been limited. Revegetated sites have lower avian diversity, densities, and reproductive success than native sites as a result of lower habitat diversity and structure, and unnatural patterns of hydrology (Larison et al. 2001, Snell-Rood and Cristol 2003). Although natural revegetation may be stimulated by releasing water from upstream reservoirs in short pulses (Richter and Richter 2000, Sher et al. 2000, Stromberg and Chew 2002, Glenn and Nagler 2005), questions remain regarding whether degraded floodplains can be restored with a designed pulse-flood regime, and how the avian community might respond to such events.

The floodplain of the Colorado River in Mexico is a degraded environment and a classic example of US-Mexico borderlands issues, where management decisions on both sides of the border have impacts on the flora and fauna of the riparian ecosystem. Before the development of the hydraulic infrastructure in the basin, the Colorado River delta supported >200,000 ha of riparian and wetland areas (Sykes 1937). After the completion of the larger dams in the 1930s, limited base or pulse flow reached the area for nearly 50 yr, resulting in the virtual loss of cottonwood-willow forests and the invasion of exotic saltcedar (*Tamarix ramosissima*; Glenn et al. 2001). This caused the local extirpation of nine breeding bird species, including Southwestern Willow Flycatcher (*Empidonax traillii extimus*), Yellow Warbler (*Dendroica petechia*), and Bell's Vireo (*Vireo bellii*), species of conservation concern for the Colorado River delta region (Hinojosa-Huerta et al. 2004). However, a modest, but significant portion of the riparian ecosystem in Mexico has regenerated in response to large-volume water releases from US dams over the past 25 yr (Glenn et al. 2001, Zamora-Arroyo et al. 2005). The releases have simulated a natural pulse-flood regime and a base flow, thus supporting the regrowth of young and dynamic stands of cottonwood and willow, which have covered >3,000 ha despite the dominant presence of saltcedar (Nagler et al. 2005). Yet we know little about how avian communities use the riparian habitat in this region throughout the year, and how birds respond to surface water and other habitat components, all important issues in understanding how birds may respond to this regenerating habitat.

To address these questions we: (1) determined the spatial and temporal patterns of avian species richness, abundance, and community structure in a regenerating floodplain, and (2) explored the relationships of species richness, density and community structure with land cover (including surface water) and vegetation features. Finally, with this information we inferred some responses by the bird community to the current regeneration and make some recommendations regarding the restoration options for the floodplain of the Colorado River in Mexico.

METHODOLOGY

Study Area

The study area was located within the floodplain of the Colorado River in Baja California and Sonora, Mexico (Fig. 1). The floodplain traverses the Mexicali Valley as the river flows toward the Gulf of California, and is confined by flood control levees on both banks. The total area is 43 000 ha, and extends for 150 km along the river. Within this region, we worked in the area from San Luis Río Colorado downstream to the confluence of the Colorado River with the Hardy River, covering 12,630 ha and extending for 65 river km. This study area included the main stem of the Colorado River, secondary streams, backwater lagoons, and portions of the major agricultural canals within the floodplain. The floodplain maintains a continuous corridor of vegetation along this stretch, dominated by saltcedar and arroweed with significant patches of cottonwood and willow (Glenn et al. 2001). Water flows in the area have been intermittent since the completion of Hoover Dam (1937), depending upon excess deliveries from the US to Mexico, and operational releases from the Mexicali Irrigation District and agricultural drainage water. These variations in flow have determined the extent and quality of riparian habitat in the floodplain, ranging from degradation due to desiccation to regeneration in response to the return of flows (Glenn et al. 1996, Nagler et al. 2005). Extended dry periods have occurred (1952–1979), in which no flows reached the area, as well as extreme flooding events of over 800 $m^3 s^{-1}$ (1981–1983; International Boundary and Water Commission 2007). During the last 12 yr, the area has experienced significant flooding events (1993, 1998, 2002, and 2005) with a magnitude of 40–100 $m^3 s^{-1}$, as well as modest semi-continuous instream

