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HABITAT USE AND THE EFFECTS OF DISTURBANCE ON WINTERING BIRDS USING RIPARIAN HABITATS IN SONORA, MEXICO

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HABITAT USE AND THE EFFECTS OF DISTURBANCE ON WINTERING BIRDS USING RIPARIAN HABITATS IN SONORA, MEXICO

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Habitat use and the effects of disturbance on wintering birds using riparian habitats in Sonora, Mexico.

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Abstract:

Riparian systems are important for breeding bird communities in southwestern United States and northern Mexico, and are highly used as migratory corridors; however, their importance for wintering birds has not been assessed systematically. In order to assess the value of riparian areas for birds wintering in Sonora, data from 1,816 standard point counts were collected from 87 locations during January and February 2004-2006. A total of 253 species were detected across 14 vegetation types, including nine categories of riparian vegetation. The mean number of species and individuals detected per count was significantly higher in riparian vegetation than in non-riparian vegetation for migratory species, but not for residents. Riparian bird communities are different from those in non-riparian habitats, and contribute 22% of the regional avifauna's species. The "Balanced Breeding Limitation Hypothesis" is discussed as a possible explanation of the relatively high abundance of migrant species wintering in riparian environments.

Anthropogenic disturbance has imposed significant changes in riparian habitats, and is known to have negative effects on biological communities. To assess the effects of human induced disturbance on wintering bird communities, I recorded community composition, relative abundance of species, and three indicators of bird condition in relatively undisturbed and highly disturbed sites at three river systems in Sonora. My results indicate that there is, in general, little effect of disturbance on the composition of wintering communities, with less than 20% of the most common species having significant differences in their abundances between relatively undisturbed and highly disturbed sites. Condition indicators were similar in the two disturbance levels, but the mean heterophil/lymphocyte ratio in the blood of sampled birds showed increased levels of physiological stress in disturbed sites. A more experimental approach is needed to determine the specific cause of the stress expression in leucocytes.

Modification of natural flooding regimes has resulted in the decrease and loss of riparian native corridors, the invasion of exotic plants, and changes in associated animal communities, as has been the case in the Colorado River Delta. In the final chapter, I present a summary of the changes experienced by riparian systems and some of the measures implemented for riparian restoration in the southwestern United States, and then I compare the scenario with that in central Sonora, where some of the same stressors exist on riparian systems, but where traditional management practices have also mitigated some of the negative consequences of flow control along mid-sized river systems.

To place my own bird survey data in a broader context, I appended a compilation of more than 48,500 records from between 1849 and 2006 on the birds of Sonora from published accounts, museum specimens, and my own field work. They include a total of 533 species, nine of which were added from the compilation and my own field work. I also discuss the status of other species for the State's inventory.

Dedication

This paper is dedicated to three pioneers in biological research of the post-naturalist era in Michoacán, México. During their time, each had a vision that inspired biology students and professionals to pursue advanced degrees in Biological Sciences, and they had a particularly important influence on my development as a scientist and professor.

Sócrates Cisneros Paz… hard working scientist, philosopher, human, intense writer, poet, and visionary… He knew in his heart that the future is in the hands of young people, and until the last days of his life he kept that important connection. I am sure he can see now his legacy as the intellectual, who established the basis for the study of the "natural resources" and the most important biological groups in Michoacán, today embodied in the research labs at the Facultad de Biología, UMSNH.

Francisco Méndez García… inspiring professor, avid lector, sower, and catalyst of initiatives… He has been a leader in designing and constantly updating the study plans for the formation of modern biologists in Mexico. He initiated the study of birds and promoted the foundation of the bird collection at UMSNH, beginning with a group of students who he involved in a common adventure that continues still and will go on into the future. By leading, trusting and supporting students, he set up the conditions for them to freely walk pathways never imagined. He is able to see the fruits of such endeavors in the present.

Laura E. Villaseñor Gómez... creative thinker, innate explorer, fighter, and never-ending dreamer… As part of the "new" generation of biologists, she has put her soul in the rejuvenation of the role of scientists and educators. I am sure that her philosophy of applying her knowledge and experience to change minds and hearts for a better future is rooting, and will bear abundant fruit soon. With her, I took my first steps into the discovery of Nature's splendor, learned and worked through good and hard times, and shared precious moments that will remain a part of the best memories of my life.

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HABITAT USE AND THE EFFECTS OF DISTURBANCE ON WINTERING BIRDS USING RIPARIAN HABITATS IN SONORA, MEXICO

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Introduction

Motivated by the finding of consistent declining population trends in migrant landbird species in the northeastern United States, there emerged numerous studies throughout the 1990's dealing with the breeding biology of Neotropical migratory species (Terborgh 1992, Hagan & Johnston 1992, Rappole 1995, Martin & Finch 1995). More recently, attention has been focused on the ecology of migration and the understanding of its importance as a limiting period during the life cycle of those species (Hutto 2000, Skagen *et al.* 2005, Heglund & Skagen 2005). However, knowledge of the wintering biology of migratory birds is limited, especially in the more northern wintering locations. We need a better understanding of the requirements of, constraints on, and threats to migratory birds during their complete life cycle, as well as on habitats they use as corridors or stopover sites during migrations. This paper focuses specifically on aspects dealing with the ecology of bird species of the Western Migration System wintering in the State of Sonora, Mexico,

Within the context of western Neotropical migrants the desert-dominated riparian landscapes of the State of Sonora in the northwestern mainland Mexico are important for several reasons. First, the southernmost distribution of riparian habitats dominated by associations of cottonwood and willow in western North America are well represented along mid-elevation rivers in Sonora. Since such habitats are known to be critical for breeding landbird species in western United States (Bottorff 1974, Rumble & Gobeille 2004), I considered it important to determine the significance of the same habitat types for migrant and resident species during the winter time. Second, although most western long-distance migrants travel farther south to central-western Mexico, Sonora also constitutes for some of them their northernmost wintering distribution. It is also the most important wintering area for most western short-distance migrants. In addition, during the coldest months of the year, some highland resident bird populations descend in elevation and join those communities at lower elevations to make use of riparian environments. Consequently, riparian bird communities in winter include a complex mixture of migrant and resident species.

In the second chapter I investigate the patterns of habitat use by wintering migrant and resident birds in Sonora to determine whether they use and prefer some habitats over others. I address specifically whether riparian vegetation types are more likely to be used than expected on the basis of sampling intensity.

Riparian habitats are very susceptible to disturbance. They have been strongly modified by human encroachment, fragmentation, grazing, erosion, pollution, water diversion, dam construction, and desiccation due to adjacent agricultural development and direct human needs. In fact, more than 80% of the riparian corridor area in North America has disappeared in the last 200 years (Naiman *et al.* 1993). Despite their limited areal extent and the disturbance they have experienced, riparian habitats are very important for avian populations (Hunt 1985, B.L.M. & P.I.F. 1998). Does disturbance have an effect on bird diversity in riparian habitats? Does it influence the physiological performance of birds and, therefore, their fitness? These questions are addressed in the third chapter.

The final chapter constitutes a general overview and comparison of human land-use practices in the southwestern U.S. and in Sonora to assess whether differences might have measurable ecological consequences as represented by patterns of bird distribution.

I conclude with a discussion of some practical measures that might help maintain the structure, function, and associated animal communities in riparian environments.

In order to have a basic understanding of what is known about birds in the state of Sonora, a compilation and revision of the extant information was considered timely and important. In Appendix A, I have included the results of this compilation. The revision covers a period of 157 years (from 1849 to 2006) and includes a database of more than 48,500 records from 89 published papers and reports, 16,008 specimens deposited in zoological museums, and more than 21,700 personal observational and banding records. A total of 533 species belonging to 71 taxonomic families and 20 orders, with 223 all-year residents, 46 summer residents, 214 long-distance migrants, and 50 partial migrants are now known to occur in Sonora. The compilation of museum specimens allowed me to include the Yellow-billed Loon (*Gavia adamsii*), the Masked Booby (*Sula dactylatra*), the Red-footed Booby (*Sula sula*), and the Orange-fronted Parakeet (*Aratinga canicularis*) as new species for the state, and to discuss the presence of the California Quail (*Callipepla californica*) and the Arctic Tern (*Sterna paradisaea*) for the state; recent unpublished observational records added the Black Rail (*Laterallus jamaicensis*) to the list, and records from my research supported the inclusion of the Northern Jacana (*Jacana spinosa*) and the Eurasian Collared-Dove (*Streptopelia decaocto*), and the modification of seasonal status for the Mangrove Warbler (*Dendroica petechia erithacoroides*). I also suggest the exclusion of the Bridled Tern (*Sterna anaethetus*) and the Sandwich Tern (*Sterna sandvicensis*), because there is not enough supporting evidence to maintain them listed as part of the Sonoran avifauna. I also include information on the conservation status of the species according to the Red list of Threatened Species of the IUCN, the United States Neotropical Migratory Bird Conservation Act, and the Norma Oficial Mexicana NOM-059-ECOL-2001.

The study of living organisms can be defined as vast, complex, continuous, dynamic, fascinating, and challenging. An outstanding professor teaching an advanced class in biology once mentioned that, "*In biological sciences, the study of organisms often brings more questions than answers*," and I can do nothing more than agree. One of the most basic things that we learn through the study of organisms, their behavior, and the way they relate to their environments, is that, in ecology, there are no set formulas. As scientists, we must be humble and recognize that we all possess our own inherent limitations. Our understanding of the actors and the processes within the arena of the living world are the best logical explanations supported by what we know as facts, what we witness in nature, and what we think occurs in a given time and space. It is hoped that the information presented in this volume can be useful in helping make some sense out of a few of the processes and environments which we and all other living beings depend upon.

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Chapter 2

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

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Abstract. Riparian systems are, in general, dynamic and diverse despite their limited areal extent. They are especially important for breeding bird communities in Southwestern United States and are highly used as migratory corridors; however, their importance for wintering birds has not been assessed systematically. Information from 1,816 standard 10-minute point counts was gathered at 87 locations in the State of Sonora, Mexico (54 non-riparian sites [944 counts], and 33 riparian sites [872 counts]) from sea level to 2,175m during January and February 2004-206. I detected 253 bird species across 14 vegetation types, including categories of riparian vegetation. Eighty percent of the species were detected in riparian, and 72% were detected in non-riparian vegetation. The mean number of species and individuals detected per count was significantly higher in riparian vegetation than in non-riparian vegetation for migratory species, but not for residents. A hierarchical classification analysis showed that riparian bird communities are different to 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. The "Balanced Breeding Limitation Hypothesis" (Johnson *et al.* 2006) is discussed as a possible explanation of the relatively high abundance of migrant species wintering in riparian environments.

Resumen. Los sistemas riparios son en general 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 1,826 conteos estándar de 10-minutos se obtuvo en 87 localidades en el Estado de Sonora, México (54 sitios no riparios [944 conteos], y 33 sitios riparios [872 conteos]) desde el nivel del mar hasta 2,175m durante Enero-Febrero de 2004-2006. Detecté 243 especies en 14 tipos de vegetación, incluyendo categorías de vegetación riparia. Ochenta por ciento de las especies fueron registradas en vegetación riparia y 72% en vegetación no-riparias. El número promedio de especies e individuos detectados por conteo fue significativamente mayor en vegetación riparia que en vegetación no-riparia 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 en sitios no-riparios, y contribuyen con 22% de las especies que conforman la avifauna regional, la mayor contribución entre los hábitats estudiados. La hipótesis "Balanced Breeding Limitation" (Johnson *et al.* 2006) se discute como una posible explicación de la relativamente mayor abundancia de especies migratorias invernando en ambientes riparios.

Introduction

Natural riparian systems constitute the interface between the terrestrial and freshwater aquatic environments in the terrestrial portion of the Earth. They encompass sharp environmental gradients, ecological processes, and communities. They also include an unusually diverse mosaic of landforms, communities, and environments within a larger landscape, and hold unique associations of soil, flora, and fauna. A typical riparian environment includes terrain adjacent to streams, rivers, and lakes, from the high water mark into the uplands, where vegetation is still influenced by elevated water tables or flooding, and by the ability of soils to hold water (Naiman *et al.* 1993, Naiman & Décamps 1997). They are known to filter agricultural contaminants, buffer landscapes against erosion, and provide habitat for high numbers of species, contributing importantly to the local and regional biodiversity (Sabo *et al.* 2005).

All riparian vegetation types are dynamic and generally more biologically diverse than surrounding uplands, with the difference in diversity being most pronounced in arid regions (Hunt 1985). In general, riparian systems have exceptional faunal diversity because of the presence of water, their high productivity, and the abundance of edge, which is maximized by the long, narrow shape of riparian habitats (Gregory *et al.* 1991). In the southwestern United States, for example, riparian systems support at least 80% of all wildlife species (Hunt 1985, B.L.M. & P.I.F. 1998). They are also very important as foraging habitat for bats in Canada (Grindal *et al.* 1999) and Poland (Lesinski *et al.* 2000); as forage, thermal cover, and corridors for movement of desert mule deer in Arizona (Krausman *et al.* 1985); as important refuges for the ground beetles in agricultural landscapes in Oklahoma (French & Elliot 2001); and as important environments for small mammal and herpetofaunal communities in agricultural landscapes of Quebec (Maisonneuve & Rioux 2001). Riparian systems also have the highest densities of small mammals in the Cascade Region of Oregon (Doyle 1990), and in the desert of Arizona (Andersen 1994). They also harbor the richest communities of butterflies in the arid lands of southwestern United States (Nelson & Anderson 1999, Fleishman *et al.* 1999), and the richest and most abundant vertebrate communities in Northern Queensland, Australia (Williams 1994).

The importance of riparian systems to birds

With respect to birds, riparian habitats have some of the most dense and species rich communities in France (Decamps *et al.* 1987), the United States (Knopf *et al.* 1988), the Caribbean Islands (Arendt 1989), Western Mexico (Hutto 1995), Canada (Wiebe & Martin 1998), Czechoslovakia (Hubalek 1999), and tropical areas of Australia (Woinarski *et al.* 2000). The importance of riparian habitats to bird species did not begin to be appreciated until the end of the 1960s, when efforts to quantify the impact of streamside vegetation removal on wildlife were first carried out (Gavin & Sowls 1975). Results of these early studies showed that riparian habitats support some of the highest densities of breeding birds in comparison with any other forested habitat type, and that they have a very important influence on the ecological dynamics of adjacent habitats (Bottorff 1974, Gavin & Sowls 1975, Stevens *et al.* 1977). Subsequent studies have continued to provide similar results (e. g. Stamp 1978, Knopf 1985, Johnson & Haight 1985, Szaro & Jakle 1985, Hunter *et al.* 1985, Anderson *et al.* 1989, Strong & Bock 1990, Rosenberg *et al.* 1991, Croonquist & Brooks 1993, Farley *et al.* 1994a, Hill 1998, Lynn *et al.* 1998, Skagen *et al.* 1998, Powell & Steidl 2000, Green & Baker 2002).

Riparian bird communities are not only exceptional with respect to species richness and overall bird abundance, but many riparian bird species occur in no other vegetation type. This takes on special significance when one considers that riparian habitats comprise a very small percentage (generally less than 1%) of land area. In Western Montana, for example, 89 (59%) of 151 landbird breeding species use riparian habitats and 36% of those breed only in riparian areas (Mosconi & Hutto 1982). Recent recalculations show that 90% (211 out of 235) of all breeding bird species use riparian, and 45% depend completely on (are restricted in their distribution to) riparian habitats; among landbirds, 87% (150 out of 173) species use riparian, and 31% are obligate riparian species (R.L.

Hutto, unpublished data). Similarly, 82% of all species breeding in northern Colorado (Plate River Watershed) occur in riparian vegetation and, on average, 42% of the species are riparian obligates (Knopf 1985). In New Mexico, 46% of the bird species that breed in the San Juan Valley (Schmitt 1976) and 49% of those that breed in the Gila Valley (Hubbard 1971) depend on riparian vegetation. Indeed, it has been estimated that 51% of all species in the southwestern United States are completely dependent upon this vegetation type (Johnson *et al.* 1977).

The importance of riparian systems to en-route and wintering migrants

The importance of riparian systems during periods of migratory passage and as wintering areas has received relatively little attention, even though these periods may be equally or more important than the breeding season in terms of population regulation (Fretwell 1972, Sherry & Holmes 1995, Hutto 1998).

With respect to the two annual migratory periods, landbirds have to make important choices about which stopover locations and habitats will provide enough food, cover, and water to enable a rapid and safe replenishment of energetic fuels while en route (Moore & Simons 1992). Indeed, mortality rates during these energetically demanding periods may be considerable (especially for young individuals) because migrants must compete for resources with other migrant and resident individuals while surviving potential predators in new and unfamiliar locations. Until more recently, and despite their potential importance, migration periods had, for the most part, been overlooked. We currently know little about the specific habitat types that are important during migration, and how the distribution, abundance, and suitability of important habitats are changing with development and land conversion. The studies that do exist, however, indicate that landbirds use riparian habitats disproportionately often during migration, especially during the spring migratory period, when the productivity of such habitats is higher than that of the surrounding uplands (Stevens *et al.* 1977, Johnson *et al.* 1977, Wauer 1977, Johnson & Jones, Jr. 1977, Hehnke & Stone 1978, Hutto 1985, Skagen *et al.* 1998, Finch & Yong 2000, Glenn *et al.* 2001, Kelly & Hutto 2005, Skagen *et al.* 2005). Indeed, migratory periods are now considered key for the conservation of migrant landbird populations (Moore *et al.* 1995, Hutto 2000, Heglund & Skagen 2005).

Information on the importance of riparian systems to wintering birds is also scant, and is based largely on occasional riparian habitat records within species accounts for specific areas or locations (Johnson & Simpson 1971, Gavin & Sowls 1975, Russell & Lamm 1978, Terrill 1981, Rosenberg *et al.* 1991, B.L.M. & AZ. 1996), or lists obtained by observers participating in the Christmas Bird Counts, and on studies that happen to involve the complete annual cycle of riparian birds (e.g., Anderson & Ohmart 1977, Wells *et al.* 1979, Strong & Bock 1990, Farley *et al.* 1994a). In the only published studies of wintering bird distribution among a variety of vegetation types in Mexico, it was found that the abundance of Neotropical migrants in riparian habitats and gallery forests are among the highest in central-western Mexico (with an average of 8.4 individuals per count, n=180 counts) (Hutto 1980, 1995). These abundances were exceeded only by bird abundances in agricultural border strips (average of 12.2 individuals per count, n=807 counts). Thus, existing data suggest that riparian corridors are important for wintering birds. Bird assemblages in riparian habitats of Southwestern United States and Northwestern Mexico may not be as species rich or abundant as during migratory periods but, in winter, they may still attract and concentrate higher proportions of species and individuals than do upland areas.

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 wintering area for short-distant migrant species of central and western United States. Riparian corridors in Sonora were once described by Johnson and Lowe (1985) as "*…linear landscape communities of luxuriant deciduous hardwood forest and microphyll woodlands, framed sharply by contrasting desert land, scrubland, woodland, and forestland of the immediately surrounding uplands*." There, the only other habitat options for wintering birds are drier, hotter, and structurally less diverse.

Riparian zones are known to be habitats of critical conservation concern worldwide because of the essential processes they play in ecological systems, and the wetlands and riparian areas in the southwestern United States and Northwestern Mexico are among those considered to be key ecosystems. Nonetheless, we know very little about the wintering use of these systems by bird species, so I sought to determine how significant riparian areas are for the wintering bird communities in the state of Sonora, Mexico. Specifically, I addressed two main questions: (1) are the wintering bird communities associated with riparian habitats significantly different from those associated with other upland habitat types in the State of Sonora? and, (2) are the riparian habitats important in terms to their contribution to the regional diversity? In order to answer these questions, I examined the community composition and the 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.

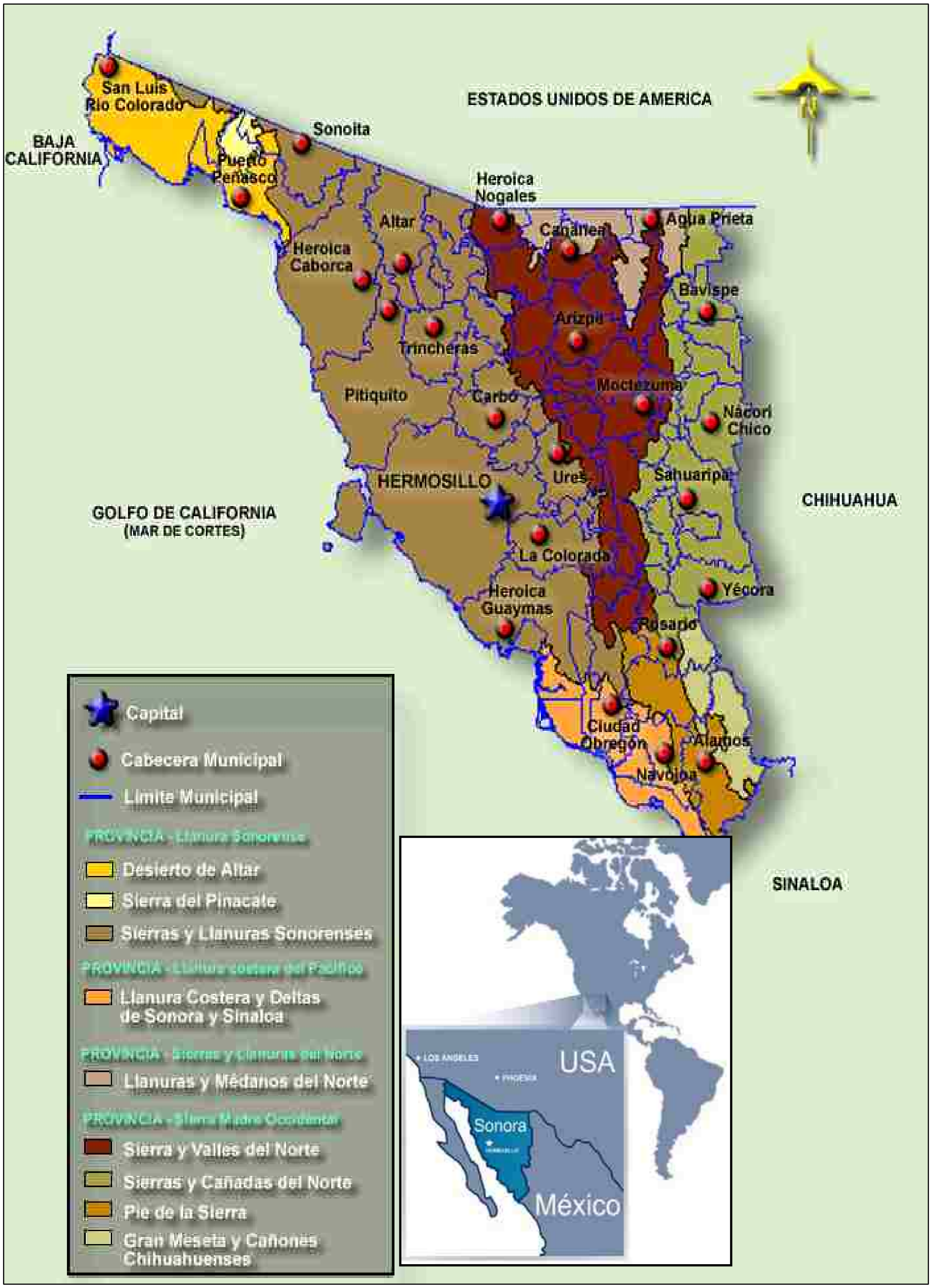
Study Area

Sonora is the second largest state in Mexico, covering 179 156 km^2. It is located at the northwestern corner of the mainland Mexico between 26° 18’ and 32° 29’ N, and 108° 25’ and 115° 03’ W. It is bounded by the United States of America to the north, the state of Baja California and the Sea of Cortés to the west, the state of Sinaloa and the Sea of Cortés to the south, and the states of Chihuahua and Sinaloa to the east (Figure 1).

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, having elements form both regions. It has an interesting and complex variation in its landscapes, within an elevational range from sea level to 2630m (in Sierra Huachinera). The lowland plains are vegetated primarily by desert and xeric scrubby types. 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 by associations of cottonwood and willows are present discontinuously along the river courses, and mangroves are distributed in isolated patches

Figure 1. The State Sonora, Mexico (INEGI 2000).

Source: http://www.semarnat.gob.mx/sonora/imagenes/Image7(1).jpg



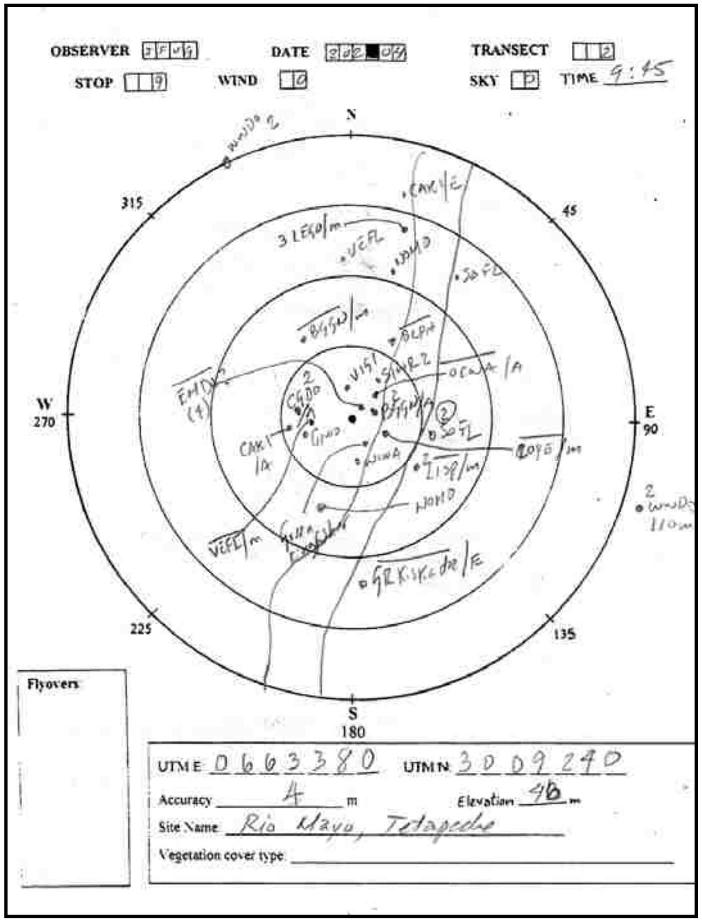
along the coast of the Sea of Cortés. For a detailed description of climate regimes and vegetation types, please refer to the Appendix B.

Rivers and underground water have played 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 form 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 (agriculture is the most important economic activity accounting for more than 25% of the state's gross revenue). Sonora is also one of Mexico's main producers of high quality beef cattle, with 50% of this production being exported to the United States; fifteen million hectares, including pasturelands, woodlands, shrublands, and prairies with buffel grass are used for raising and breeding beef cattle.

Methods

During January and February of 2004, 2005, and 2006 surveys were carried out in fourteen vegetation types and nine riparian associations at sample points scattered throughout Sonora, ranging from sea level to elevations over 2,000 m (Figure 4 and Table 5). Information was gathered through 10-minute standard point counts of unlimited-radius performed between 7:00 and 11:00 hrs. Most aquatic species, those birds flying over or farther away in the distance were recorded but not used in any of the analysis. Raptors, swallows, and other aerial species were recorded only if they were on the vegetation or the ground within the point count area (Hutto *et al.* 1986, Ralph *et al.* 2005). Undetermined species such as hummingbirds and individuals belonging to the Genus *Empidonax*, were grouped and included, respectively, in the list as "Unknown Hummingbird" and "*Empidonax* sp". A format was used to map the location and distance from the observer to each detection (Figure 3). The information gathered was entered into an Excel database and was managed for the analysis with SPSS 11.5.1 for

Figure 2. Field format used to record information from point counts.