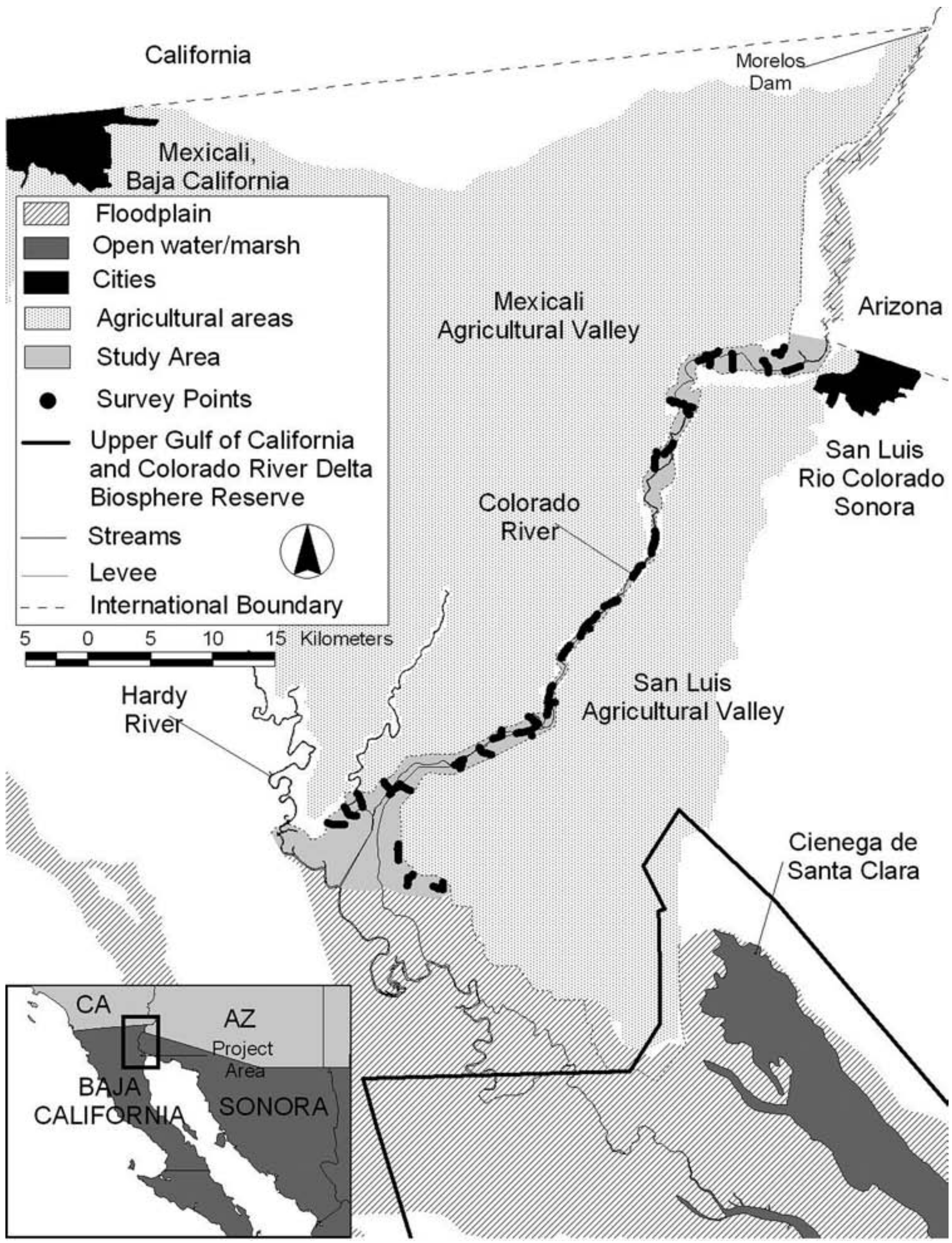

FIGURE 1. Map of the Colorado River delta, Mexico.

flows (2–8 m^3 s^{-1}) during several years (1993, 1997, 1998, 1999, 2001, 2002, and 2004; Zamora-Arroyo et al. 2005).

BIRD SURVEYS

We conducted bird counts monthly from May 2002–July 2003 following a variable distance point-count methodology (Ralph et al. 1996). The levee system includes embankment structures on both sides of the river, but these levees are not continuous on both sides for the entire 65 km of the study area. Therefore the total length of levees within the study area was 146 km. We randomly selected 30 transects, at least 2 km apart, along the 146 km of levees. Each transect was composed of 8 points, 200 m apart, and extended for 1.6 km from the levee toward the main channel of the river. Transects were run by teams of two persons, mainly for security reasons, starting at sunrise and continuing until no later than 4 hours after sunrise. At each point we counted all birds heard or seen within a 5-min period, recording the distance from the observer to the bird and the time at which it was detected.

Habitat Surveys

We measured habitat features at each point along the 30 survey transects, using a survey radius of 50 m from the center of each point. At each survey point we visually estimated the percent ground coverage, and when appropriate the minimum, maximum, and average height of each of the following strata: trees (vegetation >3 m in height), shrubs (0.5–3 m), herbs (0.1–0.5 m), forbs (<0.1 m), emergent plants, bare soil, and open water. We also collected more detailed data for each stratum by estimating the percent coverage and average height of each plant species within a stratum. For open water, we recorded type (primary or secondary stream, drain, irrigation canal, or lagoon), depth, and width. The estimates of land cover were obtained with the aid of measuring tapes, global positioning system, and pacing, using relative coverage within the 50-m radius of each survey point.

Statistical Analyses

We conducted the statistical analyses using JMP IN 3.2 (Sall and Lehman 1996) and DISTANCE (Thomas et al. 2002). Detections of flyover birds were excluded from the analyses. Distance models were selected for calculating bird densities, using a combination of goodness of fit test and the coefficient of variation in the parameter estimates. Estimates of bird abundance were obtained using the study area of the point-count surveys (12,630 ha), and the 95% confidence intervals of the density estimates from DISTANCE.

For avian density, we estimated the overall density of birds per transect per visit. For species richness, we used the average number of species/point at each transect, for each visit.

We used ANOVA and Tukey-Kramer pairwise analysis to compare species richness and density among seasons. The grouping of visits by season was based on the pattern of temporal shift in the avian community, defining spring (March, April, May), summer (June, July, August), fall (September, October, November), and winter (December, January, February).

We tested for pairwise correlation of explanatory variables. If two variables showed a correlation >0.75, we excluded the variable with less value in management or ecological terms. We determined the habitat relationships with a multiple linear regression of avian density and species richness with habitat features. We conducted a forward stepwise selection of variables for each model ($P < 0.25$) and ran the models including only variables with $P < 0.05$. The values reported are means ± SE, except for estimates of density, where 95% confidence intervals are given. We used a significance level of 0.05 for all statistical tests.

RESULTS

Vegetation Cover

The Colorado River floodplain in our study sites supported a diverse array of riparian habitat types, with overall vegetative cover of 70% of which 88% was composed of shrubs and trees (Table 1). Bare soil and open water covered almost 30%. Native plants covered 34% of the floodplain of which cottonwood and willow covered 8%, while exotic plants covered 37%. Within the tree stratum, saltcedar was the dominant species (19% cover), while cottonwoods and willows covered 7% and mesquite (*Prosopis* spp.) covered <1% (Table 2). Saltcedar was also the most common shrub, followed by arrowweed (*Pluchea sericea*), seep willow (*Baccharis salicifolia*), and saltbush (*Atriplex* spp.). Cattail (*Typha domingensis*) was the dominant emergent species, but common reed (*Phragmites australis*) and bulrush (*Scirpus* spp.) were also present.

Avian Communities

We obtained a total of 109,287 bird records for 186 species. The average abundance per point was 29.2 individuals (± 1.2) with an average richness of 8.6 species (± 0.2), and an average density of 47.7 birds per ha (± 7.0). Overall,

TABLE 1. Average percent cover and height of vegetation strata in the study area within the floodplain of the Colorado River, Mexico. Confidence intervals (95% CI) are shown in parentheses. The value of water in the mean height column represents depth.