OBSERVER

DATE

TRANSECT

STOP

WIND

SKY

TIME 9:45

N

315

45

W 270

E 90

225

135

S 180

Flyovers

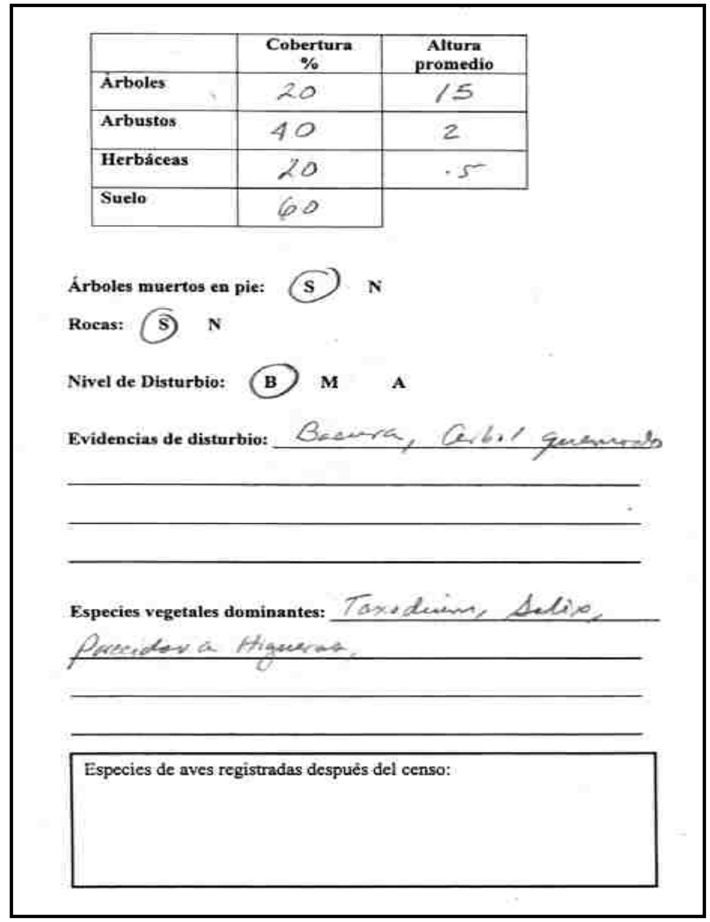
UTM E 0663380 UTM N 3009240

Accuracy 4 m Elevation 46 m

Site Name Río Mayo, Tetapeche

Vegetation cover type

(Bird locations and general data)



	Cobertura %	Altura promedio
Árboles	20	15
Arbustos	40	2
Herbáceas	20	.5
Suelo	60	

Árboles muertos en pie: (S) N

Rocas: (S) N

Nivel de Disturbio: (B) M A

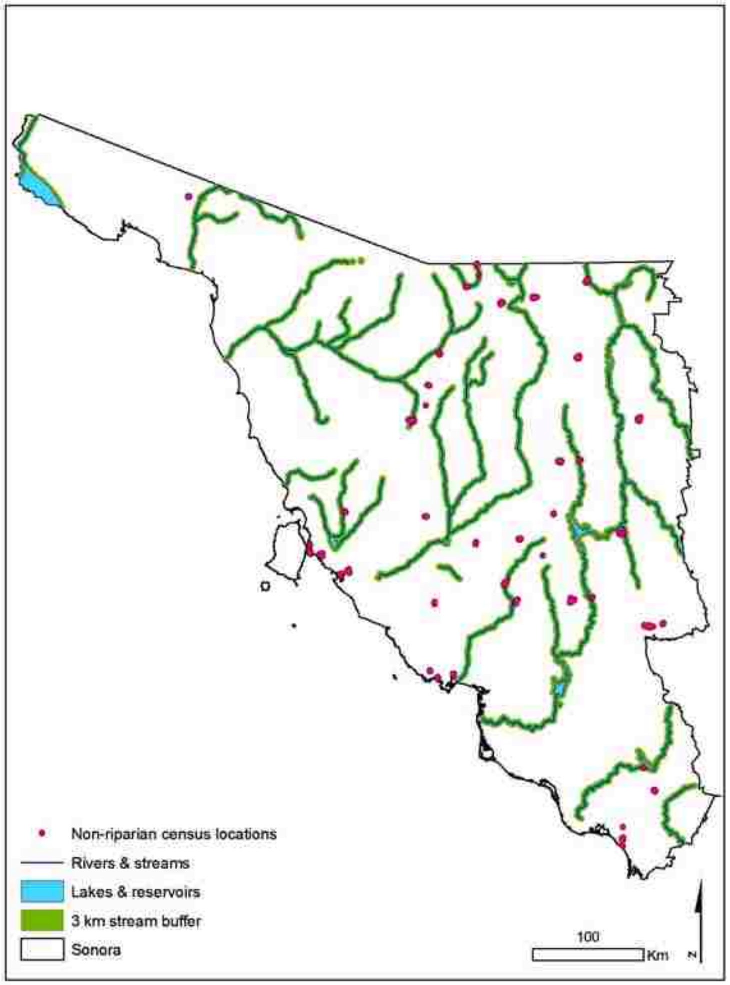
Evidencias de disturbio: Basura, árbol quemado

Especies vegetales dominantes: Taxodium, Salix,

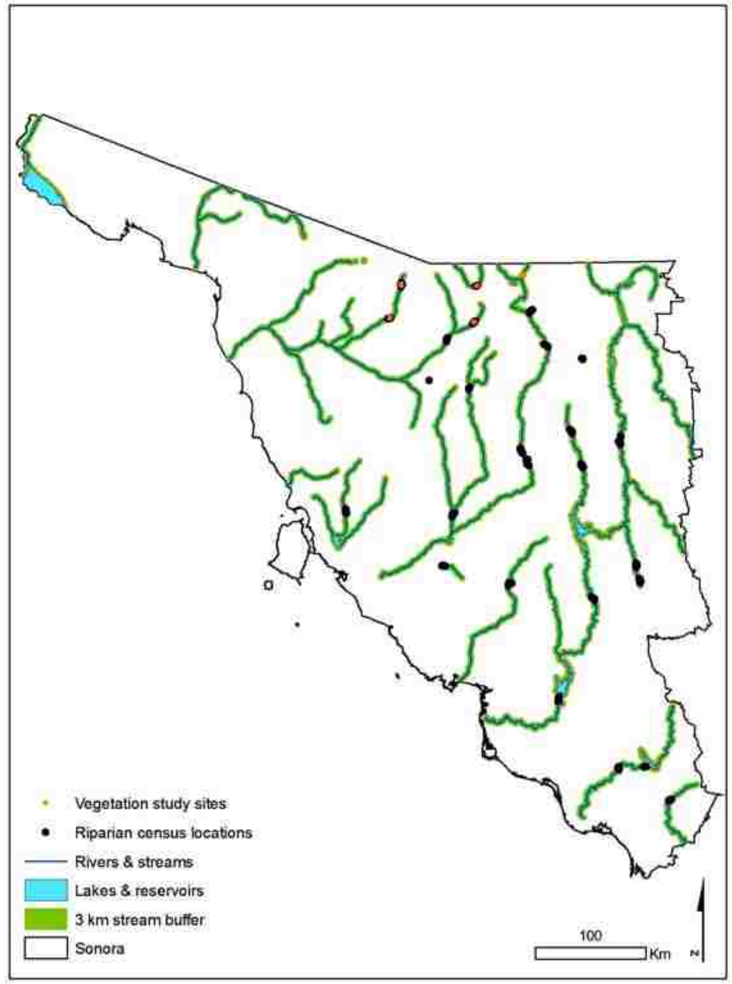
Especies de aves registradas después del censo:

(Site features and additional data)

Figure 3. Sampling locations in riparian and non-riparian habitats in the State of Sonora, Mexico.



Non-Riparian Sites



Riparian Sites

Table 1. Sampled vegetation types, number of point counts, number of species recorded, and bird sampling locations in Sonora, Mexico, during January and February (2004, 2005, and 2006).

NON-RIPARIAN SITES				
Vegetation Type	**Recorded Elevation (m)**	**Number of Point Counts**	**Number of species recorded**	**Locations Sampled**
Mangroves	Sea level	54	53 (includes aquatic and marine species)	- Estero del Soldado, San Carlos, Nuevo Guaymas - Estero Paraiso - Punta Chueca - Estero Santa Cruz – Bahía Kino - Estero Santa Rosa - Punta Chueca
Coastal Sarcocaulescent Scrubland	Sea level – 234	138	58	- Coteco - El Sahuaral, San José de Guaymas - Rancho "Monte Alto"- Road to Puerto Libertad - San Miguel, road to Punta Chueca - San Nicolás
Vegetation of sandy deserts	3-231	70	17	- Pinacate - Adair dunes NW of Puerto Peñasco - Pinacate - Cráter Cerro Colorado - Pinacate - Cráter Elegante - Pinacate – between Elegante and Tecolote - Pinacate - Gran Desierto de Altar - Puerto Peñasco – Caborca
Microphylous Scrubland	1159-1217	30	17	- El Cochito (Km 179 Road. Agua Prieta - Moctezuma)
Tropical Deciduous Forest	102-983	79	61	- El Resbalón - Sahuaripa - La Aduana - Presa Mocuzari - Río Mayo - Río Cuchujaqui - San Javier
Sarcocrassicaulescent Scrubland	307-824	58	20	- Caborca - Magdalena (Highway Magdalena-Imuris)

Table 5. Sampled vegetation types, number of point counts, number of species recorded…. (Continued 2)

Vegetation Type	Recorded Elevation (m)	Number of Point Counts	Number of species recorded	Locations Sampled
Thornscrub	184-1189	45	37	- Road to San Lázaro-San Antonio - El Llano - Moctezuma - San José de Pima - Tónichi
Subtropical Scrub	391 – 878	25	43	- Los Torreones - 10 Km W Mazatán - Rancho El 44, between Cobachi and road to Yécora - Rancho El Carrizo - Rancho El Perú - Rancho La Cuesta, Km 94 road to Yécora - Rancho Los Cuervos (N of Rancho El Carrizo) - Rancho San Fermín, ca. Cobachi
Sarcocaulescent Scrubland	13-551	152	47	- Ejido Ganadero - Puente El Tigre, Guaymas - La Pintada - Tetabejo - Pinacate - Sierra Ladrilleros - Puerto Peñasco - Caborca - N Rancho La Noria - Rancho Piedras Negras (Road to Mine Nyco) - San Carlos – road to Cañón de Nacapule - San Miguel, road to Punta Chueca
Grasslands	316 – 1592	83	14	- San Marcial - Mesa del Toro - Ej. Ignacio Zaragoza, Cananea - Rancho El Carrizo - Santa Cruz
Low Oaklands	970-1250	54	41	- S San Lázaro, Rancho Papalote - Road to San Lázaro-San Antonio - La Majada, between Moctezuma-Mazocahui - Sierra Mazatán

Table 5. Sampled vegetation types, number of point counts, number of species recorded…. (Continued 3)

Vegetation Type	Recorded Elevation (m)	Number of Point Counts	Number of species recorded	Locations Sampled
High Oaklands	1400-2010	75	61	- Aribabi – Sierra Alta - La Palmita - Yécora - Los Alisos - Santa Cruz
Highland Coniferous Forest	1525-2175	60	37	- La Mesa del Campanero - Sierra La Elenita, Cananea - Yécora
Oases	50-233	21	37	- Cañón de Nacapule
Non-Riparian Vegetation	**Sea Level – 2175**	**944**	**183**	
RIPARIAN SITES				
Willow–Mesquite-Chino (*Pithecoellobium*)	36-102	57	96	- El Chiculi, Hornos - Río Yaqui - Presa Mocúzari - Río Mayo - Tetapeche – Río Mayo
Mesquite Desert Riparian	117-823	89	108	- Agua Caliente springs Aconchi - Río Sonora - Arroyo La Poza - Ónavas - Río Yaqui - Presa Teópari - Sierra Mazatán - Rancho "Monte Alto"- road to Puerto Libertad - Rancho San Esteban - Río San Miguel - San Jose de Pima - Río Matape - Sáric - Río Altar - Soyopa – Río Yaqui

Table 5. Sampled vegetation types, number of point counts, number of species recorded…. (Continued 4)

Vegetation Type	Recorded Elevation (m)	Number of Point Counts	Number of species recorded	Locations Sampled
Willow-Mesquite	166-823	91	96	- Bámori - Río Sahuaripa - Cajón de Onapa - Río Sahuaripa - El Novillo S - Río Yaqui - Nochebuena - Río Yaqui - San Antonio de la Huerta - Río Yaqui - San José de Pima - Río Mátape - Sáric - Río Altar - Soyopa - Río Yaqui - Tónichi – Río Yaqui
Willow	348-840	104	96	- Bámori - Río Sahuaripa - Cajón de Onapa - Río Sahuaripa - San José de Pima - Río Matape - Sáric - Río Altar
Willow-Baldcypress	222-277	31	75	- Río Cuchujaqui
Cottonwood-Willow	527-1282	230	125	- Aconchi - Río Sonora - Bámori - Río Sahuaripa - Baviácora - Río Sonora - Granados - Río Bavispe - Huásabas - Río Bavispe - Jécori - Río Moctezuma - Rancho El Arivabi - Río Cocóspera - Río Santa Cruz - San Lázaro - Sáric - Río Altar - Térapa - Río Moctezuma - Tubutama - Río Altar - Unámichi – Río Sonora

Table 5. Sampled vegetation types, number of point counts, number of species recorded…. (Continued 5)

Vegetation Type	Recorded Elevation (m)	Number of Point Counts	Number of species recorded	Locations Sampled
Cottonwood-Mesquite	555-1305	23	45	- Aconchi - Río Sonora - Rancho El Arivabi - Río Cocóspera - Río Santa Cruz - San Lázaro - Sáric - Río Altar - Térapa - Río Moctezuma
Cottonwood	505-1288	214	125	- Aconchi - Río Sonora - Baviácora - Río Sonora - Cucurpe - Río San Miguel - Jécori - Río Moctezuma - Rancho El Arivabi - Río Cocóspera - Río Santa Cruz - San Lázaro - San Ignacio - Terrenate - Sáric - Río Altar - Térapa - Río Moctezuma - Tubutama – Río Altar
Sycamore (*Platanus*)	1322-1402	33	40	- Cañón de Evans, Road Cananéa - Bacoachi - Los Alisos
Riparian Sites	**33-1402**	**872**	**203**	
Total General		**1816**	**253**	

Windows. For the different analyses performed, only the detections within a radius of 25 m from the observer were used. Although much information was unused by restricting the data to this relatively small radius, I did so to decrease the potential error caused by the inclusion of individuals detected in adjacent non-riparian habitats (and to decrease bias due to inherent differences in lateral detectability of birds among habitat types).

Because of the complexity for determining the residency status of some bird populations in Sonora, where it is possible to find local resident populations, migrants, and transients at the same time of the year, species were assigned to one of three residency status categories: Residents, Migrants, and Partial Migrants. Residents are those species that remain and live in the same area all-year long. Migrant species are those that move far from their breeding areas and occupy a completely different geographical region in the south during the winter, with no overlapping populations (this is the case of all Long-distance Migrant Species). Partial Migrants are those species that experience seasonal displacements, but their movements are not of such magnitude. As a consequence, in the southern portions of their distribution area there could have been overlapping populations of resident, transient, and wintering individuals during migration periods and winter. Some species that are regularly Summer Residents in Sonora and maintain some individuals during the winter were also considered to belong to this group of Partial Migrants. The species were assigned to one of these seasonal status categories based on published information (van Rossem 1945, Howell & Webb 1995, Russell & Monson 1998) and personal experience.

The number of species and individuals detected, the mean number of species and individuals per count, and the percentage of the resident, partial migrants, and migrant species were computed for each vegetation type and riparian association. An ANOVA of the number of individuals detected was performed for each species to determine the ones showing significant differences between non-riparian and riparian habitats. A χ^2 test was performed to look for significant differences in the mean percentage of species recorded belonging to the residency status groups between riparian and non riparian habitats.

To determine if wintering bird communities associated with riparian habitats were significantly different from those associated with other habitat types, I used two classification techniques. First, a Hierarchical Classification Method (or Cluster Analysis), which is generally used to determine how similar two groups are (in this case, the bird communities detected in each one of the vegetation types). Through a variety of algorithms this technique can produce a dendrogram showing graphically the degree of similarity among the groups under analysis, placing the more similar groups close to each other, and father away from the most dissimilar ones. The second classification technique applied is known as "Two-Way Indicator Species Analysis" (TWINSPAN), and it is based on the idea 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 (also known as Reciprocal Averaging) and classifies the samples initially in two groups. Then, it refines the classification through Detrended Correspondence Analysis (DCA), finding the indicator species for the resulting groups, and based on those species, regrouping iteratively within the groups into smaller clusters until a limit is met. An indicator species is the species (or the group species) present in all the vegetation types clustered; a preferential 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 groups identified by the dendrogram produced in the clustering technique. In order to perform these analyses, I made use of the software PC-ORD for Windows, version 3.17 (McCune & Mefford 1997).

Results

Information was gathered on 1,816 standard 10-minute point counts (944 in non-riparian and 872 in riparian sites, respectively), at 87 locations (54 non-riparian sites, and 33 riparian sites) from sea level to 2,175m (Table 5, Figure 4). A total of 32,570 individuals belonging to 253 bird species were recorded across the full range of vegetation types, including riparian vegetation. Eighty percent of the species (203) were recorded in riparian associations, and 72% (183) in all the non-riparian vegetation types. Forty-three species associated primarily with aquatic environments were excluded from all analyses.

It is apparent that the diversity of bird species in riparian vegetation is greater than in any other vegetation type. A tally of the species across vegetation types (in spite of having unequal sample sizes), shows that the species richness in all the non-riparian habitats was less than 65 species. In contrast, riparian environments for the most part were richer, with more than 75 species. Especially important were the Cottonwood-Willow associations, as well as the very restricted Willow-Baldcypress riparian. Despite the limited number of samples therein (n=31), this last riparian vegetation harbored more bird species than any other non-riparian habitat (Table 5).

By limiting the count data to information included within a 25-m radius, a total of 8,237 individuals of 168 species were detected (82 residents, 33 partial migrants, and 53 migrants; Appendix D and E). The mean number of species and individuals detected per count in riparian habitats was higher than in non-riparian habitats, with differences being highly significant (Table 6). In general, the same pattern held for the Migrants and Partial Migrants groups, wherein the values were significantly higher for riparian habitats as well. In contrast, there were no significant differences for the Resident species or individuals. These results imply that the differences are due to the increased number of migrant and partial migrant species and individuals detected using riparian habitats (Table 6).

The percentage of resident species was higher in non-riparian habitats, while the percentages of partial migrants and migrants were higher in riparian vegetation types, although the differences were not significant ($\chi2= 4.105$, df=2, p= 0.128 NS). If we combine partial migrants and migrants together as a group, then the difference becomes significant ($\chi2= 4.083$, df=1, p=0.03) (Figure 5).

The contribution of migrant species and individuals to the avifauna in riparian sites is particularly important, as well as is the fraction of species and individuals of the resident group for the non-riparian habitats (Figure 6). Numerically speaking, the migrant species 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. Out of the 168 species, 59 (35.1%) showed significant differences in their abundances between the riparian and non-riparian environments; 18 (10.7%) were primarily associated with non-riparian habitats, and 41 (24.4%) with riparian habitats (Appendix F). Considering the community as a whole, a contingency analysis shows that the residents are overrepresented in the non-riparian habitats and the frequency of the migrants is significantly higher in the riparian environments (χ^2= 13.72, df= 4, p=0.008).

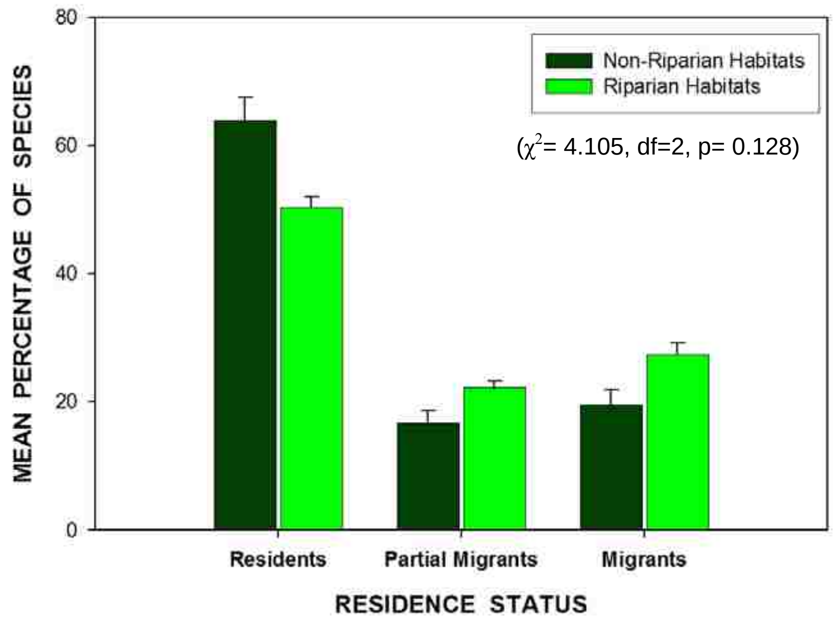
If the analysis is limited to those species with at least 20 detections (66 species) to avoid the effects of those species with low sample sizes, the differences are even more evident (χ^2= 18.35, df= 4, p=0.001) (Table 7). The general idea resulting from these analyses is that riparian associations (and mostly lowland riparian areas) are important for wintering migrants.

Table 2. ANOVA results for the mean number of species and individuals detected in point counts (25-m radius).

SPECIES	General Mean (n=1816)	Non-Riparian Habitats (n=944)	Riparian Habitats (n=872)	F	Sig.
ALL SPECIES	2.554	1.927	3.237	164.40	**0.00****
RESIDENTS	1.324	1.358	1.287	1.15	0.28 ns
PARTIAL MIGRANTS	0.589	0.316	0.885	234.99	**0.00****
MIGRANTS	0.642	0.253	1.065	424.78	**0.00****
INDIVIDUALS					
ALL SPECIES	4.292	3.338	5.329	58.43	**0.00****
RESIDENTS	2.057	2.149	1.958	1.92	0.17ns
PARTIAL MIGRANTS	1.123	0.654	1.633	46.14	**0.00****
MIGRANTS	1.112	0.535	1.739	106.41	**0.00****

Figure 4. Mean percentage of bird species by residence status in each of the vegetation types and riparian associations in Sonora. The mean represents the mean of the percentages of species recorded for resident, partial migrant, and migrant species in each of the habitat types.

A) considering the three residency status groups



B) considering partial migrants and migrants together as a single group

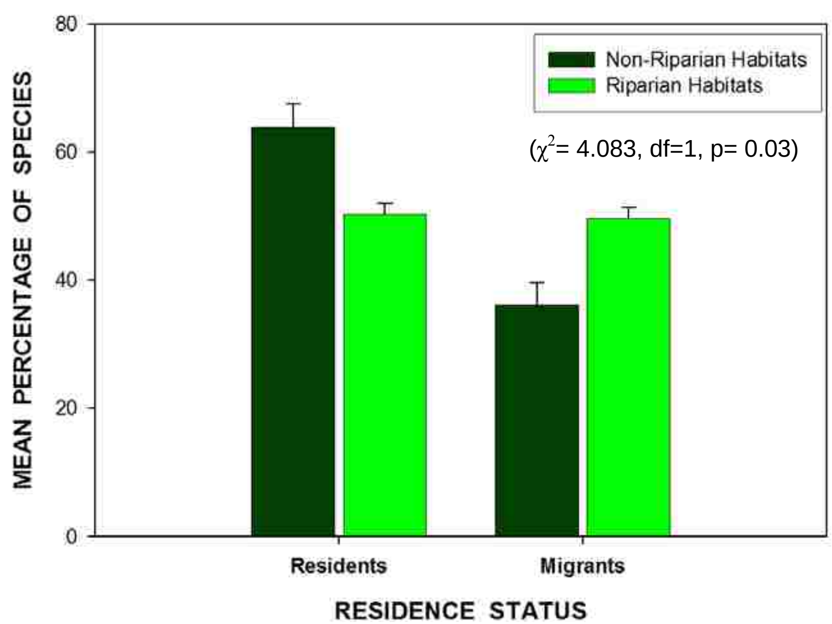
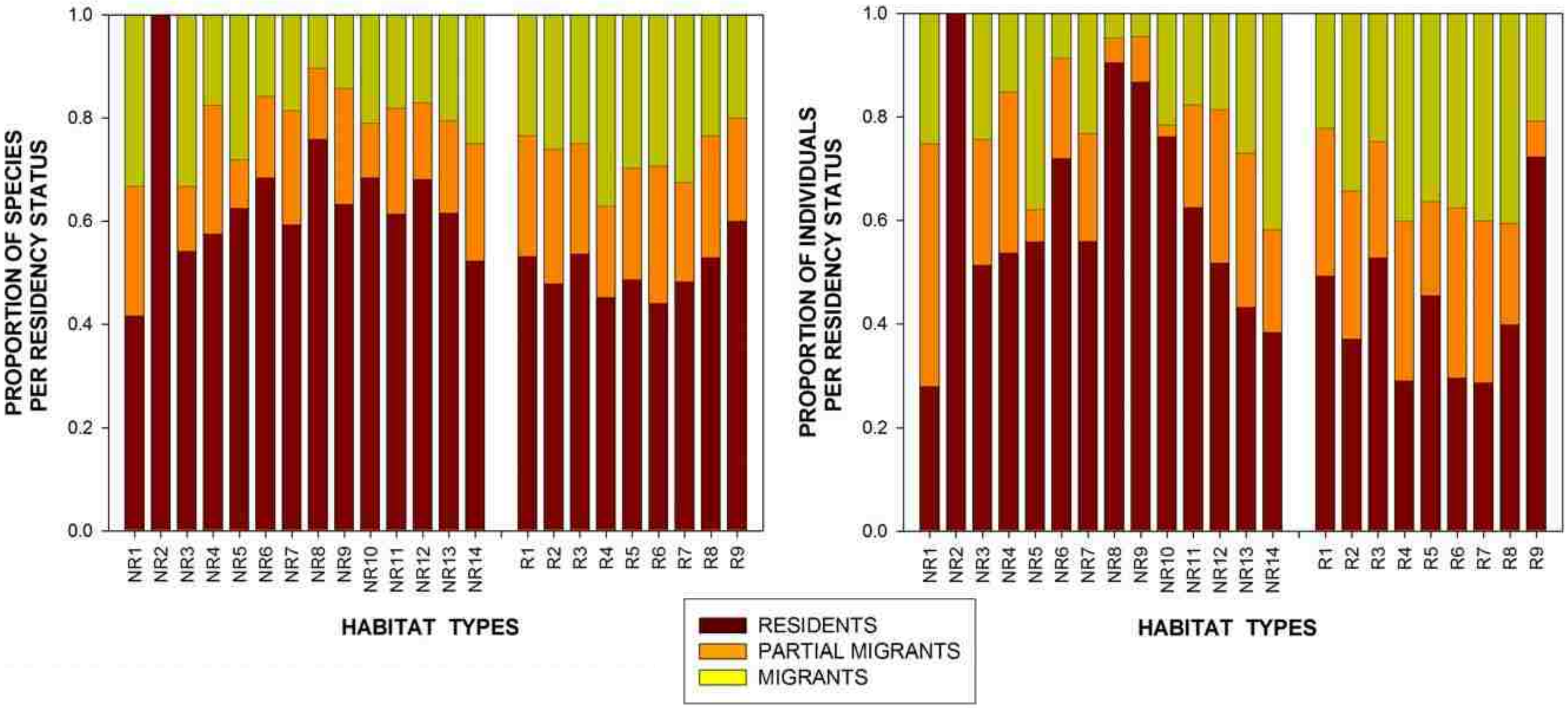


Figure 5. Contribution of the species and individuals to the avifauna of the habitats in Sonora.



(**HABITAT TYPES: NR** = Non-Riparian: 1= Mangroves, 2= Microphylous Scrubland, 3= Oasis, 4= Coastal Sarcocaulescent Scrubland, 5= Subtropical Scrub, 6 = Tropical Deciduous Forest, 7= Thornscrub, 8= Sarcocrassicaulescent Scrubland, 9= Sarcocaulescent Scrubland, 10 = Vegetation of sandy deserts, 11=Grasslands, 12= Low elevation Oaklands, 13= High elevation oaklands, 14= Highland Coniferous Forest; **R**= Riparian: 1= Willow-Mesquite-Chino, 2= Willow-Mesquite, 3= Mesquite, 4= Willow, 5= Baldcypres-Willow, 6= Cottonwood, 7= Cottonwood-Willow, 8= Cottonwood-Mesquite, 9= Sycamores.)

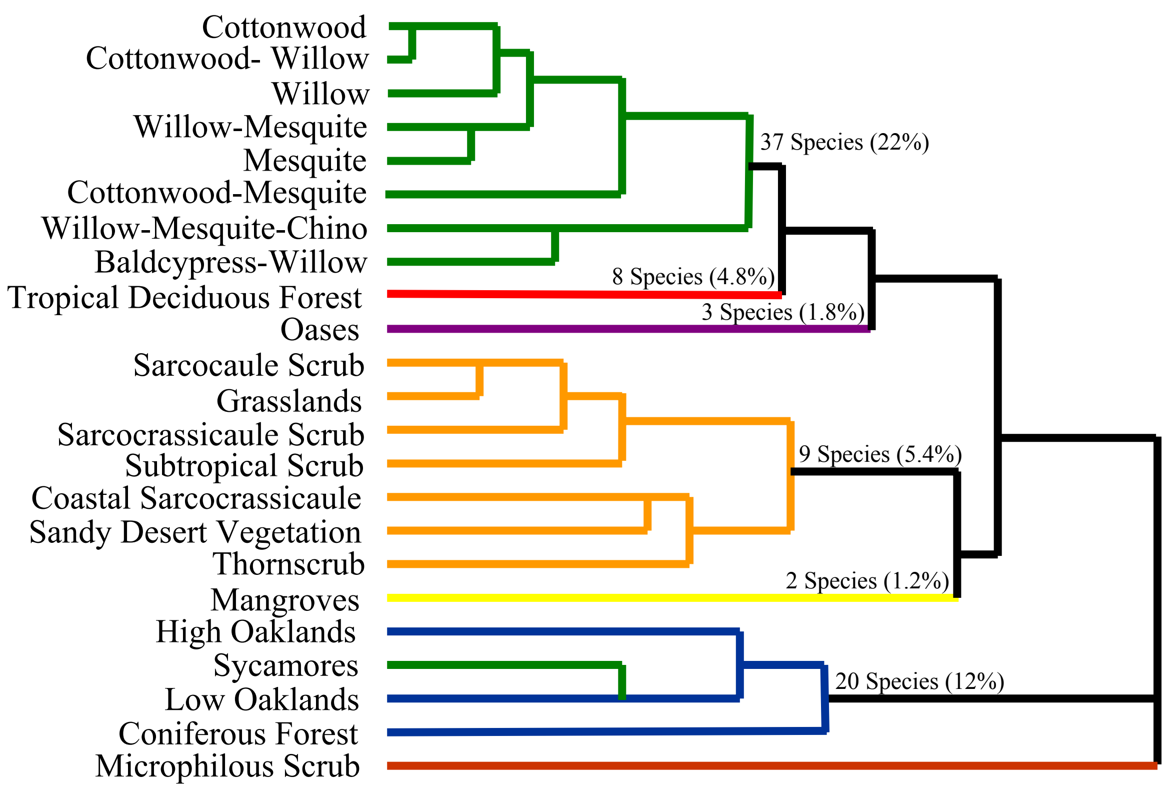
Table 3. The number of species that were and were not significantly more abundant in non-riparian and riparian habitats. (Expected frequencies shown in parenthesis).

Residence Status	All Species (n=168)				Species with at least 20 detections (n=66)			
	No sign. difference	**Non-riparian species**	**Riparian Species**	**Total**	**No sign. difference**	**Non-riparian species**	**Riparian Species**	**Total**
Residents	53 *(53.2)*	15 *(8.8)*	14 *(20.0)*	**82**	18 *(15.0)*	11 *(7.5)*	9 *(15.5)*	**38**
Partial Migrants	24 *(21.4)*	1 *(3.5)*	8 *(8.1)*	**33**	7 *(7.1)*	0 *(2.6)*	6 *(5.3)*	**13**
Migrants	32 *(34.4)*	2 *(5.7)*	19 *(12.9)*	**53**	1 *(5.9)*	2 *(3.0)*	12 *(6.1)*	**15**
Total	**109**	**18**	**41**	**168**	**26**	**13**	**27**	**66**

Knowing that riparian environments are important for wintering birds, an additional question might be: how unique riparian are bird communities during the winter in comparison with communities of other habitat types? Are they important in terms of their contribution to the regional diversity?

The dendrogram resulting form the cluster analysis (only presence-absence data, using Complete Linkage and the Ochiai Measure, Figure 7) separates the habitats into three main groups. The first one is represented by the highland habitats, the second one clusters all the desert scrubby vegetations and mangroves, and the last one groups all the riparian associations (except for the Sycamores which are grouped within the highland habitats), with the tropical deciduous forest and oases. The microphilous scrub stands by itself and independently of the other groups. This arrangement shows an interesting pattern in the composition of the avian communities: there seems to be an elevational gradient that separates the highland habitats from the low elevation ones, as well as a gradient of humidity that separates those communities of dry habitats from the ones associated to the more humid riparian areas.

Figure 6. Classification of the Vegetation types according to the wintering avifauna in Sonora, Mexico. (Riparian associations are represented by the green lines, orange lines correspond to desert scrubby vegetation types, and blue lines to highland forests. The number of species and percentages represent the numbers exclusive to the habitat or cluster of habitats).



The contribution of these habitats to the regional diversity can be assessed by determining the species that are exclusive to the habitats and would not exist if those habitats were not present in the region. According to this basic idea, the group of riparian associations contributes to the regional avifauna with 22% of the species, followed in importance by the highlands which add 12% of the species, the desert scrubby vegetations incorporating 5.4%, the tropical deciduous forest with 4.8%, the oases with 1.8%, and the mangroves with 1.2%.