Strata	Mean cover (%)	Mean height (m)
Trees	27.55 (24.82–30.28)	4.63 (4.45–4.85)
Shrubs	35.04 (32.35–37.72)	1.72 (1.68–1.76)
Emergent	5.40 (4.32–6.49)	2.06 (1.94–2.18)
Herbs	1.93 (1.43–2.43)	0.39 (0.31–0.47)
Forbs	0.52 (0.16–0.87)	0.12 (0.09–0.154)
Water	5.65 (4.59–6.71)	0.34 (0.28–0.39)
Bare soil	23.89 (21.46–26.32)	-

TABLE 2. AVERAGE PERCENT COVER AND HEIGHT OF PLANT SPECIES WITHIN THE TREE STRATUM IN THE FLOODPLAIN OF THE COLORADO RIVER, MEXICO. CONFIDENCE INTERVALS (95% CI) ARE SHOWN IN PARENTHESES.

Tree species	Mean cover (%)	Mean height (m)
Willow (*Salix* spp.)	5.52 (4.23–6.81)	4.89 (4.49–5.14)
Cottonwood (*Populus* spp.)	1.66 (1.16–2.17)	6.01 (5.39–6.62)
Honey mesquite (*Prosopis glandulosa*)	0.29 (-0.10–0.70)	3.81 (3.36–4.25)
Screwbean mesquite (*Prosopis pubescens*)	0.74 (0.29–1.19)	3.63 (3.37–3.89)
Saltcedar (*Tamarix ramosissima*)	19.36 (16.82–21.90)	3.50 (3.35–3.66)

the most common species were Mourning Dove (*Zenaida macroura*), Red-winged Blackbird (*Agelaius phoeniceus*), Verdin (*Auriparus flaviceps*) and Brown-headed Cowbird (*Molothrus ater*, Table 3), which together comprised 46% of all records. However, 64 species were commonly found (>10 records per visit), including Cliff Swallow (*Petrochelidion pyrrhonota*), Song Sparrow (*Melospiza melodia*), and Abert's Towhee (*Pipilo aberti*, Table 3). Thirty-eight species had <five total records, some of which were accidental or vagrant birds in the area, including Zone-tailed Hawk (*Buteo albonotatus*), White-breasted Nuthatch (*Sitta carolinensis*), Gray Vireo (*Vireo vicinior*), and Red-shouldered Hawk (*Buteo lineatus*), while others were formerly common (Ruiz-Campos and Rodríguez-Meraz 1997, Patten et al. 2001) and now have become rare, such as Lucy's Warbler (*Vermivora luciae*), Bell's Vireo, and Brown-crested Flycatcher (*Myiarchus tyrannulus*).

Average bird abundance was highest in winter ($F_{3,446}$ = 10.05, P < 0.001, Tukey-Kramer pairwise comparisons among seasons P < 0.001; Fig. 2). Changes in abundance of Red-winged Blackbirds in the floodplain accounted for up to 65% of the differences in abundances among seasons, because they increased from 88,500 individuals (95% CI = 29,480–265,780, 467 observations, χ^2_{480} = 0.52) in summer, to 1,473,000 individuals (95% CI = 728,285–2,979,750, 5,815 observations; χ^2_{89} = 0.48) in winter, when they were the most common species detected. In addition to the common birds whose numbers remained relatively the same throughout the year, the floodplain received an influx of wintering migrants, such as Ruby-crowned Kinglet (*Regulus calendula*), Yellow-rumped Warbler (*Dendroica coronata*), and Blue-gray Gnatcatcher (*Polioptila caerulea*), which contributed to the higher abundance during this season. However, species richness is lower than in other seasons, because this is the period with less en-route migrants passing through the area (Fig. 2).

The species richness was highest in spring (March–May, $F_{3,446}$ = 8.89, P < 0.001, Tukey-Kramer pairwise comparisons among seasons P < 0.02; Fig. 2). This pattern corresponds to the temporary presence of 64 species of neotropical en-route migrants that stop over in the floodplain on their way north, including Northern Rough-winged Swallow (*Stelgidopteryx serripennis*), Wilson's Warbler (*Wilsonia pusilla*), Warbling Vireo (*Vireo gilvus*), Willow Flycatcher, Pacific-slope Flycatcher (*Empidonax difficilis*), Yellow Warbler, Townsend's Warbler (*Dendroica townsendi*) and Western Tanager (*Piranga ludoviciana*). The pattern is also influenced by the arrival of 14 species of locally breeding migrants, arriving from their wintering grounds (Fig. 2).

During summer, the avifauna in the floodplain is composed of resident species and breeding seasonal visitors. Species richness and abundance is lower than during spring, as the peak of migration has passed, but there are

TABLE 3. DETECTIONS BY SEASON AND RELATIVE DOMINANCE OF THE 10 MOST COMMON SPECIES IN THE FLOODPLAIN OF THE COLORADO RIVER, MEXICO FROM MAY 2002–JULY 2003.

Species	Spring	Summer	Fall	Winter	Total	Relative dominance
Red-winged Blackbird (*Agelaius phoeniceus*)	2,501	1,178	3,932	9,167	16,778	19.00
Mourning Dove (*Zenaida macroura*)	4,162	4,056	4,072	4,244	16,534	18.72
Verdin (*Auriparus flaviceps*)	1,306	827	627	1,110	3,870	4.38
Brown-headed Cowbird (*Molothrus ater*)	1,892	1,434	71	283	3,680	4.17
Great-tailed Grackle (*Quiscalus mexicanus*)	693	342	803	1,484	3,322	3.76
Song Sparrow (*Melospiza melodia*)	979	392	361	927	2,659	3.01
Abert's Towhee (*Pipilo aberti*)	1,008	538	511	534	2,591	2.93
Cliff Swallow (*Petrochelidion pyrrhonota*)	896	703	0	694	2,293	2.60
Gambel's Quail (*Callipepla gambelii*)	813	382	184	340	1,719	1.95
Yellow-rumped Warbler (*Dendroica coronata*)	3	0	663	844	1,510	1.71

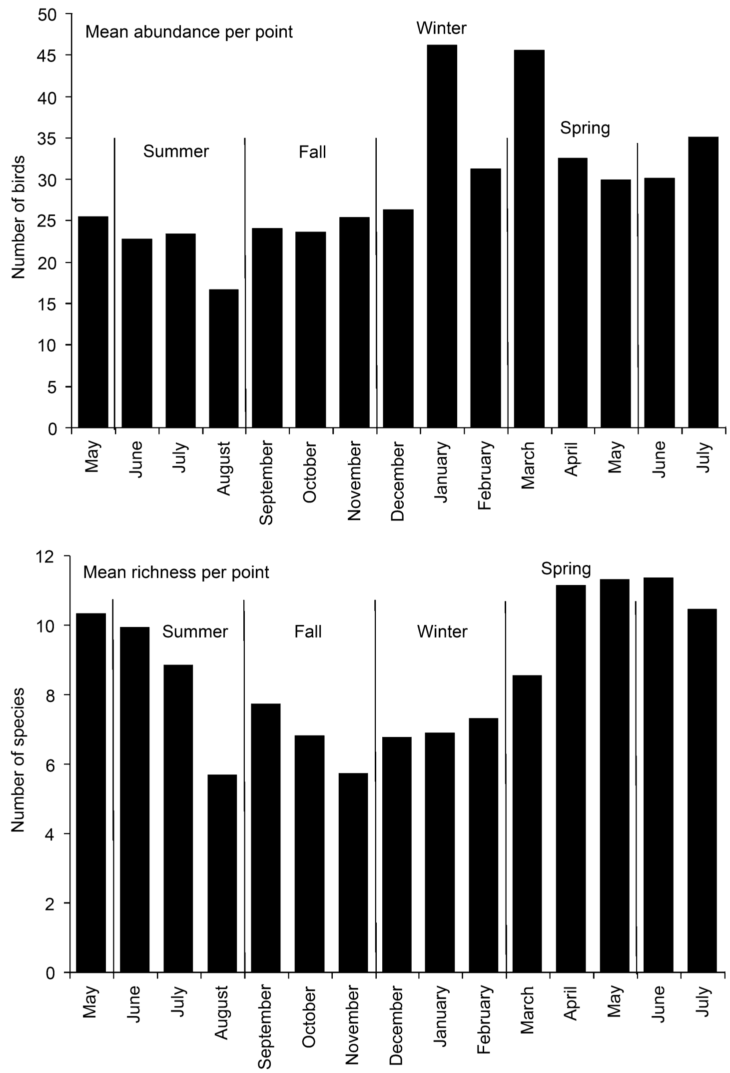

FIGURE 2. Average bird abundance and species richness per point by month in the floodplain of the Colorado River, Mexico, from May 2002–July 2003. Values for abundance are shown on the upper figure and values for richness are shown on the lower figure.