The Two-way Indicator Species Analysis (TWINSPAN) results allowed to determine those “indicator” and “preferential” species that characterize each one of the clusters produced by the hierarchical analysis. The first group defined by the analysis was the cluster of highland vegetation types that had the Acorn Woodpecker as the indicator species, and a community of preferential species including the Sharp-Shined Hawk, Band-tailed Pigeon, White-eared Hummingbird, Hairy Woodpecker, Williamson’s Sapsucker, Hutton’s Vireo, Mexican Chickadee, Eastern Bluebird, American Robin, Brown Creeper, Olive Warbler, Crescent-chested Warbler, Townsend’s Warbler, Hermit Warbler, Grasshopper Sparrow, Yellow-eyed Junco, Pine Siskin, and Scott’s Oriole. It is important to mention 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.

The Microphilous Scrubland stands as a group by itself because of its poor avifauna (only six species), and its indicator species is the Rock Wren; no preferential species were defined for this group.

The second cluster includes the different variants of desert scrubby vegetation and grasslands. They have the Green-tailed Towhee as the indicator species, and Gambel’s Quail, American Kestrel, Common Ground-dove, Broad-billed Hummingbird, Costa’s Hummingbird, Say’s Phoebe, Brown-crested Flycatcher, Vermilion Flycatcher, Loggerhead Shrike, Horned Lark, Black-capped Gnatcatcher, Bendire’s Thrasher, Phainopepla, Vesper Sparrow, White Crowned Sparrow, and Pyrrhuloxia. Mangroves were associated with this cluster, and had the American Redstart as the indicator species, and the Yellow Warbler, Northern Waterthrush, and Lincoln's Sparrow as the preferential species.

The third group included the whole set of riparian associations at lower elevations, and had the Violet-crowned Hummingbird, Green Kingfisher, and Sinaloa Wren as its indicator species. Preferential species for riparian vegetation in general were Elegant Quail, Cooper's Hawk, Wilson Snipe, Plain-capped Starthroat, Belted Kingfisher, Pacific-slope Flycatcher, Nutting's Flycatcher, Cassin's Vireo, Plumbeous Vireo, Warbling Vireo, Happy Wren, American Pipit, Lucy's Warbler, MacGillivray's Warbler, Black-and-white Warbler, Painted Redstart, Hepatic Tanager, Lazuli Bunting, Varied Bunting, Red-winged Blackbird, and Lawrence's Goldfinch. The tropical deciduous forest and the oases clustered near the riparian associations and shared with them a good number of species; preferential species for the topical deciduous forest and the oases were White-tipped Dove, Northern Beardless Tyrannulet, Nutting's Flycatcher, Ash-throated Flycatcher, Canyon Wren, Five-stripped Sparrow, Rock Wren, Black-and-white Warbler, Wilson's Warbler, Rufous-capped Warbler, Rufous-crowned Sparrow, and Streak-backed Oriole. We can conclude that wintering bird communities using riparian environments are richer in comparison to the adjacent uplands, and out of the 134 species recorded in our counts, 37 are exclusive to riparian associations.

Discussion

Riparian environments have been identified as a key element of ecological systems, the component that maintains dynamic ecological processes along a gradient of landscapes, linking wildlife, vegetation, soils, and mater transfers involving water in terrestrial systems. Normally they are very productive systems and represent the most valuable habitat for wildlife in general, specially in the xeric regions of the world.

Some of the ideas that originally prompted this study were based on the fact that Sonora is part of the area included within the Western Migration System (defined as the geographic region containing the breeding, migratory and wintering individuals of western North America (Kelly & Hutto 2005)). In addition, (1) riparian associations have been identified as the most important habitat types for breeding birds in western United States; (2) cottonwood-willow riparian associations are found as far north as Montana and extend southwards as corridor fragments along the rivers to Arizona and the state of Sonora, west of Sierra Madre Occidental, reaching their southernmost distribution at the limits of the Mexican state of Sinaloa; (3) cottonwood riparian associations have been reduced drastically, and the maybe once continuous corridor tracts are now fragmented and modified by desiccation, dam construction, water diversion, invasion of exotic species, and overgrazing (and other factors). By studying those riparian habitats in their southern distribution, it may be possible to gain some insights into their importance in western North America, and at the continental level as well.

Cottonwood riparian woodlands and their associations have been identified as the most important habitat for birds in the interior Columbia River Basin in western United States (Saab & Rich 1997), Arizona (Stamp 1978, Strong & Bock 1990, Skagen *et al.* 1998), California (Wells *et al.* 1979, Rottenborn 1999), Colorado (Bottorff 1974), Idaho (Saab 1999), Montana (Mosconi & Hutto 1982, Scott *et al.* 2003), New Mexico (Hubbard 1971, Farley *et al.* 1994a, Farley *et al.* 1994b), South Dakota (Rumble & Gobeille 2004), and Wyoming (Finch 1989), and in every case they support the highest number of species and/or densities among the studied habitats. For the few published papers that include the list of species recorded in riparian habitats, the percentage of those species in the United States found wintering in Sonoran cottonwood riparian associations ranges from 63 to 86%, the differences being due primarily to those resident species with distributional ranges restricted to the United States or to summer residents from the Southern Hemisphere. Although we do not know details on the connectivity of the populations involved here, it is noteworthy that a high proportion of the species using cottonwood habitats on their breeding grounds is also found using similar environments in the winter in northwestern Mexico.

Rivers and their associated vegetation are very attractive for animal species in general. But, how much do they contribute to the diversity at the regional level? The idea of riparian areas having more species than uplands was explored by Sabo and others through a meta-analysis (Sabo *et al.* 2005), for which they included published information "*… from seven continents and including taxa ranging from the Antarctic soil invertebrates to tropical rain forest lianas and primates…*"; in such broad analysis they found no general pattern of higher species richness in riparian habitats vs. uplands for either local or cumulative diversity; however, they support significantly different species pools, increasing the regional diversity by more than 50% on average. Although their general results bring up a new and interesting perspective on the riparian-upland system at the global level, the scale used in the meta-analysis is so broad that it is very hard to apply the idea to specific biological groups. An important criticism of their approach is that they used information from such diverse taxonomic groups, diverse ecological systems, and different methods, that they may have concealed the processes and mechanisms acting on specific biological entities. Hylander (2006) criticizes their approach to determine the contribution of riparian areas to the regional diversity and suggests a simpler and straightforward way to asses it, by simply calculating the proportion of unique species in riparian sites, as well as a complementary analysis of the unique species in the uplands as well. He also points out that the results will depend on sampling effort and scale which have to be considered in such comparisons (Hylander 2006). His comments led Sabo and Soykan (2006) to reconsider and revise the previous analysis and conclusions about the β-diversity in riparian zones, and to conclude that, on average, the percentage of unique riparian species is 24%, and riparian zones increase regional richness by 38% (and not more than 50% as they had originally suggested). This percentage is closer to the contribution of riparian habitats to the bird communities in Sonora, Mexico (22%), the highest of any other group of habitats in this study.

Besides the contribution in terms of unique species (species that would not be found in the area if the river system did not exist in the area), riparian habitats act also as corridors allowing the movement and mixture of diverse faunal components among the different habitats they pass through along their course. This is another reason for their relatively high species richness.

As happens with most of the rivers of the world, human settlements as well as a host of activities are (and have been) associated with and depend on water courses, imposing ecological pressures on riparian environments. Because it is clear that riparian areas are the most important habitats in terms of winter avian diversity in Sonora, what are the factors that make them so attractive to birds during winter?

Structural complexity of riparian environments has been proposed as one of these factors. When comparing them with the surrounding uplands, there is no doubt riparian habitats are more lush and have a more complex vertical and horizontal structure, as well as higher plant diversity and woody vegetation area, especially in environments dominated by desert vegetation types as in Sonora. Vegetation structure has traditionally been found to be important for breeding and wintering birds in general (MacArthur 1964, Rice *et al.* 1980, Anderson *et al.* 1983, Hunter *et al.* 1987, Farley *et al.* 1994a, Sanders & Edge 1998, Perkins *et al.* 2003, Rumble & Gobeille 2004, McComb *et al.* 2005), and Greenberg and collaborators found wintering migrants to be more abundant in acacia patches with relatively high tree density and understory height in managed pasturelands in eastern Chiapas, Mexico (Greenberg *et al.* 1997). However, in every case some particular species showed higher densities or relative abundances in not-so-complex and highly structured successional habitats.

An alternative explanation is that productivity is higher in riparian ecosystems in general due to higher humidity and available water that translates into a more abundant and diverse array of food items available to birds during all times of year, especially in these xeric areas. If this were the case, resident species holding territories all year long should be more abundant than migrants in riparian environments. Because this is not so, 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 has been described as a paradox; ecosystem productivity (and especially the abundance of arthropods) is low when bird abundances reach their annual high during winter. Greenberg (1995) proposed the "Breeding Currency Hypothesis" (BCH) which states that there are two important currencies for birds. The first one is represented by those large soft-bodied arthropods (e.g. Orthoptera and Lepidoptera) generally used to feed young, and on which bird productivity relies. The other currency is represented by the total year-long biomass of small hard-bodied arthropods (e.g. Homoptera and spiders) used by adults for self-maintenance. The difference between the two represents the resources that resident birds cannot exploit completely and are, therefore, available to migratory wintering birds.

His idea takes into account temporal differences in abundance and quality of food resources. Large and protein-rich insects are abundant seasonally and are critical to feeding young efficiently, and they determine the breeding productivity of resident populations. On the other hand, small insects do not show strong seasonality and can be used to maintain populations of the new generations produced and adult individuals all year long. Both groups of insects belong to different taxonomic groups, implying that the intensive harvest on one of them would not compromise future generations of the other. As a logical consequence, limitation in any of these two types of food would have different consequences on the resident local bird populations.

Greenberg made two important predictions: 1) the ratio of standing crop of large arthropods during the breeding season to total biomass of arthropods during the non-breeding season should be negatively correlated with the proportion of migrants in a particular community, and 2) disturbed habitats would be more often avoided by residents because they support lower numbers of large soft-bodied insects that can be used as valuable currency; therefore, they will have higher proportions of migrants.

Johnson *et al.* (2005) evaluated this idea in a series of sites in Jamaica by determining the proportion and biomass of large soft-bodied and small hard-bodied arthropods, and found supporting evidence for Greenberg's BCH. They found proportionally more wintering migrants using habitats with proportionally less breeding currency for resident birds, and total abundance of birds correlated with total non-breeding arthropod biomass. Their results were consistent with the first prediction implied in this hypothesis. However, they did not find supporting evidence for the second prediction; after controlling the effects of insect seasonality, they found still significantly higher proportions of migrants in disturbed than undisturbed sites. They suggest that although the BCH partially explains the proportion patterns of abundance among migrant and resident birds, there might be other factors limiting the abundance of resident species, and allowing the opening of ecological spaces for migrants, mostly in disturbed areas. Any ecological factor acting in synergy with food availability to limit breeding currency for residents could help to explain the migrant to resident ratios in the tropical areas.

Earlier, Hutto (1980) reported that migrants in their wintering grounds in western Mexico were found at higher abundances in the structurally simpler disturbed habitats. He suggested that these environments could be underutilized by residents as a result of the lack of safe nesting sites and high rates of nest predation, leaving them available for wintering species. Unfortunately, there are not much data to assess this idea, but the pattern has been found in habitats with edges and others, such as gallery forests and agricultural hedgerows, as well as in "corridor" like vegetation tracks (Dowdeswell 1987, Kricher & Davis 1992, Warkentin *et al.* 1995, Villaseñor-Gómez & Hutto 1995, Hutto 1995).

Johnson *et al.* suggested a new hypothesis that develops on Greenberg's BCH and incorporates the effects of nest predation, as it was previously invoked by Hutto. They called this new synthetic idea the "Balanced Breeding Limitation Hypothesis" (Johnson *et al.* 2006). They state that the availability of breeding currency while feeding young will affect the risk of nest predation in such a way that, in sites with low breeding currency parents will be forced to increase the number of feeding trips, attracting predators and reducing nest guarding time, therefore increasing the likelihood of nest predation. The predictions that follow to their hypothesis are: 1) the proportion of migrants will be positively related to both the rate of nest predation and the ratio of non-breeding season arthropod biomass to breeding currency biomass, and 2) habitats with similar arthropod availabilities but different levels of human disturbance, should have different bird communities, with migrants disproportionately common in the most disturbed sites.

Because riparian corridors subjected to human disturbance (as agricultural hedgerows are) are important habitats for wintering communities, and that insectivorous birds comprise the larger proportion of species in the Western migratory system (Kelly and Hutto 2005), the system provides a good opportunity to assess these predictions, particularly the effects of nest predation. Because of the presence of water riparian corridors are productive linear vegetated paths that could present a wide array of resources attractive to birds; their structure and the resources they provide might be influenced by different types of disturbance. At the landscape level, as is true for any other corridor, riparian habitats could be defined as a continuous "edge" that concentrates large numbers of species, as well as a good number of predators. As a consequence, we would expect nest predation rates to be higher there than in adjacent natural vegetation. After controlling for arthropod availability, I would also expect to find higher proportions of migrants in riparian environments that are under more heavily disturbed than in adjoining natural vegetations.

To my knowledge, in western Mexico there have been no studies designed to determine: (a) diet composition and their temporal shifts in the most common species, (b) food availability during the different periods of the year, (c) nest predation rates and/or breeding success within riparian habitats, and (d) disturbance effects at different levels, and it would be very informative to start working along such a pathway. However, in designing these studies a cautious approach has to be considered. As mentioned by Strong and Bock (1990), Knopf and Samson (1994), Saab (1999), and Martin *et al.* (2006), avian assemblages on riparian tracts and adjoining uplands are not independent, and it is complicated to define the types and strengths of the effects those environments exert into each other. In my study, I made the practical assumption that by limiting the detections to the 25-m radius I avoided most of those effects. Birds can move along the riparian corridor, as well as in and out the adjacent vegetation (and species such as Chipping Sparrows and siskins do as they feed on seeds found along the drier uplands or agricultural fields).

During my field work I was not able do detect any territorial behavior in insectivorous migrants, and found that individuals of several species stay in the same areas during the winter and show 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). Although it would be ideal to know exactly the extent to which birds move and make use of the adjoining vegetation, I am confident that for the purposes of my research, the differences found in the composition of the communities in riparian habitats and the other vegetation types sampled suggest there is a real distinction among such bird assemblages.

With respect to the importance of the area in terms of conservation, northwestern Mexico and southwestern United States are included in the Southwest Avifaunal Biome (SAB) of the Partners in Flight North American Landbird Conservation Plan (Rich *et al.* 2004). My particular area is part of two Bird Conservation Regions: the “Sonoran and Mojave Deserts” and the “Sierra Madre Occidental” regions. In that Plan, the authors include a list of the species of Continental Importance for the United States and Canada, constituted by a “Watch List Species” and the “Stewardship Species”. The SAB includes more than half of those species of special concern. In this biome, most of the species included have small population sizes, restricted ranges, high threats, and declining population trends. Within this area, the riparian woodlands support the highest diversity of landbird species of all the habitats. This helps to visualize the importance of the region at the continental level and the urgent need of international cooperation.

Taking into account the restricted areal extent of these environments in comparison to desert scrubby vegetation and the highland forests, lowland riparian habitats contribute importantly to the regional species richness by accommodating 28% of the total avifauna in the state of Sonora. Riparian areas constitute the wintering habitats for several species that descend from the highlands in the coldest periods of the year, for other summer resident populations that remain during the winter, and they also act as corridors that allow the movement of tropical species to extend farther north from their core distribution areas and permit faunal mixture on a broader scale. Furthermore, they are the areas where the density of spring migrating birds is the highest (possibly up to 42 times greater than the adjacent uplands (Kelly & Hutto 2005)). As they appropriately put it: "*riparian zones are key to effective conservation of western migrants, and effective conservation will require better data on the spatial scales at which migrants assess and use western landscapes.*" For these reasons, riparian areas in northwestern Mexico and southwestern United States are unique and essential habitats for the wintering and migrating bird species of western North America.

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Chapter 3

DISTURBANCE EFFECTS ON RIPARIAN WINTERING BIRD COMMUNITIES IN SONORA, MEXICO: DO WE PERCEIVE THE FULL PICTURE?

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Abstract. Natural disturbances are responsible for shaping and maintaining riparian corridors, which are among the most important for migrant birds during breeding and migration periods. They also maintain high proportions of species and individuals during the winter. Unfortunately, humans have significantly changed them. Anthropogenic disturbances on river systems often act in synergistic ways and are known to have negative effects on biological communities. To assess whether human disturbance compounds natural disturbance in a way that has negative effects, I recorded community composition, relative abundance of species, and three condition indicators to assess the general effects of human induced disturbance in relatively undisturbed and highly disturbed sites at three river systems in the State of Sonora, Mexico. Although the mean number of migrant species detected per count was higher in undisturbed riparian, nothing else suggested a general effect of disturbance in the composition of wintering communities. Less than 20% of the most common species had significant increases or decreases in their abundances. Mean fat scores and Condition Index (mass/wing chord) values were similar in the two disturbance levels, but the H/L ratio showed increased levels of physiological stress in disturbed sites. A more experimental approach is needed to determine the causal factors involved and other aspects of the dynamics of the stress expression in white blood cells.

Resumen. Los factores de perturbación natural crean y mantienen los corredores riparios, que se encuentran entre los más importantes para las aves migratorias durante sus periodos de reproducción y migración. También mantienen proporciones considerables de especies e individuos durante el invierno. Desafortunadamente, el hombre ha impuesto cambios importantes en ellos. Los factores de disturbio antropogénico con frecuencia actúan de forma sinérgica y tienen efectos negativos en las comunidades biológicas riparias. Para determinar si la perturbación antropogénica modifica los factores naturales de disturbio, determiné la composición de las comunidades, la abundancia relativa de especies y tres indicadores de condición de las aves en sitios relativamente conservados y sitios altamente perturbados en tres ríos del Estado de Sonora, México. Aunque el número promedio de especies migratorias por conteo fue mayor en hábitats relativamente conservados, no hubo ningún otro elemento que sugiriera efectos generales de la perturbación en la composición de las comunidades. Menos del 20% de las especies más comunes disminuyeron o incrementaron sus abundancias. Los valores promedio de los niveles de grasa y del

Índice de Condición (peso/cuerda alar) fueron similares en ambos niveles de perturbación, pero la proporción H/L mostró mayor estrés fisiológico en sitios perturbados. Un enfoque más experimental se requiere para determinar los factores causales involucrados y otros aspectos de la dinámica de la expresión del estrés en glóbulos blancos.

Introduction

"*Rivers have been used by man more than any other type of ecosystem. They have been abstracted from, fished in, boated on, discharged into; their headwaters have been diverted, their middle reaches dammed, their floodplains developed. One of the main features which has made rivers uniquely attractive to man is the presence of unidirectional moving water – a continuously renewable resource, a rapid removal system for unwanted substances, and a valuable store of potential energy. This same feature is also vitally important to many of the aquatic plants and animals inhabiting rivers and streams, providing fresh supplies of food and oxygen, downstream transport of waste, and an efficient means of dispersal. Unfortunately, where economic gain is the main motivator, other interests get short shrift. For example, the Columbia is North America's fourth largest river. Since the mid-nineteenth century it has become the world's largest generator of hydroelectricity, with 19 major dams and more than 60 smaller ones; as one writer put it, 'a river has died and was reborn as money.*" (Boon *et al.* 1992).

Riparian vegetation communities occupy one of the most dynamic areas of any landscape. The frequent natural disturbance events that shape and maintain riparian zones create a complex mosaic of landforms, and their associated biological communities are more heterogeneous and diverse than those associated with upslope landscapes. They also reflect the histories of both fluvial disturbance from floods and the non-fluvial disturbance regimes of adjacent upland areas (e.g., fires, wind, plant diseases). Consequently, riparian communities exhibit a high degree of structural and compositional diversity. In natural unconstrained rivers, flooding is relatively frequent. A single flood may modify hundreds of square kilometers of river valley, and create small and discontinuous tracts of vegetation along the river course. These riparian associations are subjected to continuous natural disturbances and are composed primarily of uneven stands of fast growing native tree species that depend on continuous water supplies (Forman & Godron 1986, Gregory *et al.* 1991, Boon *et al.* 1992).

Riparian corridors associated with fluvial systems are very important because of the different functions they fulfill within an ecological gradient of environmental conditions. They allow for the perpetuation of water, fish, wildlife, rangeland, and forest resources (Wilson 1979) and have been defined as "linear oases" (González-Bernáldez *et al.* 1989). They are highly diverse habitats harboring rich plant and animal communities, and their biological importance is great in desert environments such as those in southwestern United States and northwestern Mexico (e. g. Szaro & Jakle 1985, Hunt 1985, Gregory *et al.* 1991, Skagen *et al.* 1998). The value of riparian areas, as habitats for wildlife, has stimulated considerable research, and the protection and restoration of these streamside associations has been included as part of legislation and policies of different government agencies in the United States (Knopf *et al.* 1988).

Riparian corridors are important for the maintenance of biological communities and have also been important focal points for human societies (Carothers 1977). In the arid areas of the southwest United States and adjacent Mexico, native ethnic groups lived in close association with rivers and streams for long periods of time (Ohmart *et al.* 1977). Riparian areas were the first to be used by Euro-Americans after their arrival in the 1800s, and the first to be settled for ranching and farming; clearing of large tracts of native vegetation took place, and later on the effects of such changes were exacerbated by the establishment of growing population centers (Athearn 1988).

"*Most of the surviving river-bottom habitat has [already] been cleared, leveled, and converted to farmlands…. Perhaps nowhere else in Arizona, have these changes been more dramatic*." (Phillips *et al.* 1964). As recently as the late 1960s, native riparian vegetation was still being removed by channelization projects, which were justified by considering that *"…streamside vegetation requires substantial amounts of water, water that is lost to the atmosphere through evapo-transpiration*", and that *"…streamside vegetation impedes the rapid transport of flood waters and increases the apparent severity of floods by temporarily and partially damming channels, thus forcing high water into the adjacent floodplain lands*" (Carothers 1977). In all, more than 80% of the riparian corridor area in North America and Europe has disappeared in the last 200 years.

Most of what remains has been modified or disturbed in some fashion by human encroachment, fragmentation, grazing, soil erosion, pollution, water diversion and channelization, dam construction, and desiccation due to adjacent agricultural development, resulting in changes of flooding regimes and invasion of exotic species (U.S.Council on Environmental Quality 1978, Naiman *et al.* 1993). The fact that there are so many users and resource values found in riparian ecosystems (including wildlife, fisheries, timber, range, aquatic resources, and recreation), serves to further emphasize the importance of these zones (Grotzinger 1980).

Even today, in many countries (especially those in arid regions), more than half the population lives within 1 km of a riparian corridor, and humans use riparian corridors in one way or another on a daily basis. Therefore, modification of riparian habitat continues on a global scale, and too little attention is being paid to the ecological or human consequences of these changes (Naiman *et al.* 1993). Clearly, conservation and management of riparian environments is a globally important issue.

With respect to birds, riparian habitats are especially important (Donovan *et al.* 2002), not only for breeding (e. g. Hubbard 1971, Wells *et al.* 1979, Szaro & Jakle 1985, Powell & Steidl 2000), but for use during winter (Strong & Bock 1990, Villaseñor, this volume) and during migration (e.g. Skagen *et al.* 1998, Hutto 2000, Skagen *et al.* 2005, Heglund & Skagen 2005).

A. <u>Non-natural disturbance in riparian habitats</u>

Human changes to the natural disturbance regimes have modified and affected the processes and mechanisms responsible for maintaining riparian vegetation communities. Studies that have explored the effects of different non-natural disturbance factors have shown that grazing, human settlement, water management, and agriculture might have complex synergic negative effects on bird communities and populations (Corbacho *et al.* 2003).

Continuous expansion of urban areas creates a wide array of factors affecting riparian habitats. As human settlements were first established and people began depending upon riparian environments as sources of water, those areas have suffered from direct and immediate impacts, as well as from indirect and more gradual ones. Examples of the first are the loss of riparian tracts through vegetation removal for construction, or changes in the composition, area, structure, and quality of riparian corridors. The latter include industrial and urban pollution, human presence, feral pets, and the ecological effects of exotic plant and animal competitor species adapted to urban settings. Although these changes may favor some species, the most riparian-dependent species are negatively affected (Patten 1998, Rottenborn 1999, Green & Baker 2003, Miller *et al.* 2003b).

Dam construction and channelization have also modified the normal flooding regimes of many river systems and caused transformations in riparian vegetation communities by favoring the establishment of exotic species such as tamarisk or saltcedar (*Tamarix* sp.). This species tolerates saline soils and can grow efficiently as monospecific impenetrable thick stands often in the more disturbed downstream portions of rivers and streams (Miller *et al.* 2003a). Presently, tamarisk is a normal element of riparian habitats in southwestern U.S. (although not in most northwestern Mexico), and, according to some researchers, it is part of an ecological succession leading to cottonwood-willow native species stands when the management of water simulates natural flood pulses (Cohn 2005). The effect of this exotic's invasion has caused the decrease in abundance of breeding birds and, although some species use them during migration and winter, their numbers are lower than in native riparian stands (e. g. Anderson *et al.* 1977, Hunter *et al.* 1988, Ellis 1995).

Cattle show a strong preference for riparian zones because: 1) they find a consistent variety of quality forage available, 2) plant species are highly palatable and contain higher levels of moisture in their tissues, 3) availability of water, and 4) they provide shaded areas in which to rest (Ames 1977). Livestock overgrazing is largely responsible for the lack of riparian habitat regeneration. Heavy grazing pressures compact the soil, favor erosion, and change the plant composition and decrease the structural complexity of these river corridors. In many cases, although riparian habitats appear to be in good health, mature vegetation approaches senescence, grazing pressure can prevent the establishment of seedlings, thus producing even-aged, non-reproducing vegetative communities (Carothers 1977, Armour *et al.* 1991). Because birds respond to the structural complexity of riparian vegetation, in simpler grazed stands overall bird diversity and abundance decreases (e. g. Mosconi & Hutto 1982, Kauffman & Krueger 1984, Fleischner 1994, Saab *et al.* 1995, Popotnik & Giuliano 2000, Jansen & Robertson 2001, Curtin 2002, Tewksbury *et al.* 2002).

Agriculture is also intimately tied to riparian environments, and has had an even greater impact on bird populations. The conversion of native habitats to agricultural fields has resulted in local extirpations and shifts in species composition and abundances, and has created habitats favorable for other sets of species. Birds inhabiting riparian corridors adjacent to agricultural fields can experience higher disturbance levels, are more exposed to predators or brood parasites, and also suffer the effects of higher levels of diverse toxic agrochemicals (Rodenhouse *et al.* 1995). Unfortunately, although the dependency and use of insecticides, fungicides, herbicides, and fertilizers for agricultural production has increased since the 1940's, with the exception of a few documented cases the impact and extent of changes in physiological performance, survival, and reproductive success induced by them relative to other anthropogenic stresses cannot be reliably quantified at the present (Gard & Hooper 1995). Furthermore, the effects of these compounds travel far from the sites where they are applied and may affect other ecological systems. As a result of all these pressures, there are no riparian systems free of anthropogenic disturbance. They are, by definition, environments resulting from natural disturbance processes and modified by diverse human induced factors (Corbacho *et al.* 2003).

B. Use of riparian corridors, border strips, and hedgerows by birds

From a landscape perspective, riparian corridors are "green-belts" embedded within a mosaic of other habitat types and are similar in physiognomy to the gallery forests and border strips that surround agricultural fields. Even though these two vegetation types are excessively disturbed, they support remarkably high densities of migrants in both the wintering (Hutto 1980, 1988, 1989, 1995, Villaseñor & Hutto 1995), and breeding seasons (Stauffer & Best 1980, Keller *et al.* 1993). On the basis of bird use and bird densities, it appears that migrants thrive in these green-belt habitat types, even though each of these habitats suffers relatively high levels of disturbance.

How is it possible for birds to do so well in the face of such a wide range of disturbance factors? It might be that the occurrence and abundance of birds does not necessarily reflect over-winter performance and survivorship (Van Horn 1983).

Thus, with respect to birds that winter in riparian habitats in Mexico, I sought to determine (a) whether bird community composition (the abundances of component species) differed significantly among disturbance classes of riparian vegetation in Sonora, and (b) whether significant differences in physiological performance of wintering individuals exist in relation to riparian habitat condition during the winter. By considering that anthropogenic disturbance imposes negative effects on bird communities and populations, at the population level, I would expect relatively higher abundances of the species at undisturbed habitats with better quality, coupled with the best indicators of condition (heavier body masses and higher fat scores) and physiological performance (lower levels of physiological stress), in comparison with low quality disturbed riparian habitats.

Methods

A. Overall study design

We must first recognize that some disturbance effects result from stressors that operate within the riparian corridor itself (e.g., fragmentation, grazing, flood control, dewatering through irrigation), while other stressors result from adjacent land use (e.g., human and livestock intrusion, use of pesticides, presence of parasites, competitors, or predators that invade from adjacent unnatural land types). While acknowledging that different stressors may have different effects on the bird species, I considered all possible combinations of disturbance stressors and combined them into two basic levels along a single disturbance gradient—relatively undisturbed and highly disturbed—and collected data on the composition and health of birds in three river systems (Moctezuma, Sonora, and Sahuaripa Rivers; Figure 7) to serve as replicates of each level of disturbance. This allowed me to assess the effects of disturbance in a general sense, while leaving studies of the effects of specific stressors for the future.

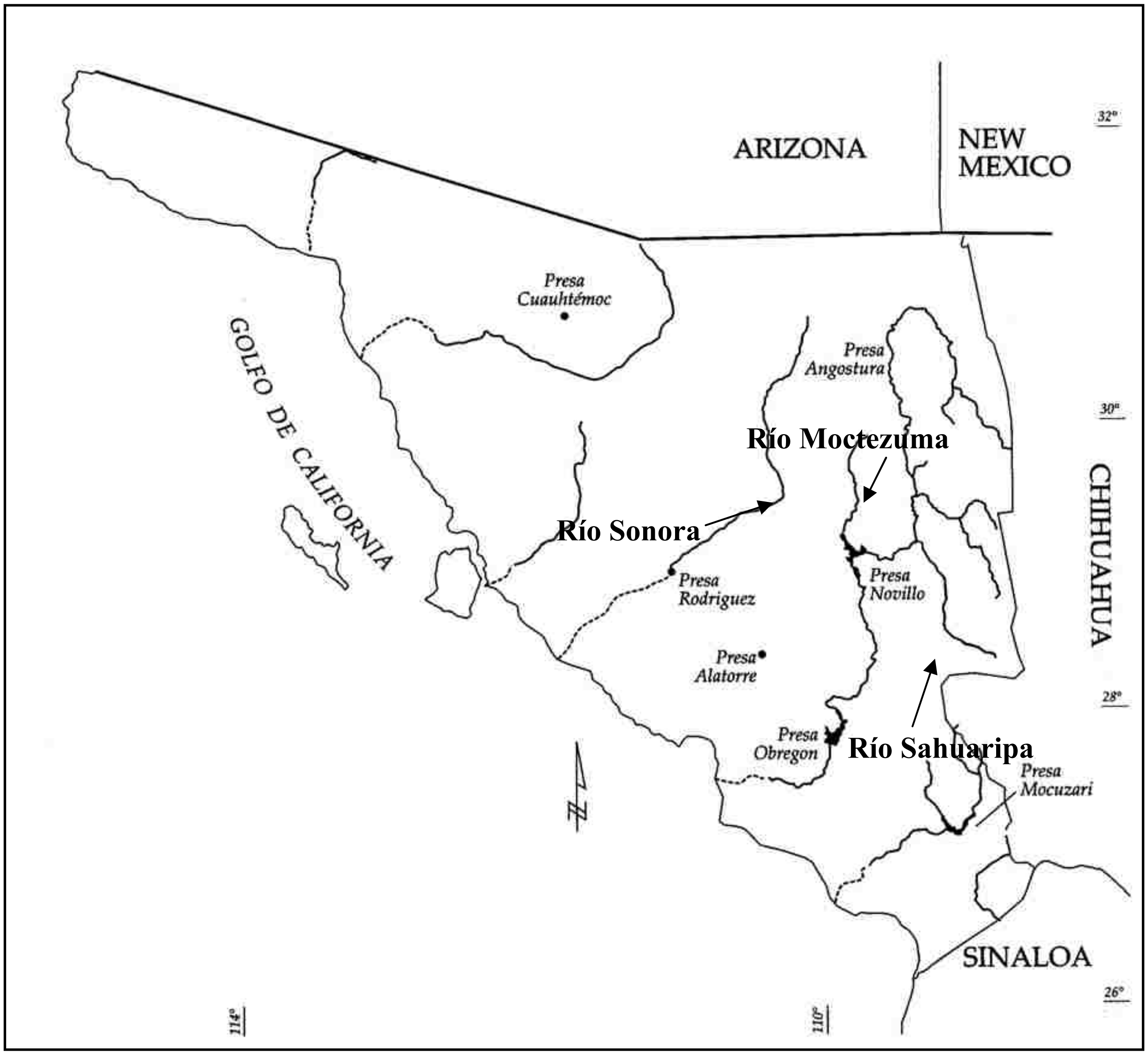
Proximity of human settlements, closeness and size of agricultural fields, and cattle grazing were used as indicators of disturbance. Because cattle (arguably the most important local stressor) compact soil, remove plant material, and reduce water infiltration, the result is generally a decrease in vegetation cover, and a change in the physiognomy and composition of plant communities (Saab *et al.* 1995). Because birds generally respond indirectly to cattle through change in the structure of vegetation that results from grazing (Bock & Webb 1984), vegetation structure within riparian corridors within 1-2 km of the river was used to help define the level of stress from within the riparian system itself. I used the proximity of human settlements and agricultural fields as indicators of the level of stress from outside the riparian corridor itself.

I classified a site as *relatively undisturbed* if it was a relatively large and continuous tract of riparian vegetation that included primarily native tree species, had a well-developed understory including saplings and seedlings of those tree species, was farther than 2 km from human settlements, and at least 200 m from agricultural lands.

In contrast, a *heavily disturbed* site was defined as a discontinuous strip of riparian vegetation within a fragmented landscape that included native as well as exotic tree species, with a poorly developed understory without recruitment of the native tree species, less than 2 km from human settlements, and less than 200 m from agricultural lands.

Fieldwork was carried out within sections of the Rivers Moctezuma (Jécori and Térapa), Sonora (Aconchi and Baviácora), and Sahuaripa (Cajón de Onapa and Bámori), each of which was visited during the periods of January-February 2004, 2005 and 2006, and

Figure 7. Location of the Sonora, Moctezuma, and Sahuaripa Rivers in Sonora
(modified from Russell & Monson 1998).



RIVER SYSTEM	RELATIVELY UNDISTURBED SITE	HEAVILY DISTURBED SITE
SONORA	**Baviácora**: 532 m 29° 41' 47" N, 111° 10' 05" W	**Aconchi**: 575 m 29° 48' 13" N, 110° 13' 26" W
MOCTEZUMA	**Térapa**: 562 m 29° 40' 53" N, 109° 39' 24" W	**Jécori**: 719 m 29° 57' 47" N, 109° 45' 18" W
SAHUARIPA	**Cajón de Onapa**: 623 m 28° 42' 32" N, 109° 07' 58" W	**Bámori**: 511 m 28° 51' 49" N, 109° 10' 04" W

November 2004 and 2005. Michael L. Scott and Elizabeth W. Reynolds of the USGS Fort Collins Science Center quantified the structural and compositional differences between relative disturbed and undisturbed sites at the three pairs of sites on the Sonora, Moctezuma, and Sahuaripa Rivers as part of the riparian forest component of the Western North American Migratory Landbird Project, funded by the U.S. Fish and Wildlife Service. They measured the agricultural land cover, plant species richness, exotic plants, and vertical structural diversity (size class diversity of dominant riparian shrubs and trees). The information presented here is based on results in their report "Riparian Forests of Sonora, Mexico" (Mesta *et al.* 2006).

B. <u>Bird species composition</u>

In order to gather information on the composition, abundance, and distribution of landbird species, a series of point count locations along linear transects within each of the six, 2-km-long river segments were established. Each linear transect was visited 6-8 times during the period of study, and on each visit an observer recorded the precise location of the point with a GPS unit and conducted a conventional 10-minute point count (Hutto *et al.* 1986, Ralph *et al.* 1993), during which the distance and direction of each bird was recorded, and the location of each individual bird detection was also recorded on a map depicting the general vegetation features within the site. Only detections within a 25-m radius from the observer were used to minimize the potential error caused by the inclusion of individuals detected in adjacent non-riparian habitats (and to minimize potential bias due to inherent differences in lateral detectability of birds).

In order to find out whether bird community composition (abundances of component species) differed significantly among disturbance classes of riparian vegetation, I determined the mean species richness per count and the mean abundance of each species within a disturbance level. To evaluate the relationship between disturbance and bird richness or bird abundance I pooled data form the three years and used an ANOVA design to compare the two disturbance levels in the river systems under study. SPSS 11.5.1 for Windows was used for all analyses.

C. <u>Condition and physiological "health" of wintering birds</u>

In any cases in which a negative impact of human activity is suspected, it is useful to have a measure of that impact upon birds. At the population level it is useful to assess population levels or distributions; impacts at the individual level could be quantified through some relevant ecological factor (e.g. demographic data such us survival or reproductive success). However, in practical terms it would be more convenient to measure some factors reflecting stress levels of birds that can be assessed in simple ways in individuals and relate them to the causal environmental factors (Vleck 2001). Some of the most common and frequently used indicators of condition in birds are related to weight and the amount of fat reserves, and such information is normally obtained as part of the standard banding protocols. As suggested by Gosler *et al.* (1998), wing chord was used as a measure of body size for passerines, and the "condition index" (body mass/wing chord) and fat scores were used as indicators of body condition (Swanson *et al.* 1999).

The study of the individual physiological responses to environmental factors such as temperature (Al Murrani *et al.* 1997), food and water deprivation (Zulkifli 1999, Acquarone *et al.* 2002, Jong *et al.* 2002), exposure to chemical agents (Mandal *et al.* 1986, Newman *et al.* 2000, Eeva *et al.* 2005), extreme weather conditions (Romero *et al.* 2000), pathogens (Gross 1988, Davis *et al.* 2004), physical handling (Collette *et al.* 2000, Ilmonen *et al.* 2003), and social interactions (Ruiz *et al.* 2002), have been studied in the poultry industry and recently have been applied to bird pets and wild species. The most important physiological responses that have been studied consist of changes in the concentration of corticosterone and lipid metabolites in plasma, cholesterol, glucose, and stress proteins (HSP70 and HSP60), changes in body and organ mass, and relative and absolute numbers of leucocytes (e. g. Williams *et al.* 1999, Thaxton & Puvadolpirod 2000, Vleck 2001, Tomás *et al.* 2004, Cerasale & Guglielmo 2006).
Elevated corticosterone levels in plasma activated by temporal perturbation factors may promote the triggering of additional physiological mechanisms that help to avoid some deleterious effects associated with chronic stress (Wingfield & Kitaysky 2002). Changes in the proportion of two types of white blood cells (heterophils and lymphocytes) are one

of those responses that has been used to assess the physiological response of individuals to continuous stress. When a stressor is detected, monocytes and macrophages rapidly release cytokines, which in turn act on the hypothalamus increasing the production of the corticotropin releasing hormone (CRH), and promoting the production of adrenocorticotropin (ACTH); this hormone causes the increase of gluco-corticosteroids. Elevated levels of gluco-corticosteroids decrease the number and activity of immune cells, particularly the lymphocytes that release the cytokines, as an important negative feedback mechanism to limit negative effects (Vleck 2001).

The Heterophil/Lymphocite ratio (H/L ratio) has been proposed as a reliable and accurate physiological indicator of stress (Gross & Siegel 1983, Maxwell & Robertson 1998, Vleck 2001, Hõrak *et al.* 2002), and its application in wildlife populations has recently begun (Newman *et al.* 2000, Vleck *et al.* 2000, Moreno *et al.* 2002, Ruiz *et al.* 2002). Leucocytes form the basis of the immune system, and their main function is protection against foreign pathogens. Lymphocytes and heterophils are the most abundant types of leucocytes in avian blood. Heterophils (the counterpart to neutrophils in mammals) are bactericidal phagocytising cells that enter tissues during the inflammatory response; they are non-specific immune cells in contrast to the highly specific response of lymphocytes (Maxwell & Robertson 1998). Lymphocytes are related to cellular immunity and increase with chronic viral diseases, but decrease with acute viral infections and stress. Eosinophils, monocytes, and basophils are the other types of leucocytes present at low proportions in avian blood. The number of heterophils goes up in a matter of several hours to days in response to increasing levels of environmental stress, as a result of maintained high levels of corticosterone, therefore reflecting long-term levels of stress (Vleck *et al.* 2000, Dufty & Lepper 2002). Multiple stressors seem to have an additive effect (McFarlane & Curtis 1989).

Information on the H/L-ratio was obtained as an indicator of physiological condition resulting from differences in habitat quality occupied by individual birds of five bird species. Birds were captured in the riparian study plots during the morning hours by mist-netting. Nets were open for a period of 7 hours (6:00 to 13:00 hr) during three or four consecutive days. Basic information was gathered from captured birds (species, sex, age, body size [through the unflattened wing chord in mm], mass (to the nearest 0.1 g), level of subcutaneous fat observed in the furcular and abdominal regions, and molt information), following the guidelines of standard monitoring protocols (Ralph *et al.* 1993). Birds were banded, held in cloth bags in shade, and released after gathering the required data. I captured birds in the month of November to find out whether the same individuals captured then remained in the same site through the following winter months of January and February (November 2004 and 2005, and January and February 2005 and 2006).

A small blood sample was taken from each individual from the brachial vein into heparinized micro-capillary tubes after puncture with a 26-gauge needle. Blood smears were made to analyze white blood cell profiles. They were dried and stained with Wright-Giemsa Stain modified [Sigma-Aldrich WG16®] (Canfield 1998), and H/L ratios were determined by dividing the number of heterophils by the number of lymphocytes (100 cells counted in two different areas of each smear = 200 cells).

I used the "condition index" (body mass/wing chord) and fat scores as indicators of condition, and H/L ratio as an indicator of physiological performance in relation to riparian habitat condition. I applied a univariate weighed ANOVA design using age (SY and ASY), site (each of the three river systems), and year (2005 and 2006 for condition index and fat scores, and 2004 and 2005 for H/L ratios) as factors, and used wing chord as a weight variable. For further testing of fat scores, which are recorded as a categorical variable, I used the Wald statistic (Wald χ^2) derived from a non-parametric ordinal regression model under the same factors and weight (Guisan & Harrell 2000). All analyses were performed by using SPSS 11.5.1 for Windows.

Results

A. Relatively disturbed and undisturbed riparian site comparisons

The amount of river bottomland area converted to agricultural use along the broad valley reaches of these three rivers was high relative to the area of riparian forest. Along the Rio Sonora, both disturbed and undisturbed reaches occurred in similar valley settings and the percentage of bottomland in agriculture was > 60%. However, because the active channel and zone of riparian forest was comparatively wide, when agricultural cover was viewed at the scale of the 50-m-radius vegetation plots centered within the riparian corridor, the amount of plot area classified as agriculture appeared to be relatively low at both sites (Figure 8). In contrast, the Moctezuma and Sahuaripa Rivers are both smaller than the Sonora, and their bottomlands, active channels, and riparian forest zones are correspondingly narrower. Thus, vegetation plots typically included fluvial surfaces that at the disturbed sites (Moctezuma River at Jécori and Sahuaripa River at Bámori) were often cleared for agriculture, leaving narrow strips of riparian forest between the field and the channel, and giving these sites relatively high values for agricultural cover. Disturbed sites (near Térapa on the Moctezuma River and at Cajón de Onapa on the Sahuaripa River) both occurred in comparatively narrow valley settings, which limited agricultural development compared with the undisturbed sites (Figure 8).

There were no clear differences in overall plant species diversity patterns between disturbed and undisturbed sites. At the Moctezuma River, both sites had relatively high species diversity (n = 21). On the Sahuaripa River, the disturbed site at Bámori had six more species (n = 20) than the undisturbed site near Cajón de Onapa (n = 14). Both sites in the Sahuaripa River are downstream of a dam at Cajón de Onapa, which was completed in the early 1980s. Following completion of the dam, base flows downstream of the dam have been more consistent and locals reported that the riparian forest at Bámori, dominated by willow species, did not exist prior to the dam. Thus, the relatively low species diversity, especially at the Cajón de Onapa site, may be due in part to the recent development of this riparian forest. Species diversity at both Sonora River sites was relatively low, likely the result of intensive agricultural activity and frequent fluvial disturbance, as suggested by stands of young cottonwoods and willows. Non-native

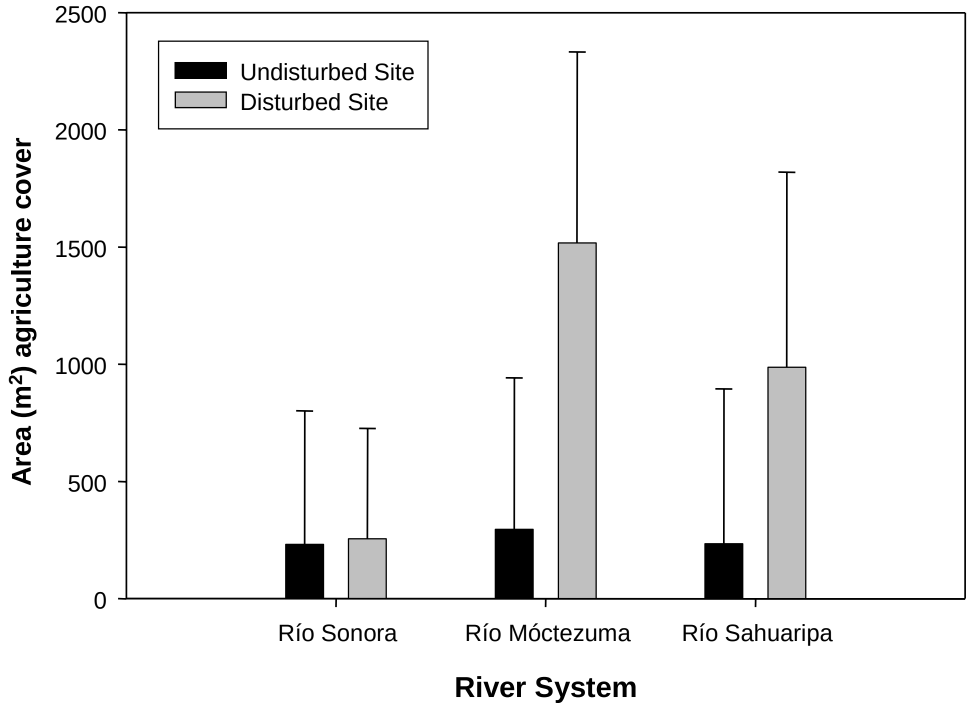


Figure 8. Mean cover (m^2/ha) ± s.d. of agricultural land-use within vegetation plots located within the riparian zone of three rivers that were paired according to level of disturbance.

species, interestingly, were not important at any of the sites sampled, and overall, had very low frequency and abundance (cover) values. At the disturbed and undisturbed site pairs, the non-native tree, Chinaberry (*Melia azedarach*), appeared at all disturbed sites but with relatively low cover (Figure 9). Tamarix (*Tamarisk ramossissima*), which was present at the Cuchujaqui and Mayo Rivers in southern Sonora, was found only at the undisturbed site on the Sonora River. Here, a sapling-sized individual was growing under the canopy of a young stand of cottonwoods in one of the sample plots. Tree tobacco (*Nicotiana glabra*), native to South America, was the most widespread non-native species having a consistently higher mean cover in disturbed versus non-disturbed sites (Figure 9), suggesting that it may be a good general disturbance indicator. Taken together, it appears that the non-native species, Chinaberry and Tree tobacco are generally more abundant at disturbed riparian sites, although their frequency and cover are very low compared to the native riparian species. Tamarisk, which is the focus of

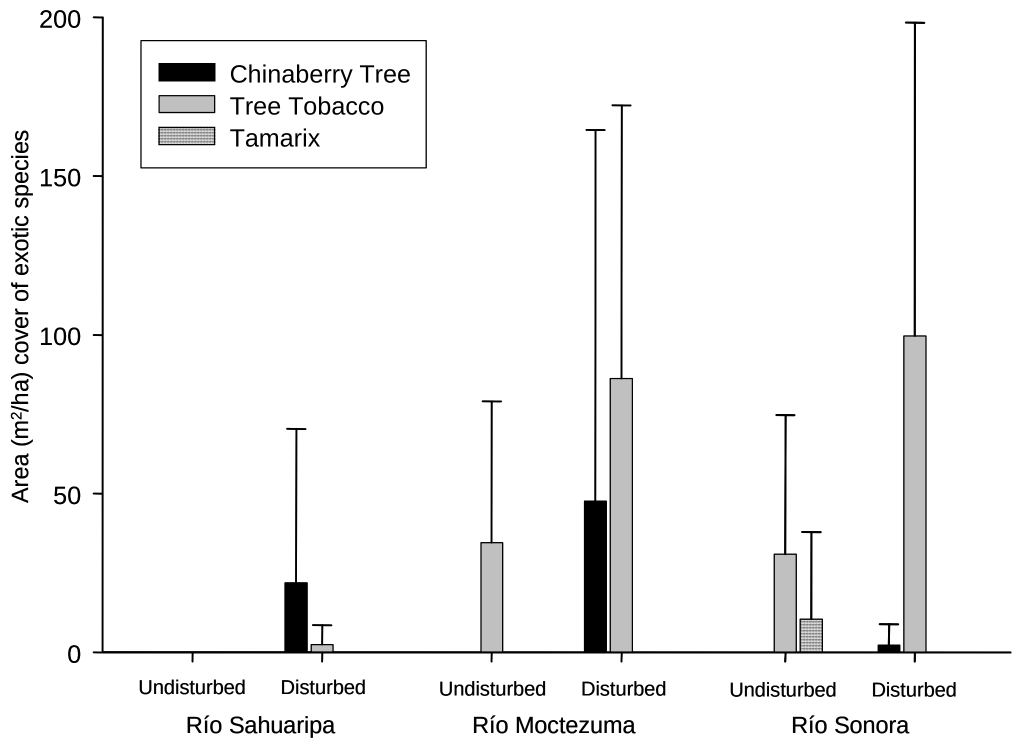


Figure 9. Mean cover (m^2/ha) ± s.d., for three non-native species found at relatively disturbed and undisturbed riparian sites along three rivers in Sonora, Mexico.

expensive eradication efforts along many rivers in the U.S. is, at present, very rare in the systems we examined in this study.

Vertical structural diversity, presented here as mean area for different size- and height-classes of important riparian trees and shrubs, appears to be greater for cottonwood and willow stems at undisturbed sites when compared with disturbed sites (Figures 10-12). Because of overall high variance and relatively small sample sizes, a robust statistical examination of structural differences of the dominant native riparian trees and shrubs was not possible. However, total cottonwood cover of all size classes in plots at undisturbed sites ($\mu = 4419$, $n = 7$) was significantly greater ($t = -4.15$; $p = 0.01$) than cover at disturbed sites ($\mu = 1572$, $n = 7$) for the Sonora and Moctezuma Rivers. This result supports the idea that, at least with regard to the dominant native riparian trees and shrubs, relatively undisturbed riparian sites have a more complex vertical structural diversity than relatively disturbed sites (Figures 10 and 11). Data from the Sahuaripa River were not included since cottonwood cover there was very low (Figure 12).

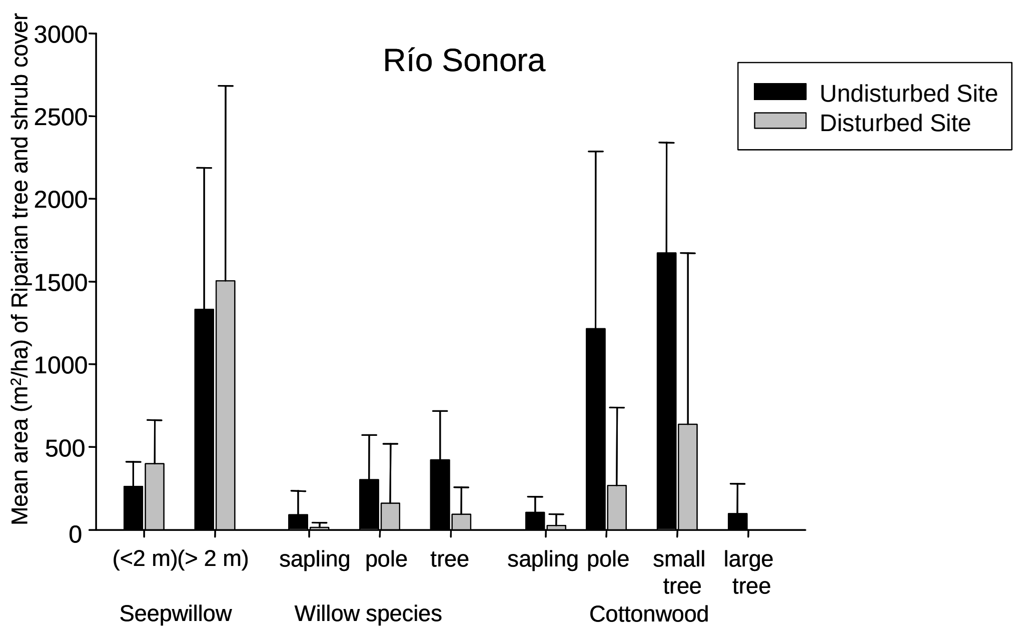


Figure 10. Mean cover (m^2/ha) ± s.d., of different stem height/size classes for Seepwillow (*Baccharis salicifolia*), Willow species (*Salix* spp.) and Cottonwood (*Populus fremontii*) along the Sonora River at disturbed riparian sites (near Aconchi) and relatively undisturbed sites (near Baviácora).

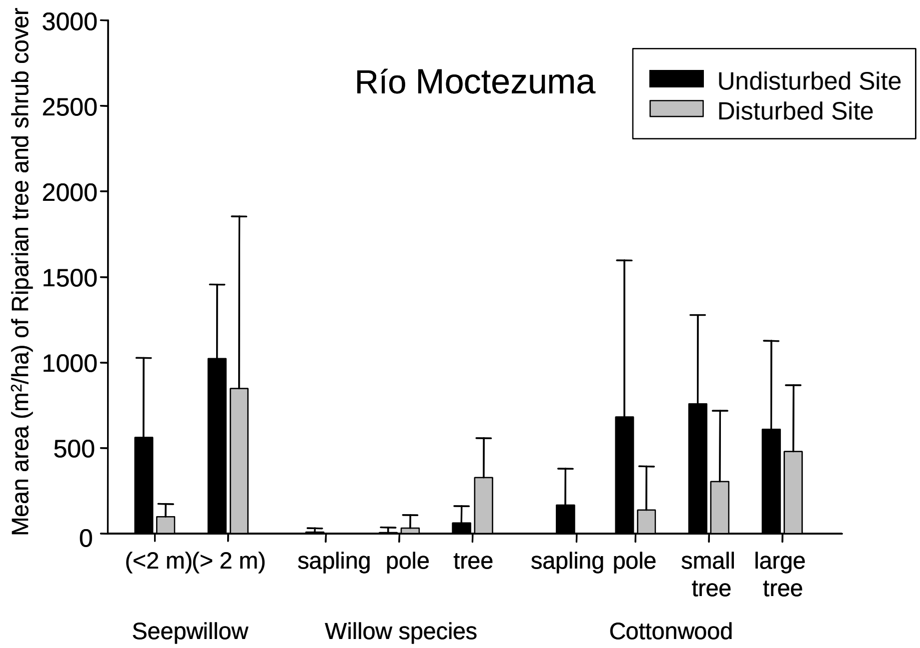


Figure 11. Mean cover (m^2/ha) ± s.d., of different stem height/size classes for Seepwillow (*Baccharis salicifolia*), Willow species (*Salix* spp.) and Cottonwood (*Populus fremontii*) along the Moctezuma River at disturbed riparian sites (near Jécori) and relatively undisturbed sites (near Térapa).

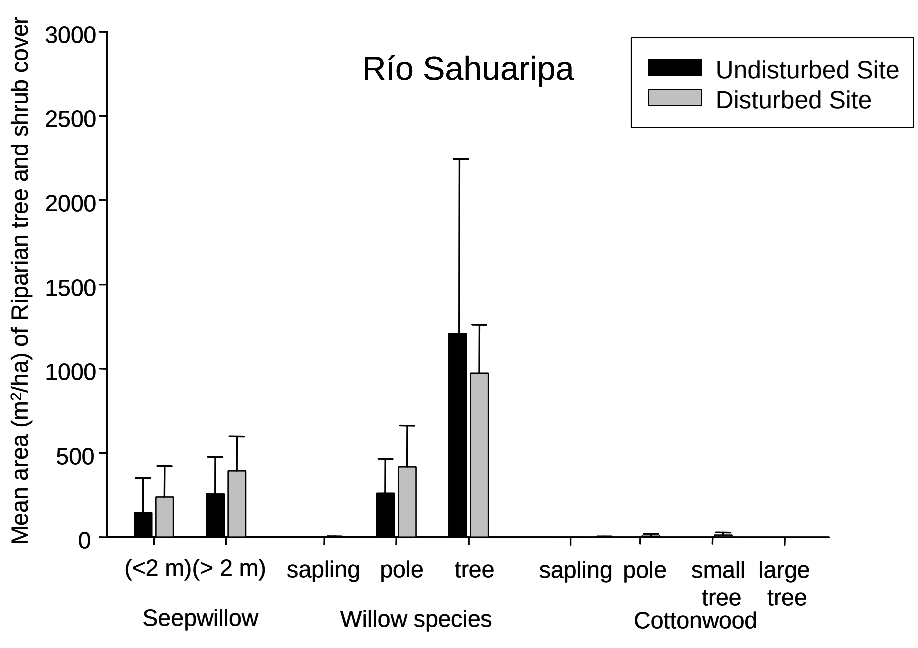


Figure 12. Mean cover (m^2/ha) ± s.d., of different stem height/size classes for Seepwillow (*Baccharis salicifolia*), Willow species (*Salix* spp.) and Cottonwood (*Populus fremontii*) along the Sahuaripa River at disturbed riparian sites (near Bámori) and relatively undisturbed sites (near Cajón de Onapa).

B. Bird community composition and abundance of species among disturbance classes of riparian vegetation in Sonora, Mexico.

I gathered information from a total of 433 point counts in the three river systems, with 218 (50.3%) counts from undisturbed and 215 (49.7%) from disturbed riparian habitats. A total of 101 species and 2,731 individuals were recorded. According to their seasonal status, 46 species are residents, 23 are partial migrants, and 32 migrants. The number of species and individuals detected in undisturbed sites was higher at the Sonora River (Baviácora), and lower in the other two river sites. All disturbed sites had similar number of species; however, the number of individuals detected was higher at the Sonora River site (Table 4).

Table 4. Number of counts, total number of species and individuals detected in the sampling sites representing undisturbed and disturbed riparian conditions in central Sonora, Mexico.

River System (n=443)	Undisturbed Riparian (n= 218)	Disturbed Riparian (n= 215)
Sonora 78 species, 1166 individuals (n= 141)	Baviácora 63 species, 660 individuals (n= 69)	Aconchi 55 species, 506 individuals (n= 72)
Moctezuma 69 species, 764 individuals (n= 155)	Térapa 47 species, 394 individuals (n= 88)	Jécori 54 species, 407 individuals (n= 67)
Sahuaripa 67 species, 801 individuals (n= 137)	Cajón de Onapa 49 species, 334 individuals (n= 61)	Bámori 53 species, 430 individuals (n= 76)

When considering the number of species per count, relatively undisturbed riparian areas had significantly more species than disturbed areas [undisturbed riparian = 3.91, disturbed riparian = 3.34, F=5.872, p=0.02]. The mean number of individuals recorded per count was a little higher in riparian disturbed areas, although not significantly different [undisturbed riparian = 5.67, disturbed riparian = 5.71, F=0.006, p=0.94] (Table 5).

Table 5. ANOVA results for the mean number of species and individuals detected in point counts (25-m radius) in relatively undisturbed and disturbed riparian habitats of central Sonora, Mexico. Data correspond to January and February 2005 and 2006. A univariate analysis of variance was performed using condition (undisturbed and disturbed) and site (Sonora, Moctezuma, and Sahuaripa Rivers) as a factor; means and standard errors are presented. Effects of site are indicated when found.

SPECIES	**General Mean [SE] (n=433)**	**Undisturbed Riparian [SE] (n=218)**	**Disturbed Riparian [SE] (n=215)**	**F**	**Sig.**
ALL SPECIES	3.628 [0.1190]	3.913 [0.1716]	3.340 [0.1627]	5.872	0.02 *[a]
RESIDENTS	1.219 [0.0596]	1.248 [0.0818]	1.191 [0.0869]	0.228	0.63 ns [a]
PARTIAL MIGRANTS	1.152 [0.0499]	1.206 [0.0715]	1.098 [0.0696]	1.187	0.28 ns
MIGRANTS	1.256 [0.0556]	1.459 [0.0825]	1.051 [0.0720]	13.824	0.00 ** [b]
INDIVIDUALS					
ALL SPECIES	5.686 [0.2636]	5.665 [0.2863]	5.707 [0.4453]	0.006	0.94 ns [a]
RESIDENTS	1.843 [0.1134]	1.872 [0.1538]	1.814 [0.1672]	0.064	0.80 ns [a]
PARTIAL MIGRANTS	1.866 [0.1436]	1.771 [0.1178]	1.963 [0.2636]	0.447	0.50 ns
MIGRANTS	1.977 [0.1356]	2.023 [0.1282]	1.930 [0.2405]	0.117	0.73 ns [a]

[a] = Significant site effect (higher detections in Sonora River).
[b] = Significant site effect (lower detections in Moctezuma River).

The mean number of species and individuals per count did not differ significantly between disturbance levels for residents and partial migrants. The mean number of migrant species per count was, however, significantly higher in undisturbed conditions [undisturbed riparian = 1.46 species, disturbed riparian = 1.05, F=13.824, p=0.00]; the mean number of migrant individuals, although a little higher in the undisturbed riparian, was not significantly different (Table 5). Except for partial migrants, there was a general effect of site in the comparisons, with the Sonora River having higher means of species and individuals detected that the other two river systems. In general, migrants were detected significantly in lower numbers at the Moctezuma River.