still en-route birds moving through the region, in particular *Empidonax* flycatchers (Fig, 2). The breeding bird community consisted of 61 species (four non-native), including riparian generalists, such as White-winged Dove (*Zenaida asiatica*), Blue Grosbeak (*Passerina caerulea*), Western Kingbird (*Tyrannus verticalis*), Ash-throated Flycatcher (*Myiarchus cinerascens*), and Ladder-backed Woodpecker (*Picoides scalaris*). The community also included riparian specialists, such as Yellow-billed Cuckoo (*Coccyzus americanus*), Vermillion Flycatcher (*Pyrocephalus rubinus*), and Yellow-breasted Chat (*Icteria virens*), marsh breeders, such as Clapper Rail (*Rallus longirostris*), Least Bittern (*Ixobrychus exilis*), and Marsh Wren (*Cistothorus palustris*), and waterbirds, such as Cinnamon Teal (*Anas cyanoptera*), Snowy Egret (*Egretta thula*), and Black-necked Stilt (*Himantopus mexicanus*).

Brown-headed Cowbirds are resident in the Colorado River delta-Mexicali Valley area. However, they exhibit regional movements almost disappearing in late fall and winter (i.e., no records in November and four records in December). Their numbers increase dramatically in summer with an estimate of

105,400 individuals in the floodplain (95% CI = 84,400– 131,700, N = 757, χ^2_{370} = 0.35). The abundance of Brown-headed Cowbirds in the floodplain during the breeding season probably causes significant impacts on the productivity of riparian songbirds (Rosenberg et al. 1991).

The indices in general for the avian community in the floodplain are lower in the fall than in the other seasons, as most of the breeding residents start their southbound migration, and the influx of transient birds is not as high as during the spring, in both abundance and richness (Fig. 2).

Habitat Relationships

Pooling the data from all seasons, the proportion of the landscape covered in surface water explained a significant amount of the variation in species richness (Table 4). When analyzing relationships for each season, the pattern was similar ($r^2 > 0.37$, $P < 0.001$). During the summer, cottonwood cover was also positively correlated with species richness (Table 4).

Considering the data pooled for all seasons, the variability in bird density was explained mostly by variations in the proportion of surface water and screwbean mesquite (*Prosopis pubescens*), both habitat features being positively correlated with avian densities (Table 4). When analyzing relationships for each season, the pattern during spring, fall, and winter was similar to that above ($r^2 > 0.22$, $P < 0.03$). Surface water remained important in explaining variation in bird densities during summer; but the other important habitat feature, replacing screwbean mesquite, was the percent cover of willows (Table 4).

DISCUSSION

The flows that have reached the floodplain of the Colorado River in Mexico in the last 25 yr have regenerated limited but important stands of native riparian vegetation, despite the previous dominance of saltcedar (Zamora-Arroyo et al. 2001, Nagler et al. 2005). Although causality has not been established, our results and the descriptions of the riparian community prior to flooding events (Ruiz-Campos and Rodríguez-Meraz 1997, Patten et al. 2001) suggest that the bird community has responded accordingly. Alternatively, we may be detecting more remnant bird species than expected.