Of the 101 species detected (Appendix G), only 31 (30.7%) had at least 15 detections. Of those, 80.6% (25) had no significant differences in mean number of detections between disturbance levels, 9.7% (3) showed a decrease with disturbance (one resident species [Lesser Goldfinch], and two migrants [Green-Tailed Towhee and Ruby-crowned Kinglet]), and 9.7% (3 species) increased with disturbance (two resident species [White-winged Dove and Gila Woodpecker], and one migrant [White-crowned Sparrow]). The mean numbers of partial migrant species did not differ significantly between the two levels of disturbance (Table 6). In general, the effects of disturbance are significant for less than 20% of the most common species.

The analysis also showed that for 14 species there were no effects of site (river system), and for the other 15 species there were some statistical site effects. Eight species (Mallard, Mourning Dove, Gila Woodpecker, Ladder-backed Woodpecker, Ruby-crowned Kinglet, Yellow-rumped Warbler, Wilson's Warbler, and House Finch) had higher mean numbers detected in the Sonora River sites, six species (Common Merganser, *Empidonax* sp., House Wren, Black-capped Gnatcatcher, Green-tailed Towhee, and Lincoln's Sparrow) had higher mean numbers detected in the Sahuaripa River system, one species (Spotted Sandpiper) was particularly abundant in the Moctezuma River, one (Orange-crowned Warbler) had lower numbers in the Moctezuma River, and another (Song Sparrow) was less abundant in the Sahuaripa River (Table 6).

Table 6. Mean number of individuals detected per count for the species with at least 15 detections in undisturbed and disturbed riparian habitats of the Sonora, Moctezuma, and Sahuaripa rivers in Sonora, Mexico during January-February 2005-2006. (Bonferroni correction p-value < 0.0016).

SPECIES	RS	Ind.	Undisturbed Riparian (n=218)		Disturbed Riparian (n=215)		F	P	
			Mean	SE	Mean	SE			
Mallard	PM	25	0.0459	0.0203	0.0698	0.0406	0.2790	0.598	ns[a]
Common Merganser	M	15	0.0642	0.0414	0.0047	0.0047	2.0165	0.156	ns[b]
Spotted Sandpiper	M	35	0.0826	0.0187	0.0791	0.0196	0.0167	0.897	ns[c]
White-winged Dove	R	30	0.0138	0.0138	**0.1256**	0.0461	5.4739	0.020	*D
Mourning Dove	R	29	0.0229	0.0189	0.1116	0.0415	3.8146	0.051	ns[a]
Green Kingfisher	R	35	0.0688	0.0172	0.0930	0.0229	0.7179	0.397	ns
Gila Woodpecker	R	61	0.0872	0.0212	**0.1953**	0.0372	6.4143	0.012	*D[a]
Ladder-backed Woodpecker	R	17	0.0459	0.0142	0.0326	0.0138	0.4515	0.502	ns[a]
***Empidonax* sp.**	M	108	0.2890	0.0346	0.2093	0.0315	2.8939	0.090	ns[b]
Black Phoebe	R	121	0.3303	0.0401	0.2279	0.0355	3.6470	0.057	ns
Verdin	R	36	0.0917	0.0244	0.0744	0.0191	0.3113	0.577	ns
House Wren	PM	39	0.1101	0.0222	0.0698	0.0186	1.9297	0.166	ns[b]
Ruby-crowned Kinglet	M	295	**0.8945**	0.0759	0.4651	0.0589	19.9077	0.000	**U[a]
Blue-gray Gnatcatcher	PM	219	0.5138	0.0571	0.4977	0.0547	0.0413	0.839	ns
Black-capped Gnatcatcher	R	53	0.1147	0.0284	0.1302	0.0337	0.1247	0.724	ns[b]
Orange-crowned Warbler	M	40	0.1055	0.0218	0.0791	0.0236	0.6760	0.411	ns[e]
Yellow-rumped Warbler	M	200	0.5275	0.0614	0.3953	0.0577	2.4569	0.118	ns[a]
Common Yellowthroat	PM	99	0.2661	0.0392	0.1907	0.0306	2.2888	0.131	ns
Wilson's Warbler	M	28	0.0872	0.0212	0.0419	0.0152	2.9943	0.084	ns[a]
Green-tailed Towhee	M	79	**0.2294**	0.0375	0.1349	0.0291	3.9424	0.048	*U[b]
Chipping Sparrow	PM	116	0.0963	0.0393	0.4419	0.2233	2.3522	0.126	ns
Lark Sparrow	M	79	0.0275	0.0194	0.3395	0.1808	2.9840	0.085	ns
Song Sparrow	PM	252	0.6514	0.0633	0.5116	0.0547	2.7844	0.096	ns[d]
Lincoln's Sparrow	M	17	0.0367	0.0143	0.0419	0.0152	0.0612	0.805	ns[b]
White-crowned Sparrow	M	84	0.0688	0.0305	**0.3209**	0.1193	4.2437	0.040	*D
Northern Cardinal	R	51	0.1330	0.0302	0.1023	0.0308	0.5061	0.477	ns
Pyrrhuloxia	R	21	0.0138	0.0102	0.0837	0.0408	2.8033	0.095	ns
Red-winged Blackbird	PM	31	0.0000	0.0000	0.1442	0.0965	2.2633	0.133	ns
Streak-backed Oriole	R	24	0.0642	0.0190	0.0465	0.0158	0.5109	0.475	ns
House Finch	R	65	0.1560	0.0433	0.1442	0.0486	0.0328	0.856	ns[a]
Lesser Goldfinch	R	77	**0.3257**	0.0910	0.0279	0.0173	10.1968	0.002	**U

RS = residence status: R=resident, PM=partial migrant, M=migrant. Ind.= total number of individuals detected. F and p result from the ANOVA applied. U = preferentially in undisturbed riparian, D = preferentially in disturbed riparian. Effects of site: a= more abundant in Sonora River, b= more abundant in Sahuaripa River, c=more abundant in Moctezuma River, d= less abundant in Sahuaripa, e= less abundant in Moctezuma.

Although a lower number of migrant species was detected in disturbed riparian, and the abundance of any given species might differ from one river system to the next, riparian disturbance does not, in general, seem to have an evident overall effect on winter bird communities (species numbers and their abundances) in Sonora. Thus, riparian environments are used by most bird species in spite of their disturbance intensity, at least within the range of disturbance levels studied.

C. <u>Condition and physiological performance of wintering individuals in relation to riparian habitat disturbance level</u>

When analyzing condition or physiological performance of individuals living under a given set of environmental conditions it is important to make sure those individuals remain in the same site during the period of study, and are not transients. Banding activities allowed the capture of 923 individuals of 77 species during January-February of 2005 and 2006, of which 265 (28.7%) represented recaptures. The percentages of recaptures from November 2004 to January-February 2005 were of 24.8% (91 individuals) and from November 2005 to January-February 2006 were of 29.4% (192 individuals); 12% (44) of the individuals banded in November 2004 returned after one year and were recaptured in January-February 2006, indicating a certain degree of site fidelity (Table 7). Only those individuals belonging to species recaptured during January-February after being captured and banded during the previous November were considered in tests of physiological performance. (For a general list of species and captures during the study refer to the Appendix H).

Ten species had sample sizes of at least 15 captured individuals and had a percentage of recaptures from November to January-February that was higher than 40% (Table 8). These species were included in the analysis of condition index and fat scores as indicators of condition. None of the ten species had significant differences in condition index (body mass/wing cord) between the two riparian disturbance levels, and just one showed significantly higher fat scores in disturbed riparian (Song Sparrow). For the condition index, there were not significant effects of age, site, and/or year. For fat scores, however, there were significant effects of year for four species (having higher mean scores during

2005, which was an unusually wet year for Sonora), and a significant effect of age for two species (with higher mean fat scores in older individuals) (Tables 8 and 9).

From this set of 10 species, the five (Green-tailed Towhee, Lincoln Sparrow, Northern Cardinal, Song Sparrow, and White-crowned Sparrow) with the largest blood smear sample sizes in both undisturbed and disturbed riparian habitats were selected to determine their values of H/L ratio as a physiological performance indicator. Information obtained from smears acquired in a pilot study performed in January-February 2004 and the ones obtained in 2006 were included in the analysis. Four showed significantly higher H/L ratios in disturbed habitats, being from 3.1 to 4.6 times the values of H/L ratios in undisturbed riparian. The only species that did not show such a difference was the Northern Cardinal. In three of the cases, a significant age effect was detected, with younger individuals having higher H/L ratios than older ones (Table 10). No effects of year were detected.

Data from the winter months of 2004-2005 were not included in the analysis due to the fact that the period was unusually wet for Sonora, and that changed the whole aspect and phenology of the riparian vegetation; birds were more dispersed, sample sizes were small, and the revised smears did not show differences that might suggest a consistent pattern. On the contrary, the winter months of 2003-2004, and 2005-2006 were cold and dry, which was much more characteristic of the "normal" winter climatic conditions in central Sonora. These results might suggest that years with the "abnormal" weather conditions (wet, not as cold, and moderate variations in daily temperature) might alleviate some environmental stress effects in those individuals inhabiting disturbed riparian habitats. More study is needed to determine if this pattern is general and can be found as well in other bird species.

Table 7. Number and percentage of individuals banded and recaptured in the different periods of time involved in the study.

Individuals	Nov-2004	Jan-Feb 2005	Nov-2005	Jan-Feb 2006
Banded	**366**			
Recaptured		91	72	44
		24.8%	19.7%	12.0%
Banded		**151**		
Recaptured			16	16
			10.6%	10.6%
			653	
Banded				192
Recaptured				29.4%

Recaptures Nov 2004 - Jan-Feb 2005 = Black-capped Gnatcatcher, Common Yellowthroat, Dusky Flycatcher, Gray Flycatcher, Green-tailed Towhee, Hammond's Flycatcher, Hermit Thrush, House Wren, Lincoln's Sparrow, Orange-crowned Warbler, Pacific-slope Flycatcher, Ruby-crowned Kinglet, Song Sparrow, Willow Flycatcher, Wilson's Warbler.

Recaptures Nov 2004 - Nov 2005 = Black-capped Gnatcatcher, Blue-gray Gnatcatcher, Common Yellowthroat, Cordilleran Flycatcher, Dusky Flycatcher, Gray Flycatcher, Hermit Thrush, Lincoln's Sparrow, Orange-crowned Warbler, Pacific-slope Flycatcher, Ruby-crowned Kinglet, Song Sparrow, White-crowned Sparrow, Wilson's Warbler.

Recaptures Nov 2004 - Jan-Feb 2006 = Common Yellowthroat, Dusky Flycatcher, Gray Flycatcher, Green-tailed Towhee, Hammond's Flycatcher, House Wren, Lincoln's Sparrow, Orange-crowned Warbler, Ruby-crowned Kinglet, Song Sparrow, Willow Flycatcher.

Recaptures Jan-Feb 2005 - Nov 2005 = Black-capped Gnatcatcher, Gray Flycatcher, Green-tailed Towhee, Lincoln's Sparrow, Wilson's Warbler.

Recaptures Jan-Feb 2005 - Nov 2005 = Cordilleran Flycatcher, Dusky Flycatcher, Gray Flycatcher, Hammond's Flycatcher, Lincoln's Sparrow.

Recaptures Nov 2005 - Jan-Feb 2006 = Bewick's Wren, Black-capped Gnatcatcher, Blue Grosbeak, Blue-gray Gnatcatcher, Canyon Towhee, Dusky Flycatcher, Dusky-capped Flycatcher, Gray Flycatcher, Green-tailed Towhee, Hermit Thrush, House Wren, Lincoln's Sparrow, Loggerhead Shrike, MacGillivray's Warbler, Ruby-crowned Kinglet, Rufous-winged Sparrow, Song Sparrow, Swamp Sparrow, White-crowned Sparrow, Wilson's Warbler.

Table 8. Analysis of Condition Index (mass/wing chord) values for the species with at least 15 records in relatively undisturbed and disturbed riparian habitats of central Sonora, Mexico. Data correspond to January and February 2005 and 2006. A univariate analysis of variance was performed using age (SY and ASY), site (river system), and year (2004 and 2006) as factors; means and standard errors are presented. No significant effects of age, site, or year were found.

Species (n)	**Undisturbed Mean Mean [SE] n**	**Disturbed Mean Mean [SE] n**	**F df=1**	**p**
BCGN (16)	0.129 [0.003] n = 6	0.117 [0.004] n = 10	2.842	0.126 NS
DUFL (18)	0.158 [0.003] n = 8	0.161 [0.005] n = 10	0.012	0.913 NS
GRFL (27)	0.161 [0.004] n = 8	0.168 [0.006] n = 19	0.086	0.772 NS
GTTO (59)	0.372 [0.008] n = 30	0.353 [0.013] n = 29	0.667	0.418 NS
HOWR (15)	0.178 [0.005] n = 7	0.181 [0.007] n = 8	0.647	0.438 NS
LISP (71)	0.258 [0.010] n = 21	0.245 [0.004] n = 50	0.496	0.484 NS
NOCA (36)	0.438 [0.007] n = 18	0.421 [0.012] n = 18	0.678	0.469 NS
RCKI (30)	0.096 [0.002] n = 20	0.098 [0.003] n = 10	0.819	0.375 NS
SOSP (31)	0.290 [0.004] n = 16	0.287 [0.009] n = 15	1.223	0.280 NS
WCSP (86)	0.332 [0.004] n = 31	0.321 [0.008] n = 55	0.579	0.449 NS

Table 9. Analysis of fat score values for the species with at least 15 records in relatively undisturbed and disturbed riparian habitats of central Sonora, Mexico. Data correspond to January and February 2005 and 2006. A univariate analysis of variance was performed using age (SY and ASY), site (river systems), and year (2004 and 2006) as factors, weighed by size (flattened wing cord); means and standard errors are presented. No effects of site were detected. Effects of age and year are indicated when found. A non-parametric ordinal regression model using the Wald statistic under the same factors and weight shows basically the same pattern (Wald χ^2). (Bonferroni correction p-value < 0.005).

Species (n)	Undisturbed Mean Mean [SE] n	Disturbed Mean Mean [SE] n	F df=1	p	Wald χ^2 df=1	p
BCGN (16)	1.951 [0.352] n = 6	2.174 [0.320] n = 10	0.101	0.757 NS	0.252	0.615 NS
DUFL (18)	2.079 [0.219] n = 8	2.226 [0.219] n = 10	0.227	0.644 NS	0.680	0.410 NS
GRFL (27)	1.995 [0.370] n = 8	1.318 [0.274] n = 19	0.001	0.973 NS	0.316	0.574 NS
GTTO (59)	1.296 [0.313] n = 30	1.413 [0.210] n = 29	0.994	0.323 NS	0.002	0.966 NS
HOWR (15)	1.531 [0.395] n = 7	1.027 [0.433] n = 8	0.000	0.986 NS	0.029	0.864 NS
LISP (71)	1.532 [0.211] n = 21	0.953 [0.354] n = 50	0.536	0.467 NS [a]	1.964	0.161 NS [a]
NOCA (36)	1.620 [0.320] n = 18	1.516 [0.225] n = 18	0.538	0.469 NS [a]	0.072	0.789 NS [b]
RCKI (30)	1.595 [0.185] n = 20	1.854 [0.285] n = 10	0.581	0.454 NS [a b]	2.153	0.142 NS [a b]
SOSP (31)	0.674 [0.162] n = 16	1.326 [0.243] n = 15	4.330	0.048 * [a]	4.900	0.027 * [a]
WCSP (86)	1.142 [0.121] n = 31	0.832 [0.121] n = 55	2.382	0.127 NS	1.077	0.299 NS

[a] = Significant year effect (higher values in 2005, a wet year). [b] = Significant age effect (higher values in older individuals [ASY]).

Table 10. Analysis of H/L ratio values for selected species in relatively undisturbed and disturbed riparian habitats of central Sonora, Mexico. Data correspond to January and February 2004 and 2006. A univariate analysis of variance was performed using age (SY and ASY), and year (2004 and 2006) as factors; means and standard errors are presented. Effects of age are indicated when found; no effects for year were detected. **(**Bonferroni correction p-value < 0.01).

Species (n)	**Undisturbed Mean** **Mean [SE] n**	**Disturbed Mean** **Mean [SE] n**	**F** **df=1**	**p**
GTTO (45)	0.4977 [0.0718] n = 18	2.3169 [0.0995] n=27	96.275	0.000 **
LISP (19)	0.5938 [0.0988] n = 8	1.8406 [0.1846] n=11	294.691	0.000 ** [a]
NOCA (25)	1.1358 [0.1167] n = 12	1.5882 [0.1464] n=13	0.380	0.545 NS
SOSP (20)	0.6168 [0.1043] n = 9	1.9786 [0.1464] n=11	52.124	0.000 ** [a]
WCSP (48)	0.5804 [0.0706] n = 24	2.1231 [0.1167] n=24	142.879	0.000 ** [a]
All Species (156)	0.6600 [0.0472] n = 70	2.0485 [0.0622] n=86	150.009	0.000 ** [a]

[a] = Significant age effect (higher values in younger individuals [SY]).

Discussion

A. Anthropogenic disturbance, bird communities, and species

Riparian environments are the result of periodic disturbance regimes, and their maintenance depends on the frequency, intensity, and severity of those natural disturbance factors. Unfortunately, changes in the normal natural disturbance regimes have interrupted the cycles and have stopped the very important processes responsible for their long-term maintenance (Scott *et al.* 2003). In general, most types of anthropogenic disturbance on riparian environments are reported to have some detrimental effects on their bird communities; however, this was not the pattern in this study. Contrary to expectations, the results did not reveal any effects of disturbance on the general composition of bird communities and the abundance of most species. Only six species showed significant differences in abundance between undisturbed and disturbed riparian habitats. Three species were significantly more abundant in disturbed riparian sites—two (White-winged Dove and Gila Woodpecker) being among the most common and characteristic resident species of open adjacent desert areas, and one (White-crowned Sparrow) being a migrant species that frequently forages in large flocks from adjacent second-growth areas that contain abundant seeds. The other three species were more abundant in relatively undisturbed areas, and included two species (the resident Lesser Goldfinch and the migrant Ruby-crowned Kinglet) that were detected frequently on cottonwoods and willows along the river courses, and one species (Green-tailed Towhee), which inhabits primarily the ground level within riparian areas.

What could be the reasons for the lack of a pronounced difference between relatively undisturbed and disturbed riparian sites? Variation in the effects of disturbance on species richness and relative abundances may be related to differences in disturbance intensity (McKee & Baldwin 1999). Western riparian zones are an important habitat for avian species, but are the most drastically modified environments in the arid United States due to grazing, water management, agricultural activities, and urbanization. Increases in human population in these areas demand an ever-increasing amount of resources and services, which make the management and conservation of healthy riparian vegetations difficult.

Sonora, however, has the second lowest human population density in Mexico, and none of the rivers studied have experienced big transformations nor are they under the influence of large human settlements and pressures as in southwestern United States. Although some of the same anthropogenic factors are acting upon biological communities in the Sonoran riparian sites, the intensity of such disturbance factors is not severe enough to cause the expected effects.

Another explanation might be related to the birds' ecological requirements, which may not be as demanding during winter as they are in summer, at least in terms of the specificity of food items required. The temporal relaxation of these requirements may allow the birds in riparian habitats to be more generalized in their needs and enable them to take advantage of what is available; irrespective of the effects that disturbance might impose on the riparian vegetation productivity and other animal communities. Indeed, most migrants seem to benefit from moderate levels of disturbance (Petit *et al.* 1995). Although there is no information on the importance of riparian vegetation as corridors, if they act by allowing the movement of individuals along the river course, they could also serve to ameliorate possible disturbance effects in adjacent sites.

Unfortunately, there have been no studies carried in Sonora that can be used to compare with the observed results, and most of the detailed information on riparian bird communities in Arizona, New Mexico, and California has emerged from studies during the breeding season or the migration periods. The few studies that include information on the wintering season do not provide adequate data to make useful comparison with these results (Wells *et al.* 1979, Szaro 1980, Rice *et al.* 1983, Anderson *et al.* 1989, Strong & Bock 1990, Farley *et al.* 1994).

One aspect that seems worth noting is the higher number of species and individuals in the Sonora River system in comparison with the other two river systems. As I mentioned before in the comparison of the sites, the Sonora River has a wider riparian corridor. The structural complexity of riparian corridors is frequently mentioned as important for birds, and it may be equally important for breeding and wintering bird communities (Strong &

Bock 1990). Structural complexity increases as the corridors becomes wider because of increases in tall shrubby and wooded vegetation (translating into more hiding cover and a wider array of available resources). This, in turn, may allow for the presence of a more diverse bird community containing both species that typically occupy the edges, as well as others that require larger vegetation fragments. This pattern has been found during the summer in different areas of the United States (Croonquist & Brooks 1993, Keller *et al.* 1993, Hodges & Krementz 1996), and Canada (Deschenes *et al.* 2003), as well as in broad riparian corridors in West-central Mexico during the winter (Villaseñor-Gómez & Hutto 1995). Furthermore, as most rivers in Sonora are not constrained, and short but intense periodic flooding events still occur, traditional riparian management practices are used to enhance the maintenance and stability of riparian vegetation, promoting the maintenance of wide corridors for protection of agricultural fields (Nabhan & Sheridan 1977).

An additional disturbance factor that might affect the Moctezuma River system in particular is the mining activity taking place in the surrounding areas of Cumpas and Nacozari. Unfortunately, there are no mitigating actions being implemented in the area, and after strong precipitation it is possible to observe the water of the river changing color to yellow due to an incredible amount of soil extracted in the mining process being eroded and carried for considerable distances. This constitutes an example of a factor that might influence organisms far from the source, and its effects could be very difficult to tease apart.

B. Fat reserves, body condition, and physiological effects of disturbance

During the life span of a bird there are periods in which energetic requirements are higher and the ability to fulfill those needs has a direct effect on individual survival and reproductive success. Breeding and migrating are the most demanding activities and it is well known that birds modify their behavior and prepare physiologically to cope with such energetic demands. Normally, fat reserves are elevated and other indicators of condition are better during breeding and migration times in comparison to the wintering period, and differences also exist between older and younger individuals (Swanson *et al.*

1999, O'Reilly & Wingfield 2003, Khoury 2004). However, generally during the winter, weight, fat scores, and condition indices are comparatively low (Diamond *et al.* 1977, Cuadrado *et al.* 1989, but see Katti & Price 1999), but increase or improve as the spring migration time approaches. In territorial species showing dominant interactions, sex and individual social status might also be related to differences in body condition, in the same way than differential habitat use between sexes and age groups (e. g. López-Ornat & Greenberg 1990, Marra & Holberton 1998, Marra & Holmes 2001, Catry 2005).

The results of this study do not show differences in condition index and mean fat scores of birds that winter in areas subject to different levels of disturbance. However, there were important effects of year in four species that showed higher mean fat scores in 2005, the year with an unusually wet winter. The same trend was noted by Gosler and Carruthers (1999) for *Parus major* in Ireland, as a result of increased winter rainfall. An effect of age was detected in at least two species, with older individuals having higher fat score means than younger ones. This has been interpreted to be the result of young individuals having less experience at finding food or competing for it with older individuals, which might translate into lower weight and fat scores (Swanson *et al.* 1999, O'Reilly & Wingfield 2003).

Overall, the interpretation of condition indices and fat scores during the winter can be difficult without considering additional data on diet, food availability, local environmental conditions, and ecosystem productivity. The generally low mean fat scores might be the result of a low productivity and availability of food in the system (Cuadrado *et al.* 1989). In other cases, low fat scores might be the response of individuals to sites with benign conditions and reliable food supplies (Broggi & Brotons 2001, O'Reilly & Wingfield 2003). Further information would be needed to determine which possibility is responsible for the observed pattern in this case.

Documentation of changes in condition and fat reserves during the complete wintering season might be useful to determine the quality of the habitats used by birds. As Johnson *et al.* have suggested, measures of body condition coupled with survival data provide a good measure of habitat quality for nonbreeding songbirds (Johnson *et al.* 2006).

Responses at the physiological level to unpredictable environmental stressors are regulated through the activation of the Hypothalamo-Pituitary-Adrenal Axis (HPA), promoting the production of gluco-corticosteroids and eliciting an array of responses that allow individuals to adjust their physiology and behavior and cope with those temporal stressors. One of these responses, the increase of corticosterone levels in plasma, promotes shifts in the types of circulating white blood cells. Smears used to assess this shift showed that the proportion of heterophiles and lymphocytes is different under the two levels of environmental stress studied. The five species analyzed had higher H/L ratio values in disturbed riparian environments, although in one of them the differences were not statistically significant; additionally, two species show a significant effect of age. This is an indication that individuals of those species sampled in disturbed riparian areas are showing the effects of some kind of stress. How can we reconcile these seemingly contradictory results?

Their interpretation proves to be difficult, and instead of getting a response to the original question, results raise more questions to be answered. The evidence suggests that there is some type of stress causing the observed pattern, and younger individuals show a more intense response than older ones (as mentioned by Vleck 2001). However, the identification of the particular causal factors responsible for the relatively elevated H/L values is not possible to determine with the available information. During the rainy winter months of 2004-2005 there was no evidence of stress based on H/L ratio response between sites experiencing low and high disturbance levels. This suggests that the stressors involved in the response could be related to or at least modulated by environmental weather conditions instead of induced anthropogenic causes.

However, it is impossible to discard a whole set of other possible causal effects. Perceived environmental stress may include factors such as weather conditions (as simple as changes in temperature and humidity at the microhabitat level), exposure to chemical agents (as those that might be used in adjacent agricultural fields and other pollutants discharged to the rivers in towns and other settlements), increased intra- and interspecific competition, increased predation risk (due to the decreased cover and the closeness to edges and open habitats), different types of pathogens and parasites, changes in social status (as a result of dominance and undetected territoriality), limited food resources (reflecting lower system productivity), human interference (noise and other direct and indirect disturbances caused by human presence), and probably many others that have not even been considered (Mandal *et al.* 1986, Newman *et al.* 2000, Romero *et al.* 2000, Vleck 2001 and pers. comm. 2006, Ruiz *et al.* 2002, Wingfield & Kitaysky 2002). The effects of individual causal factors on animal populations should be assumed only after careful comparisons with controlled situations and through use of a more experimental approach (Walker *et al.* 2005).

The values reported here for H/L ratio levels have to be considered only as relative values because there is no information on non-stressed baseline data for the studied species. Despite the consistent pattern found among the species included in this study, it is not possible to use such values in intraspecific comparisons because (1) the normal proportion of heterophiles and lymphocytes differ among even closely related species, (2) inter-individual variation might be considerable, and (3) there might be age effects as was apparent here for some species (Vleck *et al.* 2000, Collette *et al.* 2000). The physiological state during the different phases of the life cycle of individuals (i.e. wintering, migration, or breeding) might also modify the expression of this indicator as a result of hormonal changes (Wingfield *et al.* 1992, Hood *et al.* 1998, Vleck *et al.* 2000, Romero 2002).

Why do H/L ratios show the existence of certain environmental effects on individuals inhabiting the disturbed riparian sites, while condition index and fat scores do not give any indication of an effect? It is hard to find a logical answer for this question, but it could be related to the way corticosterone interacts with the immune cells producing the shifts in the proportion of heterophiles and lymphocytes. Corticosterone increases due to the effect of stressors is very fast and if the causal factor disappears, its concentration in plasma goes down rapidly as well. White blood cells changes are slower and more persistent. The detection of a high H/L ratio indicates that the individual has experienced chronic levels of stress, but does not tell us much about how long in the past the stressing factor happened. The period of time these shifts are maintained after the events that cause them is unknown and it might be possible that such effects do not have strong repercussions on other indicators such condition and fat reserves. More study is needed to determine the way different indicators relate to each other and the duration of the detected effects after their activation.

Although in this specific case it is impossible to determine the type and the intensity of stresses that caused the responses observed in H/L ratios, the data still show that there is a detectable effect. It would be important to determine whether the environmental stressors are affecting winter survival in individuals using disturbed riparian areas, and whether the effects are general, or whether effects are species, age, or site specific. Furthermore, stressful conditions on the wintering grounds may not show themselves until the individuals migrate the following spring or even, later on (Conway *et al.* 1995). It would be very useful to determine the possible delayed effects winter habitat use might have on migrant species, considering that they could be help explain the reported population declines in a good number of migratory species.

Riparian habitat transformation will continue in the future as a result of increasing agricultural activities and encroachment of humans into riparian corridors. Nonetheless, because disproportionately large numbers of bird (and other animal and plant) species depend entirely upon riparian systems for their existence, we need to understand first how human activities are affecting the health of riparian habitats, and second, whether some activities or modes of operation might be more benign than others in terms of their effects on riparian dependent species. With respect to birds, recent declines in some species (Terborgh 1989, Robbins *et al.* 1989, Askins *et al.* 1990) may be partly a product of decreases in winter performance and survivorship.

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Chapter 4

MANAGEMENT PERSPECTIVES OF RIPARIAN SYSTEMS IN THE ARID SOUTHWESTERN UNITED STATES AND NORTHWESTERN MEXICO

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Abstract. Freshwater limitations and an ever-increasing need make water management an important concern for human populations. The establishment of dams and diversions in river systems has modified natural flooding regimes, which in turn has resulted in the decrease and loss of riparian native corridors, the invasion of exotic plants, and changes in associated animal communities. Floodplains are composed of diverse habitat mosaics, and are recognized as centers of "bio-complexity" and "bio-production" (Hauer & Lorang 2004), potentially playing a key role in the stability of the most important ecological processes of riparian systems. Unfortunately, floodplains constitute areas where many primary human activities take place. In this paper, I present the Colorado River Delta as an example illustrating the effects of anthropogenic changes in riparian systems, and as an example of the results of management and restoration measures in the United States. I compare the scenario in the United States with that in central Sonora, where some traditional management measures have helped ameliorate some negative consequences of flow control along mid-sized river systems.

Resumen. La escasez y creciente necesidad del agua hace que su manejo sea indispensable para las sociedades humanas. El establecimiento de presas y canales en los sistemas riparios ha modificado los regímenes naturales de inundaciones, los que a su vez han ocasionado la disminución y pérdida de corredores riparios nativos, la invasión de plantas exóticas, y cambios en sus comunidades animales asociadas. Los valles fluviales comprenden mosaicos diversos de hábitats considerados como centros de "bio-complejidad" y "bio-producción" (Hauer & Lorang 2004) que potencialmente juegan un papel central en la estabilidad de los procesos ecológicos más importantes de los sistemas riparios. Desafortunadamente, los valles fluviales constituyen áreas donde toman lugar muchas de las actividades productivas primarias. En este artículo presento al delta del Río Colorado como un ejemplo que ilustra los efectos antropogénicos de los cambios en sistemas riparios y de algunas medidas de manejo y restauración en los Estados Unidos. Comparo este escenario en los Estados Unidos con el del centro de Sonora, donde algunas medidas tradicionales de manejo han ayudado a mitigar algunas de las consecuencias negativas del control fluvial en ríos de mediano tamaño.

Introduction

"*Human history has often been shaped by the rivers that provide water, transportation, and a means of waste disposal. Although the total surface area of rivers and streams is small compared to that of oceans and land masses, rivers are among the natural ecosystems most intensely used by humans.*" (Odum 1989:225). Unfortunately, the way humankind has used rivers historically has not been ecologically responsible, and today practically all river systems suffer in some way from the diverse anthropogenic effects of long periods of use by humans. Since freshwater limitation is expected to increase in the future, pressures imposed on rivers and their associated biological communities will continue; it is imperative that we find equilibrium between the satisfaction of water demands for human use and conservation of the integrity of these very important ecological systems.

The structure and function of river ecosystems, as well as their ecological integrity have been compromised by a series of discontinuities imposed by dams and diversions, which, as a result of flow regulation and revetment, have disrupted natural hydrologic regimes and disconnected river channels from their floodplains (Kingsford 2000, Hauer & Lorang 2004). Unfortunately, this type of change is happening at a global scale and we do not know the extent of its ecological consequences (Molles *et al.* 1998).

A value recognized only within the last decade is that floodplains along broad valleys appear to be areas of "bio-complexity" and "bio-production" at the watershed and regional scales due to the enrichment of soils by flooding, the mobilization and facilitation of nutrient-involved processes, and the presence of wetlands and riparian forests (Hauer & Lorang 2004). In general, floodplains are complex habitat mosaics that are biologically more diverse that the uplands. Consequently, floodplains are key elements that might determine the presence of biota within river corridors. The constant changes that natural fluvial processes promote in floodplain habitats are the ones responsible for maintaining the ecological integrity of river systems. Unfortunately, the dynamics associated with the habitat mosaic in floodplains is the very feature that has disappeared because of intense regulation of dams and diversions (Hauer & Lorang 2004).

What are the primary pressures causing rivers to become over-regulated? It is in floodplains where most human interests are placed because the periodic enrichment of soils favors agriculture and the production of pasture to feed cattle, where above- and underground water is available for human consumption, and where many other human uses tend to be concentrated. Thus, accomplishing management and restoration goals in these areas will be difficult due to basic conflicts between economic and natural resource interests. When faced with this conflict, planning and management actions will have to be implemented at the level of the watershed because the effects of disturbance events at the regional level are a reflection of what happens along the rivers themselves.

All riparian areas within aridlands in southwestern United States and Mexico have some features in common: (1) they constitute well-defined habitats within the much drier surrounding areas, (2) they represent a very small proportion of the overall surface, (3) they are generally more productive in terms of biomass than the remainder of the region, and, (4) they harbor the richest biodiversity in desert landscapes. Water presence and the edge effect maximized by the long and narrow shape of riparian communities account, at least in part, for their faunal diversity. In this region, alteration of the hydrograph has been directed mostly toward satisfying agricultural and urban water supply needs, and the most evident effects have been dramatic changes in the succession dynamics and the composition of riparian plant communities and their associated faunas.

Using these ideas as a framework, I present a brief review of (a) the transformations and problems experienced by riparian communities in the most important river systems of southwestern United States and northwestern Mexico, using the Colorado River system as an example, (b) some of the management and restoration measures that have been implemented in different river systems within the southwestern United States, and (c) how the riparian associations in central Sonora differ from those north of the U.S.-

Mexico border, and how some of the traditional management practices in Sonora have resulted in notable ecological benefits.

The case of the Colorado River

The Colorado River Delta, once considered one of the richest areas for wildlife and one of the preferred beaver trappers' sites, has been dramatically altered since agriculture was established at the beginning of the 1900's, first in the Imperial Valley of California, and later on in Mexico's Valle de Mexicali (Glenn *et al.* 1992). As a result of suppressing the variability associated with biotic and abiotic interactions promoted through the natural dynamics of river flow (Minckley 1982), the Colorado River system became one of the most highly modified channels in western North America. It has been compared to what happened in other great desert river deltas, such as the Nile and the Indus (Glenn *et al.* 1996). After the construction of the Hoover Dam in 1936, all the water in the Colorado River was apportioned for upstream use, mainly for irrigation, but increasingly for municipal use. Unfortunately, there was no allotment of water for the preservation of the delta ecosystem below the irrigation districts.

Historically, the Colorado River Delta occupied 780,000 ha, including two depressions below sea level (the Salton Sea and Laguna Salada); much of the upper delta has been converted subsequently to irrigated farmland, and the two depressions have become saline evaporation basins receiving irrigation return flows, flood waters, and municipal sewage. Today, the three remaining wetland areas ("Cienegas" of Rio Hardy, Santa Clara, and El Doctor, Figure 13) are not, for the most part, natural marshes, but are instead incidental creations resulting from water management decisions in the United States and Mexico. The treaty allotment of water to Mexico was defined in 1944 as approximately 10% of the base flow in the lower Colorado River during non-flood years. This water does not usually reach the delta wetlands, but is diverted at the border into the Canal Central for irrigation use in the Mexicali and San Luis districts in Mexico (Glenn *et al.* 1992, Glenn *et al.* 1996).

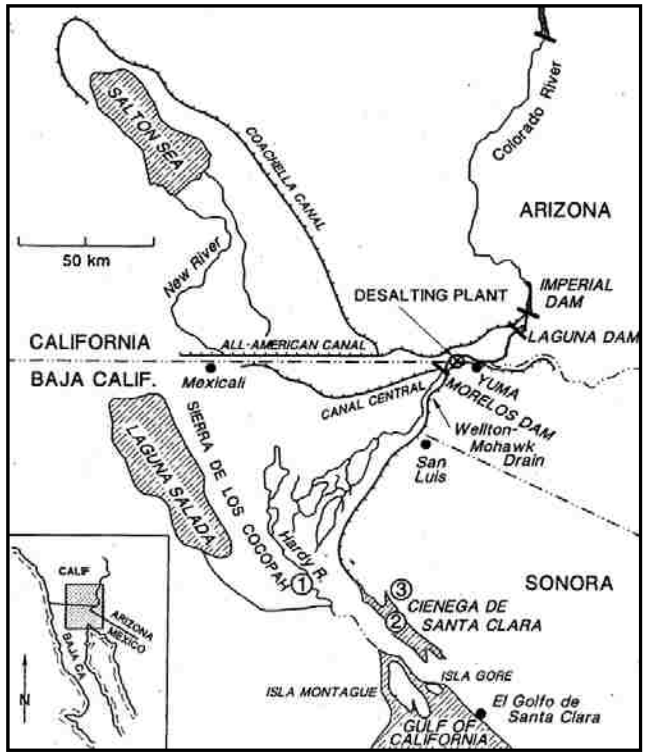

Figure 13. Map of the Colorado River Delta. The location of the wetlands is indicated by the numbers: 1, Rio Hardy; 2, Ciénega de Santa Clara; 3, El Doctor (Source: Glenn *et al.* 1996).

Back in the early 1900's, plant communities in the area were probably represented by associations of cottonwood (*Populus fremontii*) and willow (*Salix gooddingii*) along the river banks, and shrub seepwillow (*Baccharis salicifolia)* and coyote willow (*Salix exigua*) as understory plants. Cattail (*Typha* spp.), bulrush (*Scirpus* spp.) and reed (*Phragmites australis*) formed emergent communities. At slightly higher levels and along drier banks, honey mesquite (*Prosopis glandulosa*) and screwbean mesquite (*P. velutina*) occurred. Other species such as arroweed (*Tessaria sericea*), inkweed (*Suaeda torreyana*), saltbush (*Atriplexpolycarpa*, *A. canescens*), quail bush (*Atriplex lentiformis*), creosotebush (*Larrea tridentata*), smoke tree (*Psorothamnus spinosus*), ocotillo (*Fouquieria splendens*), and palo verde (*Cecidium floridum*). were found mostly in deserts adjacent to the river (Ezcurra *et al.* 1988). Two varieties of the grass *Panicum sonorum* (an Indian cultivated, and a wild form) occurred on the flats that were flooded by the river every year. In general, the Colorado River Delta is thought to have included 200-400 species of wetland vascular plants, most of which have disappeared (Ezcurra *et al.* 1988), as well as the *Panicum sonorum* grass forms and most of the riparian forests (although some patches of isolated trees remain, mostly including senescent trees with low productivity and no replacement). The establishment of saltcedar woodlands (*Tamarix ramosissima*), an Asiatic native species introduced in 1837 for erosion control, has expanded along rivers and now replaces native cottonwood-willow forest (Stromberg 1998); the vegetation at present is dominated by salt-tolerant or halophytic plants.

The aquatic fauna of the lower Colorado River is also known to have changed as a result of the effects of dam construction and introduced exotic species (Mellink and Ferreira-Batrina 2000). Only three of the 14 fish species currently recorded were native (the striped mullet [*Mugil cephalus*], the desert pupfish [*Cyprinodon macularis*], and the machete [*Elops affinis*]). There is not much information on the amphibians that might have historically existed there, but the bullfrog (*Rana catesbiana*), the Rio Grande leopard frog (*R. berlandieri*), and the tiger salamander (*Ambystoma tigrinum*) have been introduced in the area and might be responsible for compounding negative effects on native amphibian populations that might already have been induced by the disruption of the natural water flows.

Only two native species of aquatic reptiles inhabit the Lower Colorado: the Sonoran mud turtle (*Kinosternon sonoriensis*), which seems to have been extirpated from the area, and the checkered garter snake (*Thamnophilus marcianus*), which has very diminished populations at present due to a reduction in area of riparian habitats. On the other hand, three species have been introduced: the soft-shelled turtle (*Apalone spinifera*), the painted turtle (*Crysemys picta*), and the American alligator (*Alligator mississipiensis*) (Mellink & Ferreira-Bartrina 2000). The bird communities of the area have been studied by Mellink and collaborators (Mellink & Palacios 1993, Mellink *et al.* 1996, Mellink *et al.* 1997), and they are probably among the most affected by the river changes. Although detailed information on their status in the past does not exist, it is possible that waterfowl species may have increased as a result of agriculture. It is also unknown whether the original conditions of the area supported more or fewer shorebirds and wader species than at the present. Three species considered important from a conservation perspective are the Large-billed Savannah Sparrow (*Ammodramus sandwichensis rostratus*), which breeds almost exclusively in the marshes of the Colorado River delta, the Yuma Claper Rail (*Rallus longirostris yumanensis*), whose populations in Cienega Santa Clara is almost 50% of the known population of the subspecies, and the endangered Black Rail (*Laterallus jamaicensis*), recently recorded in the area by Osvel Hinojosa (Hinojosa-Huerta *et al.* 2004). Three aquatic mammals are known to inhabit the delta area: river otter (*Lutra canadensis*), beaver (*Castor canadensis*), and muskrat (*Ondatra zibethica*). All are considered at risk due to the modification of the dynamic of water streams (Mellink & Ferreira-Bartrina 2000).

In this area, the Cocopáh ethnic group maintained fishing camps along the banks of the Rio Hardy until 1977, making use of the wetlands for hunting, fishing, and collecting plant materials for food, fuel, basket making, and medicinal use (Glenn *et al.* 1996). In 1993, the Mexican Government created a Biosphere Reserve that included the Northern Gulf of California and the Colorado River Delta, to protect the biological resources of the area, and the endangered marine totoaba fish (*Cynoscion macdonaldi*) and vaquita porpoise (*Phoceona sinus*) (Diario Oficial de la Federación 1993).

The two main problems in the delta area have been (a) a loss of the original riparian vegetation and an establishment of opportunistic exotic plant species as a result of decreased amounts of water and the modification of normal flooding regimes, and (b) a loss in biodiversity caused by changes in water quality, increased predation, competitive interactions with exotic species, and the restriction of displacement up and downstream by dam construction and channelization. Although livestock do not have a substantial direct effect on the vegetation within the area, maintenance of productive pasturelands contributes additionally to the increase in water demand.

Management and restoration in riparian habitats

Responsible water management is imperative to human populations; however, due to ever increasing limitations, riparian communities have suffered the effects of inadequate management. A desirable condition would be the maintenance and restoration of minimal conditions for riparian habitats to continue to perform key roles in the river's ecological processes. For that reason, research and management actions have been implemented trying to mirror natural regimes and to test strategies for future restoration projects.

Molles *et al.* (1998) tested the effects of flooding during three consecutive years in experimental and control stands of old mixed cottonwood forests in the upper Rio Grande in New Mexico. Those stands had been isolated from flood pulses for more than 50 years. They simulated the conditions of low energy floods between May and June (1993-1995) coinciding with the historic flood peaks and found that after flooding events, the level of soil bacteria and fungi decomposer activity increased, and the forest-floor arthropod communities experienced changes in composition but not in general abundance. However, there were no measurable effects on small-mammal populations. At the ecosystem level, the large quantities of organic matter created a very high biological oxygen demand, and decomposer activity increased the level of organic matter reincorporation into the soil. The responses were interpreted as the beginning of a system reorganization process that could lead to the restoration of the sites, emphasizing the importance of flooding regimes to promote natural succession and long term maintenance of healthy riparian stands.

Dam construction and other flood control structures can have longer lasting effects on vegetation and animal communities than severe natural flooding effects. For example, the construction of a flood control structure on the Tahquitz Creek, California. in 1980, caused considerable loss of riparian vegetation and shifts in the breeding bird communities. Five years after dam construction and implementation of vegetation restoration, only four of 18 breeding species continued breeding at the site (Patten & Rotenberry 1998). In contrast, the impact of natural flooding events which are often short and catastrophic, are not as dramatic, and populations can recover in a shorter period of time. That was the case along the Snake River in Idaho and Oregon where, after severe flooding, overall relative abundances decreased slightly and groups of species responded differently. Some species did not show changes, some decreased as a result of nest inundation and the loss of some of habitat features (e.g., understory cover), and others increased probably due to elevated densities of aquatic insects. The existence of patches affected differently within the landscape mosaic allowed temporal shifts in the local distribution of the species, and faster natural recovery of their populations (Turley & Holthuijzen 2005).

In many other cases, the original vegetation have been replaced by invasive exotic species (saltcedar [*Tamarix ramosissima*] and other species of the same genus and Russian olive [*Elaeagnus angustifolia*]). These invasive species are reproductively opportunistic, have high water use efficiency and deep roots, and are tolerant to drought, flooding, and salinity; consequently, reduced stream flows, lowered water tables, altered flood timing, and increased salinities may give these species a competitive advantage over native cottonwood and willow species on managed rivers (Everitt 1980, Stromberg 1998).

Some methods used to control these exotic species have been mechanical, chemical, and biological control procedures. Initial mechanical control methods involved chaining followed by mowing yielded very poor results. Simple removal of aboveground material did not help, and plants quickly resprouted from buried root crowns. The use of bulldozers, chain saws, and hand pulling were implemented later, with better results. Chemical treatments have ranged from the application of herbicides to individual plants, to spraying large monotypic stands with Imazapyr, Triclopyr, or a mixture of Glyphosate/Imazapyr followed by prescribed fires after the treatment. Biological control involves the introduction of specialist plant-feeding insects from the regions where the plant species come from. The most important approved insect species has been the leaf-feeding beetle from central Asia (*Diorhabda elongata*). Herbicidal and mechanical methods are very damaging to native plant communities, and chemicals could have some effects on animal populations. Hand methods (usually cutting and stump treatment with herbicides, or pulling seedlings by hand) do not damage native plants, but are highly labor intensive. All methods are very expensive and require periodic retreatment to prevent or control reinfestations, and their results are not completely satisfactory. Biological control has shown some promising results, but those results can be gradual and heterogeneous (Brock 1994, Taylor & McDaniel 1998, A.R.S. 2000, Sprenger *et al.* 2002, Lewis *et al.* 2003, Shafroth *et al.* 2005).

It has been emphasized that the dynamics of surface water, ground water, and sediment largely determine water availability for plants and the potential for natural recruitment of riparian plant species (Shafroth *et al.* 2005). The understanding of the ecophysiology of these species and the way flow regimes affect the establishment and survival of seedlings may help to restore native species as dominants and provide alternatives to control measures already being applied (Stromberg 1998, Pettit & Froend 2001, Cleverly *et al.* 2006). A test for a combination of mechanical and chemical methods followed by experimental flooding to stimulate native species reestablishment from seed showed the importance of maintaining adequate soil humidity for the survival of seedlings (Sprenger *et al.* 2002).

Recent research suggests that under natural flow regimes, native trees are competitive with saltcedar in germination and establishment during flood years, and have equal or faster growth rates. An effective strategy for management of saltcedar must include the restoration of more dynamic regimes in regulated rivers, allowing the coexistence of native species and saltcedar (Tiegs *et al.* 2005, Lite & Stromberg 2005, Glenn & Nagler 2005, Cohn 2005). However, it has been noted that in the Colorado River Delta, where saltcedar is dominant, native cottonwoods and willows have regenerated because of frequent flood releases from U.S. dams since 1981 (Nagler *et al.* 2005). The restoration of pulse flood regimes would contribute to the regeneration of native riparian vegetation despite the presence of saltcedar; however, fire management is necessary to allow the development of mature tree stands (Nagler *et al.* 2005). The removal of saltcedar has shown positive effects on some native endemic fish species such as the Ash Meadows speckled dace (*Rhinichthys osculus nevandensis*) and the Ash Meadows pupfish (*Cyprinodon nevadensis mionectes*), by changing the way aquatic species interact in the system (Kennedy *et al.* 2005).

Livestock grazing is another land-use activity that has had an important impact. Cattle exhibit a strong preference for riparian zones because of the availability of water, forage quality and variety, and shade. The effects of grazing vary greatly depending on the habitat and the intensity of grazing. There are several predictable effects on the stream, the riparian vegetation per se, and the associated wildlife. Intense grazing can modify the quality of the stream by increasing runoff levels and levels of suspended solids as a result of stream bank vegetative reduction and erosion, and increases in fecal coliform counts. In turn, these changes can strongly affect aquatic communities by causing, for example, important reductions of invertebrate and fish populations (Kauffman & Krueger 1984, Armour *et al.* 1991). Modifications due to grazing include compaction of the soil (which increases runoff and decreases water availability for plants), understory removal (causing increased temperatures and evaporation at the soil level), trailing and trampling damage, a decrease in productivity, and changes in plant species and vegetation structural diversity (Fleischner 1994). Changes in vegetation have been linked importantly to increases and declines of riparian bird and small mammal species as a consequence of modified physical and structural features of the habitat, availability of resources, cover plants, and nesting sites (Geier & Best 1980, Mosconi & Hutto 1982, Andersen 1994, Saab *et al.* 1995, Popotnik & Giuliano 2000, Krueper *et al.* 2003).

Some of the methods for riparian rehabilitation have incorporated the exclusion of livestock grazing, reduction of stocking densities, alternative short term or fall-winter grazing schemes, restricted access to riparian areas, fencing of critical areas (such as streams and associated riparian vegetation in farmlands), the provision of alternate water sources (such as off river water supplies), and designated rest periods to allow recovery; in severely degraded systems the complete removal of cattle was suggested to allow for a rapid and substantial recovery of vegetation and wildlife populations (Kauffman & Krueger 1984, Saab *et al.* 1995, Jansen & Robertson 2001, Krueper *et al.* 2003).

When management actions are considered, an important uncertainty is the extent to which human activities have compromised the structure and function of the natural river ecosystem. If function has been substantially compromised, then the question would become "Can a reasonable amount of natural functionality be restored while also allowing the traditional human uses of the rivers and their floodplains?" (Hauer & Lorang 2004). This is the most challenging question.

Diversity of riparian associations in central Sonora, Mexico

According to the latitude, climatic conditions, availability of water, and elevation, nine types of riparian associations have been defined in central Sonora. These associations show the effects of the variety of stressors already described but, in general, the level of disturbance is not as extreme as in areas of southwestern United States, due to a much lower human density in the area. The exceptions to this might be the Mexican section of the Colorado River already discussed, and the lower portions of the Sonora, Yaqui, and Mayo Rivers that have been impounded and where water reaches the coastal plain, only in very rare occasions when rainfall is enough to overflow the reservoirs.

A. Description of the riparian associations in central Sonora

Sonoran riparian associations can be placed into three groups: (1) lowland associations, (2) mid-elevation associations, and (3) highland associations.

1. Lowland Associations: In lowland sites, willows (*Salix* sp.) and mesquites (*Prosopis* sp.) are dominant near sea level, and can be associated with baldcypress (*Taxodium sp.*) at inland sites. In lowland valleys (sea level to 200 m), watercourses are characterized by the substantial deposition of fine-grained materials by periodic and variable floods. In the few rivers having permanent water flow, or in shallow aquifers, the riparian corridor is composed of trees such as bondpland willow (*Salix bondplandiana*), Goodding willow (*Salix gooddingii*), baldcypress (*Taxodium distichum* var. *mexicana*), Mexican cottonwood (*Populus mexicana* var. *dimorpha*), and honey mesquite (*Prosopis glandulosa*). Near Navojoa and Ciudad Obregón, gallery forests of Mexican cottonwood and Goodding willows are found along the old river channels Mayo and Yaqui Rivers, and may be considered historical relicts. The construction of dams has modified the very important natural flooding cycles needed for the recruitment of cottonwood, which require newly deposited sediments. The association of willow-mesquite-chino (*Pithecoellobium*) can found below 100 m elevation at sites in the Mayo and Yaqui Rivers in southern Sonora.

Major lowland arroyos (seasonal streams) in the coastal plains and in xeric landscapes of higher elevations might have a dominance of honey mesquite and other species restricted to tropical deciduous forests, such as man vine (*Agonandra racemosa*), zapote (*Diospyros sonorae*), guamuchil (*Pithecellobium dulce*), Tepic zapote (*Sideroxilon tepicense*), purple tabebuia (*Tabebuia impetiginosa*), and Sinaloa silk tree (*Albizia sinaloensis*). They correspond to associations known as mesquite desert riparian which can extend from 100 m to almost 800 m of elevation in northern Sonora, where drier conditions are extreme. They are found in sites of the Yaqui, Altar, Sonora, San Miguel, and Mátape Rivers, as well as in some temporal streams near sea level.

In places where thornscrub is the dominant vegetation, species such as honey mesquite, Jerusalem thorn (*Parkinsonia aculeata*), and bondpland willow are the most important riparian elements. In these instances they establish an association of willow-mesquite found between 150 and 800 m above sea level at Sahuaripa, Yaqui, Mátape, and Altar Rivers. They can be associated also with shrubs like shrub seepwillow (*Baccharis salicifolia*), jeco (*Hymenoclea monogyra*), Mexican camphorweed (*Pluchea salicifolia*), and pearlberry (*Vallesia glabra*). In more protected canyons the riparian tree species are man vine, figs (*Ficus* spp.), guasima (*Guazuma ulmifolia*), guamuchil, Tepic zapote, huevos (*Stemmadenia tomentosa*), uvalama (*Vitex mollis*), garabato (*Celtis iguanea*), and pisonia (*Pisonia capitata*), and may include other species more related to tropical forest, such as palo mulato (*Bursera grandifolia*), palo piojo (*Willardia mexicana*), mauto (*Lysimoma divaricata*), tepeguaje (*L. watsonii*), and purple tabebuia.

An exceptional case is the magnificent and endangered baldcypress "sabino" gallery forest along the Río Cuchujaqui, and other river systems, where water is always available. This association of willow-baldcypress is normally found between 200 and 400 m at inland locations.

2. Mid-elevation Associations: Above 500 m elevation, riparian systems consist mainly of cottonwood and/or willow associations, with Fremont cottonwood (*Populus fremontii*), bondpland willow, Goodding willow, and coyote willow (*Salix exigua*). They are fast-growing deciduous communities that develop on flood plains as gallery forests in warm-temperature zones where surface water flow reliably occurs at least during winter-spring months, when these species leaf, set seed, and germinate. The canopy can be up to 30 m in height, with an open understory in mature stands, or populated by thickets of young cottonwood or willow depending upon stage and grazing intensity. Mulefat is an abundant secondary species present as part of the understory in most cases. The associations in these instances are: a) cottonwood-willow found between 520 and 1250 m at sites in Sonora, Bavispe, Sahuairpa, Moctezuma, Cocóspera, and Altar Rivers; b) cottonwood-mesquite found between 550 and 1300 m at Sonora, Cocóspera, Santa Cruz, Altar, and Moctezuma Rivers; c) pure willow stands, as in the cases of sites at Sahuaripa, Mátape, and Altar Rivers between 350 and 850 m, or d) pure cottonwood stands found over 500 m and below 1200 m at Sonora, San Miguel, Moctezuma, Cocóspera, Santa Cruz, San Ignacio, Altar, and Moctezuma Rivers.

3. Highland Associations: Sycamores (*Platanus wrightii*) appear higher in elevation (1200 – 1450 m) and constitute a different type of riparian system. They are normally associated with oak woodlands and grasslands and, at least in Sonora, are distributed as relatively small and discontinuous patches on the watercourses. They are described as "Riparian Deciduous Woodlands" by Brown (Brown 1994), and can be found, for example, at higher areas of the Moctezuma and Sonora Rivers.

Higher in the mountain areas above 1,500 m, there are characteristic riparian elements of highland vegetation, but they do not establish riparian stands per se. The species include

Arizona alder (*Alnus oblongifolia*), willow (*Salix* sp.), narrowleaf cottonwood (*Populus angustifolia*), quaking aspen (*Populus tremuloides*), other alder species (*Acer* sp.), as well as shrubby species of elder (*Sambucus* sp.), dogwood (*Cornus* sp.), and hawthorn (*Crataegus* sp.). The lack of perennial streams that could maintain continuous corridors at these higher elevations in the state of Sonora is the reason that these riparian elements appear as isolated individuals or small patches in the most humid situations; they are normally associated with pine and oak trees.

B. <u>General observations on the state of riparian habitats in central Sonora</u>

Sonora is one of the driest areas in Mexico, and rivers are not as important in terms of their water runoff as in other areas. Thus, water management is basically directed to provide basic human needs, and to support agricultural and livestock operations. Dams of considerable dimensions were constructed between 1943 and 1955 to contain the waters of the Mayo, Yaqui, and Sonora Rivers, and these have supported the increasing needs of the largest cities and the productivity of important agricultural districts located in the lowlands at the western section of the state. During the 1980's, a water crisis was already evident, and agricultural productivity decreased at the same time that the most important human settlements increased in size, being most extreme in the State capital of Hermosillo, which increased by a factor of 25 in a period of only 50 years. The dam "Abelardo Rodríguez Luján" constructed in 1948 to provide water to Hermosillo is dry at the present, and sedimentation processes have limited its capacity. Therefore, inhabitants of Hermosillo depend primarily on underground water and are considering the construction of a desalinization plant at Bahía Kino, 68 miles west of Hermosillo. In contrast, human populations in the "sierras" have maintained low growth rates for a long time, and human land-use patterns have remained as basic as they have been for a long period of time.

Development of water control structures in the rivers flowing form the "sierras" in central Sonora are limited, and the hydrology has been modified in just a few sectors. The maintenance of the natural flooding regimes along the Sonora, Moctezuma, and Sahiaripa has allowed riparian vegetation to persist in very good condition in some areas. Saltcedar trees can be found along the river corridors, but they are present only as isolated individuals, and never as an invasive species, as tends to occur in most managed systems of southwestern United States.

Livestock production is probably the most important agent of human influence in central Sonora. Cattle ranches encompass large expanses, and grazing could be defined as extensive in the area of the “sierras”. Because of the topography and the aridity that characterize these areas, ranchers make very efficient use of springs, temporal “aguajes” (natural pools filled with rain water), and “temporales” (small dam-type structures in side canyons). Water yields of these temporal sources vary greatly according to the timing and the amount of rainfall. Then, during dry years, farm animals are more dependent on river water, and the effects on streams are more evident in riparian vegetation.
Local riparian corridors in central Sonora show strong biological variation and striking differences can occur within very short distances. For example, in some areas, running water (as well as most vegetation) disappears and comes again to the surface a few kilometers downstream. In other situations, runoff over constricted sections impedes the establishment of riparian plants, as occur in canyons where riverbeds are comprised primarily of gross sand and stones. This is one of the reasons that riparian vegetation occurs in fragmented stands along the rivers of Sonora.

Human use has frequently modified positively the structure and maintenance of riparian corridors. Riparian tree species are periodically cut down to clear the land for agricultural proposes, construction, or as fuel. In many areas, agricultural practices take advantage of wide floodplains by continually changing the pattern of land use due to temporal water channelization. This results in the establishment of new patches of riparian trees that are not necessarily close to the original river course. The use of riparian trees as support for fences also results in the establishment of shelterbelts and hedgerows. These are examples of management actions that have an important positive influence on animal communities at the local level.

Traditional management of riparian communities in Sonora

Floodplain farming in Sonora is limited by one important variable: the availability of arable land near water. In Sonora, both water and land resources are scarce: "…*wherever more than two or three hundred acres are in cultivation, there is invariably a small nucleated oasis-pueblo. They are strung out like beads along the Rio San Miguel*" (Dubier 1970, cited by Nabhan & Sheridan 1977). In fact the distribution of towns devoted mainly to agriculture and livestock correspond with the establishment of early Spanish missions along the most important rivers, as it was the case of the San Miguel River (Figure 14). The historical record of towns along river systems in Sonora shows that during the past century many farming communities along the Sonora, Moctezuma, Yaqui, and Mayo Rivers shrank and eventually disappeared as a consequence of the lands being washed away by intense floods, as shown by the records of the Historical Archives of Localities for the municipalities crossed by the above mentioned rivers (INEGI 2006). However, some other settlements have prospered and maintained stable agrosystems in the floodplains of the same rivers for at least three centuries. One of the main reasons is that traditional management makes use of riparian tree species for the creation of what are called "living fencerows," which are made primarily from cottonwood and willows. This traditional management was found to be a normal practice at Bámori, Térapa, Cajón de Onapa, Baviácora, and Aconchi.

Floodplain farming has not changed much since Spanish missionization of the area between the 1630's and 1640's. The limited supply of water and arable land has restricted the development of modern industrial agriculture. Most farmers work communally and have a basic subsistence pattern: they cultivate corn, legumes, yams, "chile verde", squashes, and other vegetables for family consumption, and barley, wheat, or alfalfa for their livestock. Irrigation is done by means of channels derived from the river leading from earth and stick diversion weirs. In contrast, agriculture in the coastal plain of Sonora is highly mechanized, and depends to a great extent on underground water and wells, as well as on agrochemicals and fertilizers. This is the predominant form of agriculture in districts near the largest cities such as Hermosillo, Ciudad Obregón, Navojoa, and Caborca.