Assuming that our estimates of avian indices and those from the Lower Colorado in the US (Anderson et al. 1983) are comparable and unbiased, we calculate that species richness is similar, but that densities are an order of magnitude higher in Mexico than in the US (Fig. 2). In addition, although the influence of the adjacent agricultural areas and long-lasting degradation are evident along the Colorado River in Mexico, the floodplain continues to support large populations of many species of riparian birds, many of which are protected species or are targets of continental or regional bird conservation plans (Hinojosa-Huerta et al. 2004). The floodplain also functions as an important migration link between breeding and non-breeding grounds for Neotropical migratory landbirds and some waterbirds. During spring, the floodplain provides a migration connection between the coast of the Gulf of California and the Colorado River corridor, also serving as a stopover area for birds that migrate through coastal and central California (Ecton 2003).

TABLE 4. Effects and coefficient results of the multiple regression models of avian richness and density against habitat features in the floodplain of the Colorado River in Mexico, May 2002–July 2003.

Response variable/Effect	r^2	F	Coefficient	SE	Standard coefficient	t	P
Bird species richness	0.45	24.83					<0.001
Constant			20.74	1.34	0	15.49	<0.001
Water			0.84	0.17	0.67	4.98	<0.001
Bird species richness summer	0.53	17.4					<0.001
Constant			19.89	1.07	0	18.55	<0.001
Water			0.63	0.12	0.65	5.09	<0.001
Cottonwoods (*Populus* spp.)			0.32	0.13	0.32	2.49	0.02
Bird density	0.28	6.63					0.005
Constant			22.50	9.38	0	2.40	0.02
Water			2.74	1.07	0.41	2.57	0.02
Screwbean mesquite (*Prosopis* spp.)			4.21	1.45	0.46	2.90	0.01
Bird density summer	0.31	7.44					0.003
Constant			9.75	7.50	0	1.30	0.20
Water			1.84	0.73	0.39	2.54	0.02
Willows (*Salix* spp.)			1.83	0.61	0.47	3.01	0.01

Species that were considered extirpated in this region, such as Yellow-billed Cuckoo, Vermillion Flycatcher, and Clapper Rail (Ruiz-Campos and Rodriguez-Meraz 1997, Patten et al. 2001) were found to be regularly present and presumably breeding in the floodplain during our study. Although no controlled bird surveys were performed before and after the regeneration events, the historic information on vegetation dynamics in the area during the last 25 yr (Glenn et al. 1996, Glenn et al. 2001, Zamora-Arroyo et al. 2001) shows that habitat for these species disappeared from the floodplain. It is reasonable to assume that these birds returned as breeders after the regeneration of the riparian ecosystem vegetative communities.

However, not all historically present breeding species occur in the floodplain (e.g., Southwestern Willow Flycatcher, Elf Owl [*Micrathene whitneyi*], and Summer Tanager [*Piranga rubra*]). In some cases, this could be attributed to the overall status of the population, and not to the lack of appropriate habitat features in the area, as might be the case for the Southwestern Willow Flycatcher. The floodplain appears to have adequate vegetation features (young stands of willows and saltcedar with very dense mid- and understory, near shallow water areas) for breeding Southwestern Willow Flycatchers (Sogge et al. 1997), but source populations may simply be too small or too distant to colonize recently restored areas. In other cases, the lack of certain vegetation attributes might preclude the colonization of some species. For example, Summer Tanager, Lucy's Warbler, Bell's Vireo, Yellow Warbler, and Elf Owl, require older, mature trees and/or cavities that do not currently exist in the floodplain (Rosenberg et al. 1991). Although the floodplain supports significant riparian forests, the estimated median age of cottonwoods and willows is 3 yr, with a rapid turnover rate due to the prevalence of human-induced disturbance events, particularly logging, fire, and flood-prevention clear cuttings (Nagler et al. 2005). Thus, stands of older trees (>8 yr old) are missing.

Both ground and surface water have been long recognized as the foundation upon which riparian ecosystems function. Water is not only valuable as a base flow to maintain the vegetation and as pulse-flood events to maintain dynamics and enhance recruitment, it is also a land cover feature (surface water) that provides habitat for a variety of species and promotes primary productivity and insect biomass (Naiman et al. 2005). In our study, the presence of surface water was a significant predictor of both species richness and abundance, regardless of vegetation type or other land cover features. Since surface water was a less common feature prior to the flooding events (Glenn et al. 1996, Zamora-Arroyo et al. 2001), it is reasonable to assume that the avian indices were lower then than during our study.