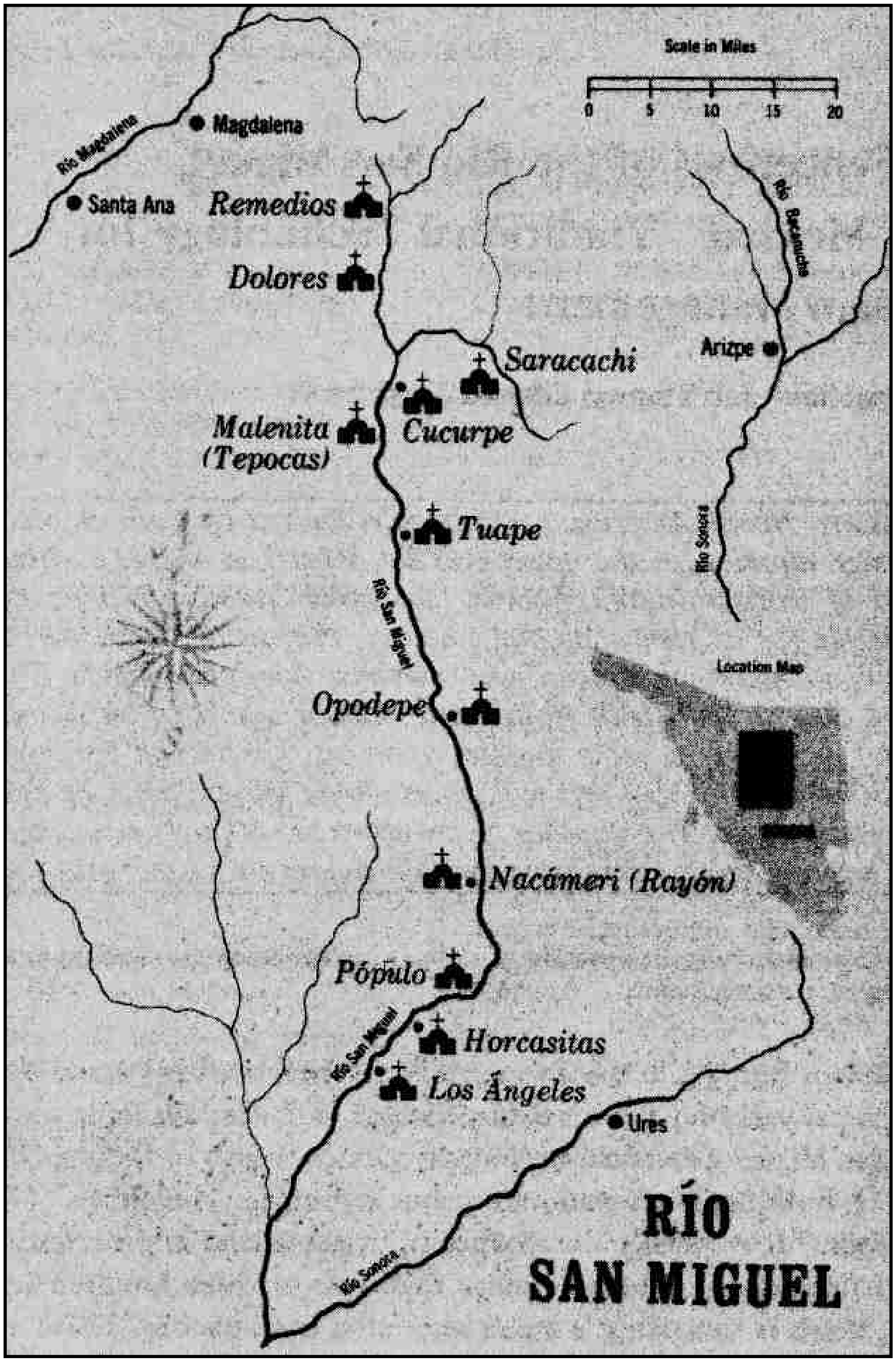

Figure 14. Map of the San Miguel River in Sonora, Mexico, showing the sites where early Spanish Missions were established. (Cartography by D. Bufkin. Source: Nabhan & Sheridan 1977).

With few exceptions, permanent flood control waterworks are absent along most rivers of central Sonora, and the runoff from heavy rains can cause sudden strong changes in the river channel and the stream vegetation. The “living fencerows” described earlier retard channel cutting, limit erosion, and trap floodwater sediments. In this way, local farmers of San Miguel and other towns along the Sonora, Moctezuma, and Sahuaripa Rivers protect themselves from erosion, and preserve, extend, and fertilize their floodplain fields. The material used for the fencerows is obtained from riparian vegetation of the floodplain. Cuttings of cottonwoods and willows, both fast-growing species, are planted sometime during the winter months (between November and February) when they can root and grow; after two to three years, those cuttings are pruned for additional fencerows (Nabhan & Sheridan 1977). Basically this old technique has been “revived” as a restoration tool mostly in tropical areas because the fencerows provide shade and improve local microclimatic conditions in areas where fast-growing trees can be maintained and are useful for the protection of streams and/or agricultural fields (Zahawi 2005).

Another protective measure used in riparian areas, especially in relation to longed-lived plantations near unconstrained rivers (such as pecan orchards at the town of Unamichi at Sonora River), local inhabitants make use of big logs tied to fixed structures at the edge of the river to diminish the runoff erosive force on the river banks, especially in places where runoff could be very strong after occasional heavy rainfall in the mountains. This measure has emulated the effect of log steps formed by fallen trees in natural unmanaged streams, and it helps to dissipate the current energy and velocity, and allows other organic material to form deposits and promote the development of soil and the stabilization of the river channel (Heede 1985).

Final Remarks

The widespread modification of river and riparian ecosystems has created an urgent need for a better understanding of their ecological effects and the development of methods to restore or better manage these highly modified ecosystems. The development of principles to guide in the restoration of aquatic ecosystems, the determination of general principles to maintain biodiversity, and the exploration of the effects of modified hydrologic flow patterns on their ecological processes, are all of the highest priorities (Naiman *et al.* 1995). The response of wildlife populations to increased vegetative cover and structure is another reason. The maintenance of wide riparian forest corridors would allow the presence of both edge species and other species with more specialized habitat requirements (Keller *et al.* 1993).

From a conservation perspective, it appears that agricultural conversion of riparian forest in central Sonora is especially evident along perennial and intermittent reaches of mid-sized rivers within relatively broad and unconfined valley settings. In such places, agricultural clearing encroaches on the active channel of the river, resulting in narrow and discontinuous bands of riparian trees between the channel and the field, leaving little room for the recruitment of new individuals. In some cases, a single row of cottonwood or willow trees separates the channel from the field edges. This, in essence, is a substitute for the natural recruitment process and maintains limited vertical structural diversity. In contrast, wider and more continuous tracts of riparian forests exist between the active channel and agricultural fields on the Sonora River near Baviácora. This may relate to the fact that the Sonora River here is a larger river and a large buffer of forest is left by the farmers to protect fields from floods. These larger forest buffers provide superior habitat for wildlife. Wider riparian forest buffers along some of the smaller rivers in the state could be encouraged as a way of protecting fields from floods while providing improved wildlife habitat (Mesta *et al.* 2006). Fencing of critical areas should be stressed, restricting the free movement of cattle along the streams or back rivers, and as much as possible, food and water should be provided as far as possible from the river channels.

Traditional management of riparian areas in Sonora, although not widely applied for reasons related to economic gains associated with more rigid and more highly mechanized agricultural practices, suggests that similar methods could be used in restoration projects to a much wider extent. When dealing with cottonwood, willow, or other local species (especially the ones with fast growing rates), the creation of windbreaks, hedgerows, or any other kind of corridor along the river channel would be beneficial for the associated biological communities (Farley *et al.* 1994, Twedt *et al.* 2002, Twedt 2006), and would support the protection of both the river system and adjacent agricultural areas.

Management strategies that recognize all resource values must be designed to maintain and restore the integrity of riparian ecosystems (Kaufmann & Krueger 1984). These ecosystems are the most critical zones for multiple-use planning and offer a significant challenge for proper management practices. Despite all anthropogenic needs and issues, we must take into consideration the protection of stream banks and vegetation from multiple disturbance factors in order to improve the potential of river systems to enhance wildlife and maintain other key ecological processes.

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Appendix A

AVIFAUNA OF SONORA, MEXICO

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Abstract. This appendix represents a revision and update of the bird species recorded in the State of Sonora, Mexico. The revision included published records of 89 papers and reports, 16,008 specimens deposited in zoological museums, and more than 21,700 personal observational and banding records. A database with more than 48,500 records was compiled incorporating information from 1849 to 2006. The avifauna of Sonora includes 533 species belonging to 71 families and 20 orders, with 223 all-year residents, 46 summer residents, 214 long-distance migrants, and 50 partial migrants. Museum specimens not considered previously and my own data added nine species to the number reported by Russell and Monson in 1998, and allowed me to discuss the status of other species for the state. Twenty-nine of the species are of concern at the global level according to the Red list of Threatened Species of the IUCN, 288 are listed in the Neotropical Migratory Bird Conservation Act in the United States, and 63 are included in Norma Oficial Mexicana NOM-059-ECOL-2001.

Resumen. Este trabajo representa una revisión y actualización de la avifauna para el Estado de Sonora, México. La revisión incluyó registros de 89 artículos y reportes, 16,008 especimenes depositados en colecciones zoológicas de museos, y más de 21,700 registros corresponden a observaciones y datos de anillamiento personales. Una base de datos de más de 48,500 casos fue recopilada incorporando información que abarca de 1849 a 2006. La avifauna de Sonora incluye un total de 533 especies pertenecientes a 71 familias y 20 órdenes, con 223 especies residentes, 46 residentes de verano, 214 migratorias de larga distancia y 50 migratorias parciales. Especimenes de museos no considerados previamente y datos personales adicionaron nueve especies al número reportado por Russell y Monson en 1998, y permitieron la discusión del estatus de otras especies en el Estado. Veintinueve especies están en riesgo a nivel global de acuerdo a la Lista Roja de las Especies Amenazadas de la IUCN, 288 están incluidas en el Acta de Conservación de Aves Migratorias Neotropicales de los Estados Unidos y 63 están incluidas en la Norma Oficial Mexicana NOM-059-ECOL-2001.

Introduction

"Biological diversity or Biodiversity refers to the variety of life forms on earth: the different plants, animals and microorganisms, the genes they contain, and the ecosystems they form" (Australian Museum 2005). This variety is the result of biological processes occurring over long time periods, which are affected by the influence of human populations on natural environments. Biodiversity increases when new genetic variation is produced, a new species is formed or a different ecosystem is shaped, and decreases when the genetic variation within a species is reduced, a species becomes extinct, or an ecosystem complex vanishes. Furthermore, the loss of biological diversity is recognized as one of the most serious environmental problems humankind is facing.

In order to describe diversity, biologists have amassed important collections of biological material that form essential depositories of knowledge for describing the diversity of life on earth. The basis of much knowledge comes from specimens accessioned in museum collections. During the period when the description of new forms was the primary objective of many naturalists and museums, expeditions were directed to explore new and distant areas, resulting in many specimens collected and new species described.

Knowledge on local and regional diversity is essential for management of biological resources, including the promotion of species conservation (Bojórquez-Tapia *et al.* 1994). For these reasons, listings of species or "biological inventories" are essential to understand the diversity of living organisms in a given geographical area, their history, function, management, and conservation.

In practical terms, the most common means of describing and assessing biodiversity is through collections. Birds constitute the best known group among the vertebrates, and they have also been used as models in many areas of biological research. Museum specimens, observation, and banding activities are the sources of information for avian systematics, evolution, biogeography, ecology, behavior, and conservation. Avian species are sensitive to changes in their surroundings and can be used as indicators that reflect environmental transformations through changes in their distribution and temporal differences in abundances (Hutto 1998).

The Neartic and Neotropical realms of North America meet in Mexico. Combined with a complex geologic history, rough terrain, and an elevation range from sea level to over 5600m, a variety of environmental conditions are found in Mexico. This variety together with biological and historical processes have fostered high levels of *in situ* differentiation at the level of endemic species, which enhance the exceptional biological diversity found in Mexico (CONABIO 2000). As a consequence of such processes, Mexico is recognized as one of the megadiverse regions of the world (Mittermeier 1988). Terrestrial vertebrates including amphibians, reptiles, birds, and mammals are among the best known biological groups in Mexico and they include a total of 2,494 species, 42.5% of which are birds (Flores-Villela & Navarro-Sigüenza 1993).

Sonora, the northwestern state of mainland Mexico, is where the northern border of the tropics meets the southern limits of the temperate region, allowing a rich mixture of animal and plant species from both Neartic and Neotropical origins. It is a region of extremes; from sea level the terrain goes up to more than 2630m, an elevation gradient with extreme variation in temperature and precipitation that supports a variety of vegetation communities. In most of Sonora, climate is dry, with high temperatures and scarce precipitation. However, the Sierra Madre Occidental modifies this pattern by having less extreme temperatures and more abundant rainfall. With the exception of the San Luis Colorado section in the northern part of the state (where the Mediterranean climate affects the amount of winter rain), the Sonoran Desert is characterized by a bimodal precipitation pattern, with most of the precipitation concentrated in the summer and lower levels during the winter months. In general, climate varies during the year from hot and dry to moist and cold, with annual precipitation varying from almost zero to beyond 100 cm (García 1973).

Sonora includes a variety of environments including deserts, grasslands, rocky mountains, barren and dry or covered by forest and divided by large canyons, and a coastline with sandy beaches and rocky cliffs. The Gran Desierto de Altar in the northwest is the most xeric region, with sand dunes and sparse vegetation. In the western section, the area is dry and semidry, with planes, bajadas or outwash plains, rolling hills, and sierras, with xeric vegetative communities such as microphyllous desert scrub, sarcocaulescent scrub, and mesquite formations. The foothills of Sierra Madre Occidental lie in the central section of Sonora, and are covered by subtropical scrub and tropical deciduous forest. Finally, the mixed-conifer forests and oak woodlands constitute the vegetation on the higher mountains of the eastern portion. The river valleys are bordered by gallery woodlands and irrigated fields.

Within the State of Sonora, four physiographic provinces have been defined: The Sonoran Desert (Llanura Sonorense) in the Northwest and West, the Sierra Madre Occidental in the East, the Northern Sierras and Plains (Sierras y Llanuras del Norte) in the central North, and the Pacific Coastal Plains (Llanura Costera del Pacífico) in the South (INEGI 2000) (Figure 1, page 5).

Considering the environmental diversity within the state of Sonora and the importance of birds as a group, I deemed it important to synthesize the research that has been conducted to the present in order to establish a framework of the ornithological knowledge for current and future studies. My objectives were to (a) compile a database on the bird records of Sonora, (b) describe the history of the ornithological research in the state, and (c) update the inventory of the avifauna for Sonora.

Methods

I used three sources of information: (a) data on bird specimens deposited in zoological museums throughout the world and indexed in the *Atlas de las Aves de México* database (Navarro-Siguenza *et al.* 2003) as well as additional data from on- line collection catalog

(UNAM 1999, UABC 2003, YPM 2006, CAS 2006, FMNH 2006, MCZHU 2006, MVZ-Berkeley 2006); (b) a comprehensive review of the ornithological literature that referred directly or indirectly to Sonoran bird records; and (c) data obtained personally through field work in Sonora, involving observational records and banded individuals (January, February and November 2004-2006). The information was compiled and managed by using Microsoft® Office Access 2003 and included five tables: Specimens, AOU Taxonomy listings, Localities, Sources, and Authors. Although this compilation represents a substantial effort to update the inventory of birds of Sonora, there is still information on observations and banding activities that was unavailable and, therefore, not included.

Results

A. Database on bird records from Sonora

The database I compiled consisted of 48,572 records of 533 bird species, of 71 families and 20 orders. This information covers a period of 155 years (from 1849 to 2006) from 1653 localities in Sonora.

A.1. Bird Specimens. Thirty-three percent of the records (16,008) are specimens of 426 species from 810 localities, deposited in 41 institutions, more than half of which were museums within the United States. More than 53% of the specimens were concentrated in three institutions: the Museum of Comparative Zoology at Harvard University, the University of California in Los Angeles, and the Louisiana State University Museum of Zoology (Table A1). Some specimens were located in collections in Canada, England, Netherlands, Germany, and Russia. Only 224 specimens (1.4%) were located in Mexican institutions.

Specimens were collected between 1859 and 2001. When plotting the number of specimens by periods of ten years, two phases of intense collection activity are apparent (Figure A1). During the first period from 1882 to 1891, the most important contribution was by Marston Abbott Frazar who collected mainly in the region of Alamos, and John

Table A1. Number of Sonoran bird specimens in research institutions and museums.

(Source: Atlas de las Aves de México database)

Institution	Number of Specimens
Museum of Comparative Zoology, Harvard University, Cambridge, MA	4,109
University of California, Los Angeles, CA	3,258
Louisiana State University, Museum of Zoology, Baton Rouge, Louisiana	1,049
University of Kansas, Natural History Museum, Lawrence , KS	743
San Diego Natural History Museum, San Diego, CA	700
Museum of Vertebrate Zoology, Berkley, CA	659
University of Michigan, Museum of Zoology, Detroit, MI	651
Moore Laboratory of Zoology, Occidental College, Los Angeles, CA	639
Western Foundation of Vertebrate Zoology, Camarillo, CA	496
University of Arizona	483
Field Museum of Natural History, Chicago, Illinois	466
Delaware Museum of Natural History, Greenville, DE	460
United States National Museum of Natural History, Washington, DC	437
British Museum (Natural History), London	311
Los Angeles County Museum of Natural History, Los Angeles, CA	263
American Museum of Natural History, New York, NY	239
Southwestern College, Chula Vista, CA	197
Museo de Zoología, Facultad de Ciencias – UNAM, México, D.F.	125
Canadian Museum of Nature, Ottawa, Ontario	120
Carnegie Museum of Natural History, Pittsburgh, PA	99
California Academy of Sciences, San Francisco	81
Royal Ontario Museum, Toronto	78
Bell Museum of Natural History, University of Minnesota, St. Paul, MN	70
Cornell University Museum of Vertebrates, Ithaca, New York	62
Museo de las Aves de México, Saltillo, México	58
Academy of Natural Sciences of Philadelphia, PA	48
Universidad Autónoma de Baja California, Ensenada, México	26
Peabody Museum, Yale University, New Haven, Connecticut	20
Sistema Nacional de Información Sobre Biodiversidad, México	13
Museum Für Naturkunde, Humboldt-Universität Zu Berlin, Germany	12
Natuurhistorische Museum, Linden, Netherlands	9
Florida Museum of Natural History, Gainesville, FL	5
Burke Museum, University of Washington, Seattle, WA	5
Denver Museum of Natural History, Denver, CO	4
Zoologische Forschungsinstitut und Museum Alexander Koenig, Germany	4
Übersee – Museum Bremen, Germany	3
Instituto de Historia Natural y Ecología, Chiapas, México	2
Senckenberg Naturmuseum, Frankfurt, Germany	1
University of British Columbia, Museum of Zoology, Vancouver	1
Zoological Museum, Moscow State University	1
Museum Mensch Und Natur, Munich	1

C. Cahoon in the Sierras around Oposura (presently Moctezuma). Both collectors worked for William Brewster, and their specimens were deposited in the Museum of Comparative Zoology. During the Mexican civil war (1911 - 1921) only 23 specimens were collected. At that time, scientific collecting was suspended for security reasons. During the ten years (1922 to 1931) following the Mexican Revolution, social conditions improved and many important collections were made by John T. Wright in the Colorado River delta and the mountains in the southern portion of the state near Guirocoba. Other important collectors in Sonora were Wilmot W. Brown, Jr., Laurence M. Huey, Chester C. Lamb, Adrian Joseph van Rossem, William J. Sheffler, and Allan R. Phillips.

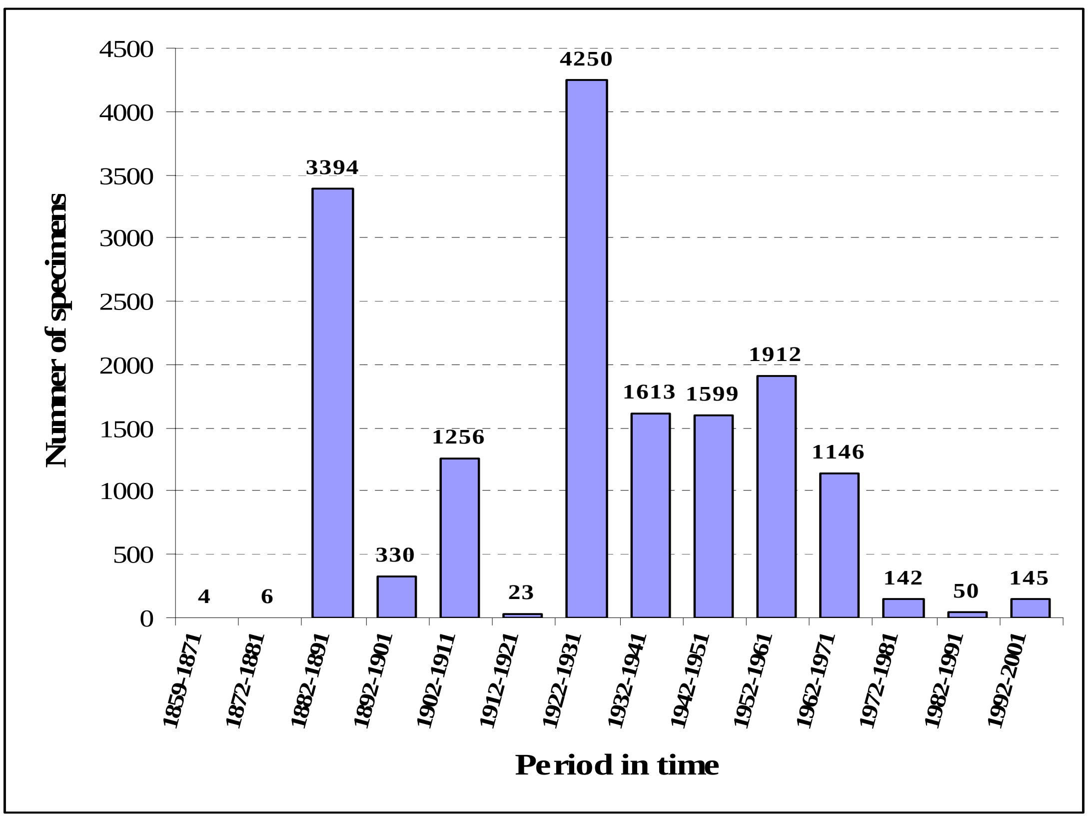

Figure A1. Number of specimens collected in Sonora between 1859 and 2001, by ten-year periods.

A.2. Ornithological literature review. Publications between 1874 and 2005 (89) contributed 8,750 records (18%) (Table A2). Most records were in ornithological journals: such as The Auk (13), The Condor (12), American Birds (7), Wilson Bulletin (6), Western Birds (4), Journal of Raptor Research (2), Journal of Field Ornithology (1), Journal of Wildlife Management (1), Pacific Coast Avifauna (1), The Euphonia (1), Studies in Avian Biology (1), Colonial Waterbirds (1), and Continental Birdlife (1). Others appeared in journals of Natural History Societies as the Transactions of the San Diego Natural History Society (16), Proceedings of the U.S. National Museum (2), Memoirs of the Boston Society of Natural History (1), Proceedings of the Biological Society of Washington (1). A few were part of technical reports, and university theses. The two largest contributions were from Occasional Papers of the Museum of the Louisiana State University (van Rossem 1945), and the second as a book (Russell & Monson 1998). Only three appeared in Mexican scientific journals (Acta Zoológica Mexicana and Anales del Instituto de Biología, UNAM). Due to the way information is presented in Russell and Monson's book, I have included only those records mentioned explicitly in the text.

These publications include 527 species from 954 localities. Some published data refer to collected specimens without making reference to collectors, numbers, or institutions. Van Rossem's work includes information on most specimens collected prior to 1945. I added into the database only those records for which I had locations not reported previously by museum specimens. For this reason, there might be some redundancy with the information from museum specimens.

A.3. Data from field work. During the months of January and February 2004, 2005, and 2006, and November 2004 and 2005, monitoring activities were carried out in 145 localities in Sonora. Through point counts, 305 species were recorded from a total of 21,767 observations. Intensive capture and banding were conducted at six localities in riparian vegetation in central Sonora (Baviácora and Aconchi at Sonora River, Térapa and Jécori at Moctezuma River, and Cajón de Onapa and Bámori at Sahuaripa River);

Table A2. References to the Birds of Sonora from which data were obtained.

Periods	References
Prior 1890	Lawrence 1874, Belding 1883, Stephens 1885, Brewster 1885, 1888a, and 1888b, Ridgway 1887b, Goss 1888
1891-1900	Allen 1893, Jouy 1894, Clark 1898
1901-1910	Stone and Rhoads 1905, Thayer and Bangs 1906
1911-1920	NONE
1921-1930	Bancroft 1927, van Rossem 1930, 1930a, 1930b, 1930e, 1930f, 1930h, 1930i, 1930k
1931-1940	van Rossem 1931b, 1932, 1933b, 1934a, 1935, Huey 1935, van Rossem and Hachisuka 1937a, 1937e, Moore 1938
1941-1950	Abbott 1941, Kenyon 1941, Sheffler and van Rossem 1944, van Rossem 1945, Neff 1947, Pitelka 1948
1951-1960	Phillips and Amadon 1952, Booth 1952, Vaurie 1953, Marshall 1957
1961-1970	Banks 1963, 1965, Zimmerman and Boettcher 1967
1971-1980	Smith and Jensen 1970, Short 1974, Alden and Mills 1974, Phillips 1975, Witzeman *et al.* 1976, DeWeese and Anderson 1976, May 1976, Harrison and Kiff 1977, Russell and Lamm 1978, Kaufman and Witzeman 1979
1981-1990	Landres and MacMahon 1980, 1983, Gallucci 1981, Terrill 1981, 1985, Clark 1984, Brown and Warren 1985, Terrill and Terrill 1986, Monson 1986, Williams 1987, Brown *et al.* 1987, Rising 1988, Brown 1988, Dunning Jr. 1988, Rodríguez-Estrella and Brown 1990a, 1990b, 1990c
1991-2000	Bates 1992a, 1992b, Howell 1993, Mellink and Palacios 1993, Robbins and Howell 1995, Howell and Robbins 1995, Palacios and Mellink 1995, 1996, Mellink *et. al* 1996, 1997, Russell and Monson 1998
2001-2006	Rojas-Soto et al 2002, Rodríguez-Estrella 2002, Flesh 2003, Hinojosa-Huerta et al. 2004, Zuria and Mellink 2005, Flesh and Hahn 2005, Duberstain et al. 2005, Flesh and Steidl 2006

2,047 individuals (4.2%) of 96 species were banded and released after collecting basic morphometric data.

B. Historic account of ornithological studies in Sonora, Mexico

Recording birds “south of the border” in Sonora has for a long time captivated many naturalists, scientists, and birdwatchers. They have been attracted by the diversity of avian communities with tropical and subtropical species that can be found at the northernmost extent of their distribution ranges, not that far south from the border with the United Sates. The islands and coastal areas of the Sea of Cortez, the “*terra incognita*” represented by extensive deserts adjacent to the southern border of the United States, isolated mountain ranges, the continuous highlands of the Sierra Madre Occidental, and the tropical and subtropical plant communities of southern Sonora, attracted many naturalists and collectors.

According to van Rossem (1945), the first known Sonoran specimen referr in the literature is the type for *Picolaptes bruneicapillus* Lafresnaye, 1835, which was likely obtained near Guaymas or Agiapambo. John Woodhouse Audubon mentions some birds in his narrative on a journey across Sonora from the Sierra Madre in…. to Altar and Sonoyta in 1849; however, his expedition obtained no specimens. Between 1851 and 1855, a few specimens were obtained near Guaymas, Nogales, and the Cañón de Guadalupe on the Mexico-US border. Four species collected by A.J. Grayson in Guaymas during the 1860’s are included in a report on the birds of western Mexico (Lawrence 1874), and Thomas Streets collected a few specimens in Sonora during April 1875 (van Rossem 1945).

Reports on the birds in Sonora increased in the last part of the 1800’s, when active collecting of specimens and description of taxonomic forms was the main objective of natural history museums. They hired scientific collectors including M. Abbot Frazar

(1887-1888) and John C. Cahoon (1887), and organized general expeditions to document the distribution of avifauna in the Guaymas, Alamos, and Cumpas-Moctezuma areas. As a result of this early work, several general lists were published without many specific details on localities or specimens, such as Belding's list of 46 species for Guaymas (Belding 1883), five marine species for the island of San Pedro Mártir (Goss 1888), 104 species from 18 Sonoran localities of the Lumholtz Archaeological Expedition during 1890-1892 (Allen 1893), 29 species collected in 1884 by F. Stephens between Sásabe and Puerto Lobos (Stephens 1885, Brewster 1885), an account of winter birds in the lower Colorado Valley by W.W. Price (1899), and a list of 67 breeding species for the Sierra de Antonez [Sierra de San Antonio] west of Arizpe by J.E. Thayer and O. Bangs (1906).

The islands of the Sea of Cortes and coastal locations were the focal points of some scientific expeditions and occasional visits between 1875 and 2000. In March and April 1911, C. H. Townsend, H. E. Anthony, P.I. Osburn, and P. Bartsh collected 804 specimens of 159 species, when the U.S. Fisheries Steamer "Albatross" visited the Baja California Peninsula, the Sea of Cortes, and its islands. Thirty-two species were obtained or observed in Sonora at Tiburon and San Esteban Islands, and Guaymas). Tiburon Island was visited again in May 1930 by Griffin Bancroft, and between December 1931 and January 1932 by A.W. Anthony and A.J. van Rossem. All their notes and records of specimens are included in a report on the avifauna of these island by A. J. van Rossem (1932), that totals 81 species. Later on, Charles Vaurie spent some days on Tiburon Island during July 1952 and added six species to van Rossem's list (Vaurie 1953). Laurence M. Huey spent the month of February 1934 in Puerto Peñasco and recorded 75 species (Huey 1935). Clinton G. Abbott visited Guaymas in April 1940 and published observations on 23 aquatic species (Abbott 1941).

Between 15 March and 26 April 1962, the San Diego Natural History Museum lead the "Belvedere" Expedition with the objective of exploring 32 islands of the Gulf of California (Lindsay 1962). Richard C. Banks recorded a total of 36 species on Tiburón, San Pedro Mártir, and San Esteban islands (Banks 1963). Rojas-Soto *et al.* surveyed Tiburon island in February 2000, and listed 137 species resulting from a review of literature and specimens deposited in museums; 41 species were new additions to the avifauna of the island (Rojas-Soto *et al.* 2002).

Collections in mainland Sonora were initiated by John C. Cahoon, who worked for William Brewster in 1887. His important collections include specimens obtained in the area of Cumpas, Oposura (now Moctezuma), and Granados. Frazar M. Abbott made extensive collections for William Brewster in 1888, working mostly in the south (Alamos, Mina Abundancia [San Antonio, NW Alamos], and Hacienda San Rafael [NE Alamos]).

John T. Wright worked continuously for Mr. Griffing Bancroft as a collector from 1928 to 1930; information on more than 3,550 specimens, as well as others collected by W. Leon Dawson, F. Stephens, G. Bancroft, A. J. van Rossem, and A. W. Anthony, were included in a report of the landbirds of Sonora, the first detailed account for the state that listed 205 species (van Rossem 1930g).

During the 1930's, A. J. van Rossem published a note on the addition of thirteen species new to Sonora (van Rossem 1933b). Chester C. Lamb, another professional collector, worked during 1932 and 1933 at El Alamo, Hermosillo, Rancho Costa Rica, San José de Guaymas, Ures, and Agiabampo, obtaining around 200 specimens. Between 1933 and 1937, Robert T. Moore made four trips to study the distribution of birds in southern Sonora, southwestern Chihuahua, and Sinaloa, covering from sea level to the high mountains in the Sierra Madre. From these expeditions he published information on unusual range extensions for thirteen selected species (Moore 1938).