As expected, native trees had a positive association with the avian indices, particularly during the breeding season. Saltcedar was dominant in the upper, saltier and drier terraces, but cottonwood and willow appear to survive and reproduce successfully when adequate water is present, even where saltcedar is common (Sher et al. 2000, Stromberg and Chew 2002, Nagler et al. 2005). As with surface water, the cover of native trees was scarcer prior to the flooding events (Zamora-Arroyo et al. 2001, Nagler et al. 2005), thus it is probable that bird abundance and richness were lower then, and that the indices were enhanced at the time of our study.

The areas dominated by cottonwoods and willows still had significant cover of saltcedar, but mostly as a mid- or understory species, adding structural diversity to a site. Similar results were found in a Mojave Desert watershed, where bird diversity was not affected by the invasion of saltcedar, and the avian indices were best modeled by total vegetation volume and structural diversity (Fleishman et al. 2003).

Of major concern with respect to restoration is the screwbean mesquite, which only represents a small fraction of the vegetation cover in the floodplain, and yet is an important predictor of bird density. The proportion of mesquite in the landscape has probably been widely reduced, as it once occupied elevated terraces adjacent to the cottonwood-willow forests (Stromberg and Chew 2002). These areas are now converted into agriculture, or otherwise have become too saline for mesquite and are dominated by sparse saltcedar shrubs.

Prior to this study, no active eradication of saltcedar or restoration projects (e.g., reforestation with native riparian trees) was conducted in the floodplain of the Colorado River in Mexico. Yet, significant patches of native riparian vegetation and wetlands have naturally regenerated in response to flooding events and modest instream flows (Zamora-Arroyo et al. 2001, Nagler et al. 2005). It is reasonable to conclude that the characteristics of the bird community and the current avian indices in the floodplain are also primarily a function of the hydrologic events.

Based on the response of riparian vegetation to restored hydrologic regimes (Stromberg and Chew 2002, Glenn and Nagler 2005, Nagler et al. 2005), and considering the avian-habitat relationships we observed, we propose several key strategies to maintain and enhance habitat values for birds in the Colorado River floodplain in Mexico: (1) a base flow should be secured, to maintain existing native vegetation and maximize surface water (see Glenn et al. 2001 for details), (2) pulse-flood events should be allocated to maintain dynamism and the regeneration of native trees, (3) human-induced disturbances (fires and logging) should be avoided or minimized in the floodplain, especially if they prevent the establishment of older stands of cottonwood and willow, and (4) active manipulation may be needed to re-establish mesquite-dominated terraces.

The Colorado River basin has experienced below-average precipitation in the last 5 yr (Balling and Goodrich 2007). This has resulted in new research and analyses and has sparked discussions about shortage criteria for water deliveries in the lower basin states and into Mexico (USDI Bureau of Reclamation 2007). At the same time, water demands in the basin in the US and Mexico continue to increase (Barnett et al. 2004). Under this scenario, the probability of having unplanned flood events into the Colorado River delta has been drastically reduced (Christensen et al. 2004). Yet, several water resource management alternatives have been designed and initiated to guarantee an allocation of water to restore and maintain the Colorado River delta. These strategies include the creation of a water trust and the acquisition of water rights in Mexico to secure an instream flow (Gutiérrez-Lacayo and Hinojosa-Huerta 2007). Other strategies include guaranteeing a portion of the outflow of wastewater treatment plants for wetland restoration, as well as the dedication of agricultural drainage for this purpose (Hinojosa-Huerta et al. 2007).

Our study provides information on the status of the birds in the floodplain of the Colorado River in Mexico during a 15 mon period. We show the characteristics of an avian community and its habitat relationships in a riparian area where the vegetation was regenerated after flooding events. The patterns we observed for population levels and community structure of birds are likely to change throughout the years as characteristics in the floodplain change due to variations in water flows, restoration efforts, drought, fire, and other events. Monitoring efforts in the floodplain to document variations in numbers, species richness, and community structure of birds in relation to vegetation dynamics, water flows, and restoration efforts will provide critical information to develop better management strategies to protect and recover birds in riparian areas.

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