Johnson A. Neff and George W. Paterson studied the distribution and abundance of the White-winged Dove in Sonora, between May and July 1942. Their notes on the general avifauna were published several years later, and included a short list of observations on 22 species (Neff 1947).

The first comprehensive, in-depth distributional and taxonomic account of the bird fauna of a mainland state in Mexico was A. J. van Rossem's monograph on the birds of Sonora (1945). This work was the result of a major effort in compiling information from museum specimens, observations, and previously published accounts. It included a distributional account for 407 species and a list of 37 species of unverified occurrence. Critical analysis allowed him to distinguish, in some cases, migration, breeding, and winter records. Later, two major comprehensive publications summarized the distribution of birds of Mexico (Friedmann *et al.* 1950, Miller *et al.* 1957). The treatment at the level of subspecies in these two publications is still used today.

Van Rossem (1945) included a section on new forms described at the level of species or subspecies based on specimens obtained in Sonora (Table A3). From a total of 111 forms described between 1835 and 1945, and one described later, at the present 46 are still considered as valid species or subspecies, 24 are considered synonyms, 41 have changed names as a result of changes in their taxonomic placement, the type specimen of *Cyanomia salvini* was found to be a hybrid between the Broad-bellied Hummingbird (*Cynanthus latirostris*) and Violet-crowned Hummingbird (*Amazilia violiceps*) (Brewster 1893, Graves 2003), and the type specimen for the Florence Hummingbird (*Saucerottia* [*Amazilia*] *florenceae*) –the only specimen known for the species), is uncertain and probably lost. Frank A. Pitelka reported on nine species recorded in several Sonoran locations during October and November 1946 (Pitelka 1948).

Allan R. Phillips and Dean Amadon studied the avifauna and collected specimens in the northwestern part of Sonora, visiting the areas of Altar, Caborca, Pitiquito, Sierra Carrizal (San Juan), and Sonoyta in October and November 1948; they report a list of 62 species (Phillips & Amadon 1952). The most important contribution to our knowledge of highland oak and pine-oak forest birds in northwestern Mexico was done by Joe T. Marshall between 1951 and 1955 in the mountain ranges of Arizona, New Mexico, and Sonora (Marshall 1957); he reported 137 species for 13 Sonoran "Sierras." Recently,

Table A3. Taxonomic forms (species and subspecies) described from specimens collected within the state of Sonora, Mexico. The table includes the original name, the valid name at the present or the indication for synonyms, the location of the specimen and the reference for the original description.

Described Form	Present Name	Locality	Reference
Ortalis wagleri griseiceps		Álamos	(van Rossem 1934b)
Callipepla elegans bensoni	*Callipepla douglasi bensoni*	18 mi. N Cumpas	(Ridgway 1887a)
Lophortyx gambeli pembertoni	*Callipepla gambeli pembertoni*	Tiburon Island	(van Rossem 1932)
Callipepla gambeli fulvipectus		Camóa, Río Mayo	(Nelson 1899a)
Colinus ridgwayi	*Colinus virginianus ridgwayi*	18 mi. SW Sásabe	(Brewster 1885)
Cyrtonyx montezumae morio	*Cyrtonyx montezumae mearnsi* Nelson **Synon.**	Guirocoba	(van Rossem 1942d)
Sula gossip	*Sula neuboxi* Milne-Edwards **Synon.**	San Pedro Mártir	(Goss 1888)
Sula brewsteri	*Sula leucogaster brewsteri*	San Pedro Mártir	(Goss 1888)
Phalacrocorax olivaceus chancho	*Phalacrocorax brasilianus chancho*	Tesia	(van Rossem & Hachisuka 1939a)
Ixobrichus exilis pullus		Bahía Tóbari	(van Rossem 1930a)
Heterocnus cabanisi fremitus	*Tigrisoma mexicanum fremitus*	Guirocoba	(van Rossem & Hachisuka 1937g)
Geranospiza nigra livens	*Geranospiza caerulescens livens*	Álamos	(Bangs & Penard 1921)
Asturina plagiata maxima	*Asturina nitida maxima*	San Javier	(van Rossem 1930c)
Buteo refescentior	*Buteo jamaicensis calurus* (Cassin) **Synon.**	Hermosillo	(Salvin & Godman 1900)
Polyborus cheriway ammophilus	*Caracara cheriway audubonii* (Cassin) **Synon.**	Tesia	(van Rossem 1931b)
Falco albigularis petrophilus	*Falco rufigularis petrophilus*	Guirocoba	(van Rossem & Hachisuka 1937b)
Rallus obsoletus rizophorae	*Rallus longirostris rizophorae*	Bahía Tóbari	(Dickey 1930)
Sterna albifrons mexicanus	*Sterna antillarum mexicana*	Bahía Tóbari	(van Rossem & Hachisuka 1937a)
Columba flavirostris restricta	*Patagioenas flavirostris flavirostris* Wagler **Synon.**	Tecoripa	(van Rossem 1930k)
Leptotila verreauxi Santiago	*Leptotila verreauxi angelica* Bangs & Penard **Synon.**	Guirocoba	(van Rossem & Hachisuka 1937e)
Aratinga holochlora brewsteri		Hacienda San Rafael	(Nelson 1928)
Ara militaris sheffleri		Guirocoba	(van Rossem & Hachisuka 1939b)

Table A3. Taxonomic forms described from specimens collected within the state of Sonora, Mexico. (Cont… 2).

Described Form	Present Name	Locality	Reference
Psittacula cyanopyga pallida	*Forpus cyanopygius pallidus*	Álamos	(Brewster 1889)
Amazona albifrons saltuensis		Guirocoba	(Nelson 1899b)
Amazona finschi woodi		Guirocoba	(Moore 1937a)
Piaya cayana extima		Guirocoba	(van Rossem 1930h)
Geococcyx velox melanchima		Guirocoba	(Moore 1934b)
Glaucidium brasilianum cactorum		Between Guaymas and Empalme	(van Rossem 1937b)
Amazilia violiceps conjunta	*Amazilia violiceps ellioti* (Berlepsch) **Synon.**	Álamos	(Griscom 1934)
Cyanomia salvini	Hibrid: *Cynanthus latirostris* X *Amazilia violiceps*	Nacozari	(Brewster 1893, Graves 2003)
Saucerottia florenceae	*Amazilia florenceae* (Uncertain status??)	Rancho Santa Bárbara	(van Rossem & Hachisuka 1938b)
Anthoscenus constantii surdus	*Heliomaster constantii pinicola* Gould **Synon.**	Álamos	(van Rossem 1934b)
Trogon elegans canescens		San Javier	(van Rossem 1934b)
Momotus mexicanus vanrossemi		Chinobampo	(Moore 1932a)
Chloroceryle americana leucosticte	*Chloroceryle americana hachisukai*	Rancho La Arizona	(van Rossem & Hachisuka 1938d)
Centurus uropygialis fuscescens	*Melanerpes uropygialis fuscescens*	Chinobampo	(van Rossem 1934b)
Centurus uropygialis tiburonensis	*Melanerpes uropygialis tiburonensis*	Tiburon Island	(van Rossem 1942c)
Piculus auricularis sonoriensis		Rancho Santa Bárbara	(van Rossem & Hachisuka 1937c)
Dryobates sclateri agnus	*Picoides scalaris sinaloensis* (Ridgwayi) **Synon.**	Camóa, Río Mayo	(Oberholser 1911)
Colaptes chrysoides tenebrosus		Ciudad Obregón	(van Rossem 1930b)
Ceophloeus lineatus obsoletus	*Dryocopus lineatus obsoletus*	Álamos	(van Rossem 1934c)
Phloeoceastes guatemalensis dorsofasciatus	*Campephilus guatemalensis dorsofasciatus*	Guirocoba	(Moore 1935)
Xiphorhynchus flavigaster tardus		Hacienda San Rafael	(Bangs & Peters 1928)
Lepidocolaptes leucogaster umbrosus		Between San José and Guirocoba	(Moore 1934a)

Table A3. Taxonomic forms described from specimens collected within the state of Sonora, Mexico. (Cont… 3).

Described Form	Present Name	Locality	Reference
Mitrephanes phaeocercus tenuirostris		Mountains near Oposura	(Brewster 1888b)
Pitangus sulphuratus palliates	*Pitangus sulphuratus derbianus* (Kaup) **Synon.**	Álamos	(van Rossem 1937a)
Myiozetetes similis primulus		Tesia	(van Rossem 1930k)
Myiarchus nuttingi vanrossemi	*Myarchus nuttingi inquietus* (Salvin & Godman) **Synon.**	El Gavilán, Río Sonora	(Phillips 1959)
Tyrannus crassirostris sequestrates	*Tyrannus crassirostris pompalis* Bangs & Peters **Synon.**	Rancho La Arizona	(van Rossem 1941c)
Tyrannus crassirostris pompalis		Álamos	(Bangs & Peters 1928)
Platypsaris aglaiae richmondi	*Pachyramphus aglaiae richmondi*	Rancho La Arizona	(van Rossem 1930j)
Tityra semifasciata hannumi	*Tityra semifasciata griseiceps* (Ridgway) **Synon.**	Cañón de San Francisco	(van Rossem & Hachisuka 1937d)
Vireo hypochryseus nitidus		Hacienda San Rafael	(van Rossem 1934b)
Vireo virescens hypoleucus	*Vireo olivaceus hypoleucus*	Cañón de San Francisco	(van Rossem & Hachisuka 1937h)
Calocitta colliei arguta		Chinobampo	(van Rossem 1942d)
Otocoris alpestris pallida	*Eremophila alpestris leucansiptila* (Oberholser) **Synon.**		(Dwight 1890)
Iridoprocne albilinea rhizophorae	*Tachycineta albilinea rhizophorae*	Bahía Tóbari	(van Rossem 1939a)
Stelgidopteryx ruficollis psammochrous	*Stelgidopteryx serripennis psammochrous*	Oposura = Moctezuma	(Griscom 1929)
Petrochelidon albifrons minima	*Hirundo rustica melanogaster* Swainson **Synon.**	Río Cuchujaqui	(van Rossem & Hachisuka 1938c)
Auruparus flaviceps fraterculus		Chinobampo	(van Rossem 1930i)
Psaltriparus plumbeus cecaumenorum	*Psaltriparus minimus cecaumenorum*	Mina La Chumata	(Thayer & Bangs 1906)
Psaltriparus minimus dimorphicus	*Psaltriparus minimus lloydi* (Sennett) **Synon.**	Rancho Santa Bárbara	(van Rossem & Hachisuka 1938a)
Picolaptes brunneicapillus	*Campylorhynchus brunneicapillus*	Guaymas	(Lafresnaye 1835)
Heleodytes brunneicapillus seri	*Campylorhynchus brunneicapillus seri*	Tiburon Island	(van Rossem 1932)
Catherpes mexicanus meliphonus	*Catherpes mexicanus mexicanus* (Swainson) **Synon.**	Álamos	(Oberholser 1930)

Table A3. Taxonomic forms described from specimens collected within the state of Sonora, Mexico. (Cont… 4).

Described Form	Present Name	Locality	Reference
Thryophilus sinaloa cinereus	*Thryothorus sinaloa cinereus*	Álamos	(Brewster 1889)
Pheugopedius felix sonorae	*Thryothorus felix sonorae*	Guirocoba	(van Rossem 1930f)
Troglodytes cahooni	*Troglodytes brunneicollis cahooni*	Mountains "near Oposura" = Moctezuma	(Brewster 1888a)
Polioptila caerulea gracilis		Rancho Santa Bárbara	(van Rossem & Hachisuka 1937f)
Polioptila melanura lucida		10 mi. N Guaymas	(van Rossem 1931a)
Polioptila melanura curtata		Tiburon Island	(van Rossem 1932)
Polioptila nigriceps restricta	*Polioptila albiloris restricta*	Álamos	(Brewster 1889)
Myadestes obscurus cinereus	*Myadestes occidentalis cinereus*	Mountains "near Álamos"	(Nelson 1899b)
Turdus assimilis calliphthongus		Baromico	(Moore 1937b)
Turdus rufopalliatus grisior		Guirocoba	(van Rossem 1934b)
Toxostoma bendirei candidum		10 mi. N Guaymas	(van Rossem 1942d)
Toxostoma bendirei rubricatum		Tecoripa	(van Rossem 1942d)
Harporhynchus curvirostris maculatus	*Toxostoma curvirostre maculatum*	Álamos	(Nelson 1900)
Toxostoma curvirostre insularum		San Esteban Island	(van Rossem 1930f)
Melanotis caerulescens effuticus	*Melanotis caerulescens caerulescens* (Swainson) **Synon.**	Hacienda San Rafael	(Bangs & Penard 1921)
Compsothlypis pulchra	*Parula pitiayumi pulchra*	Hacienda San Rafael	(Brewster 1889)
Dendroica aestiva sonorana	*Dendroica petechia sonorana*	Oposura = Moctezuma	(Brewster 1888a)
Dendroica erithachorides rhizophorae	*Dendroica petechia rhizophorae*	Bahía Tóbari	(van Rossem 1935)
Geothlypis trichas chryseola		Rancho La Arizona	(van Rossem 1930d)
Geothlypis trichas riparia	*Geothlypis trichas chryseola* van Rossem **Synon.**	Tesia	(van Rossem 1941b)
Euthlypis lachrymosa tephra	*Euthlypis lachrymosa* (Bonaparte) **Synon.**	Hacienda San Rafael	(Ridgway 1901b)
Basileuterus rufifrons caudatus		Álamos	(Nelson 1899b)

Table A3. Taxonomic forms described from specimens collected within the state of Sonora, Mexico. (Cont… 5).

Described Form	Present Name	Locality	Reference
Icteria virens tropicalis	*Icteria virens auricollis* (W.Deppe) **Synon.**	Tesia	(van Rossem 1939b)
Piranga flava zimmeri	*Piranga flava hepatica* (Swainson) **Synon.**	Chinobampo	(van Rossem 1942b)
Piranga erythrocephala candida		Hacienda San Rafael	(Griscom 1934)
Melozone rubricatum grisior	*Melozone kieneri grisior*	Hacienda San Rafael	(van Rossem 1933a)
Pipilo fuscus jamesi		Tiburon Island	(Townsend 1923)
Pipilo fuscus intermedius		Álamos	(Nelson 1899b)
Aimophila carpalis bangsi	*Aimophila carpalis*	Guirocoba	(Moore 1932b)
Peucaea aestivalis arizonae	*Aimophila botterii arizonae*	Nogales	(Ridgway 1873)
Aimophila ruficeps simulans		Mina La Abundancia	(van Rossem 1934b)
Peucaea megarhyncha	*Aimophila rufescens mcleodi*	Santa Ana	(Salvin & Godman 1889)
Aimophila rufescens antonensis		Mina La Chumata	(van Rossem 1942a)
Aimophila cahooni	*Aimophila rufescens mcleodi*	Mountains "near Oposura"	(Brewster 1888a)
Aimophila quinquiestriata septentrionalis		Hacienda San Rafael	(van Rossem 1934b)
Amphispiza bilineata pacifica		Álamos	(Nelson 1900)
Amphispiza bilineata cana		San Esteban Island	(van Rossem 1930e)
Passerculus sandwichensis atratus		Bahía Tóbari	(van Rossem 1930e)
Richmondena cardinalis townsendi	*Cardinalis cardinalis townsendi*	Tiburon Island	(van Rossem 1932)
Cardinalis cardinalis affinis		Álamos	(Nelson 1899b)
Passerina versicolor dickeyae		Chinobampo	(van Rossem 1934a)
Scaphidurus major nelsoni	*Quiscalus mexicanus nelsoni*	Álamos	(Ridgway 1901a)
Icterus wagleri castaneopectus		Mountains "near Oposura"	(Brewster 1888a)
Icterus cucullatus restrictus	*Icterus cucullatus nelsoni* Ridgway **Synon.**	Agiabampo	(van Rossem 1945)
Icterus pustulatus microstictus		Guaymas	(Griscom 1934)
Tangara elegantissima viscivora	*Euphonia elegantissima rileyi*	Cañón de San Francisco	(van Rossem 1941a)
Carpodacus mexicanus sonoriensis	*Carpodacus mexicanus ruberrimus* Ridgway **Synon.**	Álamos	Ridgway 1901b

some additional "sky islands" dominated by oak woodlands west of those described by Marshall were visited and described by Flesh and Hahn (2005).

During the 1960's, an analysis of biogeographical relationships of the avifauna of San Esteban Island, located approximately midway between mainland Mexico and the Baja Peninsula, was published by Richard C. Banks. He investigated the affinities of seven species and concluded they are associated with mainland Sonora (Banks 1969). A guide to finding birds in western Mexico directed primarily to birdwatchers was published in 1969 (Alden 1969). Between 1969 and 1973, L. A. May intensively studied the vertebrate fauna of the Gran Desierto de Altar, and recorded a list of 153 bird species (May 1976). The tropical deciduous forest near Alamos in southern Sonora was studied by Lester L. Short during July and August 1971. His detailed findings on 86 breeding species were included in a report on the relation between timing of nesting and the summer monsoon, as well as a short list of nine non-breeding birds he recorded (Short 1974). Stephen M. Russell and Donald W. Lamm provided information on the status of 65 bird species in Sonora, including information on 20 species new to the state (Russell & Lamm 1978). Thomas O. Clark and Dean Hendrickson obtained information on birds incidentally while studying fish in eastern Sonora in April and May 1978 and published an account on six noteworthy species: (Military macaw [*Ara militaris*], White-tailed Hawk [*Buteo albicaudatus*], Blue Mockingbird [*Melanotis caerulescens*], Tropical Parula [*Parula pitiayumi*], Flame-colored Tanager [*Piranga bidentata*], and Orchard Oriole (*Icterus spurius*] (Clark 1984).

Several papers have focused on individual species in Sonora: the Imperial Woodpecker (*Campephilus imperialis*) (Ridgway 1887b), for the Harlequin Duck (*Histrionicus histrionicus*) this was also the first record for Mexico (Kaufman & Witzeman 1979), an observation of White Wagtail (*Motacilla alba*) (Morlan 1981), the first Bald Eagle (*Haliaeetus leucocephalus*) nesting in Sonora (Brown *et al.* 1987), the status of the Piping Plover (*Charadrius melodus*) (Howell 1993) and Sandhill cranes (*Grus canadensis*) (Drewien *et al.* 1996) in Mexico with specific information on Sonoran records, the status of Thick-billed Parrot, Golden Eagle, and probably the last records of the Imperial Woodpecker in Sonora (Lammertink *et al.* 1996), and winter reports of Tundra Swans (*Cygnus columbianus*) near Ciudad Obregon and another unspecified location on the Sonora Coast (Drewien & Benning 1997).

Erick Mellink and Eduardo Palacios described the breeding waterbird communities in Bahía San Jorge, nearby islands, and Estero San Francisquito, at the extreme northwest of Sonora (Mellink & Palacios 1993); the bird communities of the estuaries San José and Tóbari in the southern coast of Sonora in 1994 (Palacios & Mellink 1995); and the breeding birds of Ciénega Santa Clara in the coast of northwestern Sonora (Mellink *et al.* 1996). Another study described the waterbird communities associated to the wetlands of the Colorado River Delta in the states of Sonora and Baja California Norte between September 1999 and August 2000, where 71 species were recorded, including the first and only record for the Black Rail (*Laterallus jamaicensis*) (Hinojosa-Huerta *et al.* 2004). The breeding avifauna of Isla Alcatraz (off Bahía Kino) was studied by Duberstein *et al.* (2005).

The only attempt to specifically study wintering avifauna in riparian vegetation in Sonora was carried out by Scott B. Terrill, and Ken and Gary Rosenberg. They visited two sites with cottonwood-willow riparian vegetation at “San Rafael” on the Sonora River near Ures), and at San Ignacio on the Magdalena River near Magdalena de Kino during the winter of 1979-1980 (Terrill 1981) and recorded 114 and 102 species in the Ures and Imuris areas, respectively.

There are several studies involving Sonoran birds with more specific research questions. For example, the organization of a breeding community of species in oak woodlands in Sierra Purica near Nacozari was described by Peter B. Landres and James A. MacMahon in March-May 1977 (Landres & MacMahon 1980). John M. Bates studied wintering territorial behavior and feeding ecology of Gray Vireos in the coastal deserts of Sonora in relation to Elephant Tree (*Bursera microphylla*) (Bates 1992). Iriana Zuria and Erick Mellink (2005) studied the relationship between the nesting chronology of the Least Tern

(*Sterna antillarum*) and near shore abundance of fish at La Purinera, in Bahía San Jorge, northwest Sonora.

Other studies in Sonora have been on raptors. They include estimation of density and habitat use along the rivers Bavispe and Yaqui (Rodríguez-Estrella & Brown 1990a, Rodríguez-Estrella & Brown 1990b, Rodríguez-Estrella & Brown 1990c), as well as reports on the status and productivity of Ospreys (*Pandion haliaetus*) along the coast of Sonora (Cartron 2000), and distributional information of the Golden Eagle (*Aquila chrysaetos*) (Rodríguez-Estrella 2002). Most recently a study of population trends of Ferruginous Pygmy-owls in northern Sonora documented an estimated 9.2% annual decline in abundance between 2000 and 2004 and the factors associated with this decline (Flesch & Steidl 2006).

Perhaps the most extensive study of any single species in Sonora was conducted by Aaron D. Flesch who documented distribution and abundance, and factors associated with habitat use and selection of Ferruginous Pygmy-owls along over 1,100 km of survey transects in 7 major vegetation communities throughout Sonora (Flesch 2003). This study was motivated by efforts to understand the ecology of pygmy-owls to aid recovery in neighboring Arizona where populations have declined to near extinction.

In "The Birds of Sonora" Russell and Monson (1998) describe the status and distribution of 525 bird species from mainland Sonora and incorporate information on seasonal patterns of occurrence, abundance, and habitats. They include 35 species considered hypothetical (those *"…reported with substantial documentation yet not supported by a specimen, a clearly diagnostic photograph, or extensive detailed information from multiple observers*"). They summarize and include van Rossem's information (van Rossem 1945), integrate unpublished information on specimens collected after van Rossem's publication, and add their own observations up to 1994. This is considered the second-most important effort in time to compile data on avifauna in Sonora. Unfortunately, the islands on the Gulf of California were not included.

C. <u>Species of Birds recorded for the State of Sonora</u>

The avifauna of Sonora includes 533 species, 50% of the 1,070 species recorded for Mexico (Howell & Webb 1995) of 71 families and 20 orders. Parulidae (wood-warblers), Anatidae (swans, geese, and ducks), Tyrannidae (tyrant flycatchers), Emberizidae (emberizid sparrows), Scolopacidae (Sandpipers, phalaropes, and allies), Laridae (gulls, terns, and skimmers), and Accipitridae (kites, eagles, and hawks) are the most numerous families (Table A4 and Appendix A1). According to the new information, the revision allowed the addition of Yellow-billed Loon, Masked Booby, Red-footed Booby, Black Rail, Eurasian Collared-Dove, and Orange-fronted Parakeet to the list of Sonoran species. I question the validity of specimens of California Quail and Artic Tern, which were supposedly obtained within the State, and suggest the change of status for the Northern Jacana considered by Russell and Monson as a hypothetical species, as well as the exclusion of Bridled and Sandwich Terns because of the weak evidence that sustain their consideration even as hypothetical species for the State.

According to seasonal status, 223 (41.8%) species are "permanent residents," 46 (8.6%) are "summer residents" that breed in the region but winter in other areas, and 214 (40.2%) are migratory species that winter in Sonora. After the northern breeding season, some populations retract from their summer ranges and join local resident populations in the southern sections of their range; I have defined this group of species as "Partial Migrants." The complexity of these migratory movements makes it impossible to distinguish migrant from resident populations without the use of banding or molecular techniques such as stable isotopes. Fifty species (9.4%) recorded in Sonora are "partial migrants"; most of these species belong to the group of "short-distance migrants" which includes members of Emberizidae, Icteridae (blackbirds and orioles), Parulidae, and Accipitridae, and other families. Other species are included in this group because they have distinctive migrant and resident populations, such as Mallard (*Anas p.platyrhynchos* and *A. p. diazi*, respectively), House Wren (*Troglodytes aedon parkmani* and the resident highland populations of *T. a. brunneicollis* and *T. a. cahooni*) and Yellow Warbler

Table A4. General summary of the bird species recorded for Sonora, Mexico, by taxonomic families.

FAMILY	SPECIES	SEASONAL STATUS				NMBCA	ENDEMISM			NOM-059-ECOL-2001				IUCN-2006			
		R	SR	PM	M		End	Qen	Sem	Edg	P	T	Ex	CR	EN	VU	NT
ANATIDAE	33	1	1	2	29	20	0	0	0	1	0	1	0	0	0	0	0
CRACIDAE	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
PHASIANIDAE	2	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
ODONTOPHORIDAE	5	5	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1
GAVIIDAE	4	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
PODICIPEDIDAE	6	1	0	0	5	4	0	0	0	0	1	0	0	0	0	0	0
PROCELLARIIDAE	3	1	0	0	2	0	0	0	1	1	0	0	0	0	0	0	2
HYDROBATIDAE	2	1	0	0	1	0	0	0	2	0	0	2	0	0	0	0	0
PHAETHONTIDAE	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
SULIDAE	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PELECANIDAE	2	1	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0
PHALACROCORACIDAE	3	3	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
ANHINGIDAE	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
FREGATIDAE	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ARDEIDAE	13	10	1	1	1	12	0	0	0	0	2	1	0	0	0	0	0
THRESKIORNITHIDAE	2	1	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0
CICONIIDAE	1	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0
CATHARTIDAE	2	1	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0
ACCIPITRIDAE	21	11	0	7	3	8	0	0	0	2	10	3	0	0	0	0	2
FALCONIDAE	8	5	0	2	1	4	0	0	0	0	1	2	0	0	0	0	0
RALLIDAE	7	3	0	1	3	6	0	0	0	0	2	0	0	0	0	0	1

FAMILY	SPECIES	SEASONAL STATUS				NMBCA	ENDEMISM			NOM-059-ECOL-2001				IUCN-2006			
		R	SR	PM	M		End	Qen	Sem	Edg	P	T	Ex	CR	EN	VU	NT
GRUIDAE	1	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
CHARADRIIDAE	7	2	0	0	5	7	0	0	0	1	0	1	0	0	0	1	1
HAEMATOPODIDAE	2	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
RECURVIROSTRIDAE	2	1	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0
JACANIDAE	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
SCOLOPACIDAE	28	1	0	0	27	26	0	0	0	0	0	0	0	0	0	0	1
LARIDAE	28	4	3	0	21	19	0	0	3	0	4	0	0	0	0	0	2
ALCIDAE	1	1	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0
COLUMBIDAE	10	10	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
PSITTACIDAE	7	4	3	0	0	0	4	0	0	2	2	2	0	0	1	2	0
CUCULIDAE	6	3	3	0	0	2	0	0	0	0	0	0	0	0	0	0	0
TYTONIDAE	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STRIGIDAE	15	11	2	0	2	3	1	0	2	0	1	1	0	0	0	0	1
CAPRIMULGIDAE	7	3	4	0	0	4	1	0	0	0	1	0	0	0	0	0	0
APODIDAE	5	2	2	0	1	3	1	0	0	0	1	0	0	0	0	0	0
TROCHILIDAE	16	8	4	0	4	11	0	0	8	0	0	0	0	0	0	0	0
TROGONIDAE	3	3	0	0	0	1	0	1	0	0	0	1	0	0	0	0	1
MOMOTIDAE	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
ALCEDINIDAE	2	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
PICIDAE	15	11	0	0	4	2	1	1	0	0	1	0	1	1	0	0	0
DENDROCOLAPTIDAE	2	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
TYRANNIDAE	34	15	7	3	9	24	0	1	4	0	0	0	0	0	0	0	1
LANIIDAE	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0

FAMILY	SPECIES	SEASONAL STATUS				NMBCA	ENDEMISM			NOM-059-ECOL-2001				IUCN-2006			
		R	SR	PM	M		End	Qen	Sem	Edg	P	T	Ex	CR	EN	VU	NT
VIREONIDAE	12	4	2	2	4	9	1	0	3	1	1	0	0	0	0	1	1
CORVIDAE	11	10	0	0	1	0	3	0	0	1	0	1	0	0	0	1	0
ALAUDIDAE	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HIRUNDINIDAE	9	1	4	2	2	7	0	0	1	0	1	0	0	0	0	0	0
PARIDAE	3	3	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
REMIZIDAE	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AEGITHALIDAE	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SITTIDAE	3	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
CERTHIIDAE	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TROGLODYTIDAE	11	7	0	1	3	3	3	0	0	0	0	0	0	0	0	0	0
CINCLIDAE	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
REGULIDAE	2	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0
SYLVIIDAE	3	2	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0
TURDIDAE	15	7	0	3	5	8	2	1	0	0	3	0	0	0	0	0	0
MIMIDAE	9	4	0	2	3	2	1	0	1	0	0	0	0	0	0	1	0
STURNIDAE	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MOTACILLIDAE	3	0	0	0	3	2	0	0	0	0	0	0	0	0	0	1	0
BOMBYCILLIDAE	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
PTILOGONATIDAE	2	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
PEUCEDRAMIDAE	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PARULIDAE	40	3	4	5	28	35	0	1	4	0	0	0	0	0	0	0	0
THRAUPIDAE	6	3	1	0	2	4	1	0	0	0	0	0	0	0	0	0	0
EMBERIZIDAE	37	13	0	8	16	17	3	2	3	0	0	0	0	0	0	0	2

FAMILY	SPECIES	SEASONAL STATUS				NMBCA	ENDEMISM			NOM-059-ECOL-2001				IUCN-2006			
		R	SR	PM	M		End	Qen	Sem	Edg	P	T	Ex	CR	EN	VU	NT
CARDINALIDAE	11	2	2	2	5	8	0	1	2	0	0	0	0	0	0	0	1
ICTERIDAE	17	4	1	7	5	12	0	1	3	0	0	0	0	0	0	0	0
FRINGILLIDAE	13	8	0	0	5	2	0	1	0	0	0	0	0	0	0	0	1
PASSERIDAE	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	**533**	**224**	**46**	**50**	**214**	**288**	**26**	**13**	**38**	**9**	**36**	**17**	**1**	**1**	**1**	**8**	**18**

SEASONAL STATUS: R= permanent resident, SR= summer resident, PM= partial migrant, M= migrant; **NMBCA:** species of interest for the Neotropical Migratory Bird Conservation Act; **ENDEMISM**: End= endemic species to Mexico, Qen= quasiendemic species to Mexico, Sem= semiendemic species to Mexico; **NOM-059-ECOL-2001**: Species included in the Norma Oficial Mexicana NOM-059-ECOL-2001: Edg= endangered, P= Protected, T= threatened, Ex= Extinct; **IUCN**: species included in the Red list of Threatened Species of the International Union for Conservation of Nature and Natural Resources: CR= critically endangered, EN= endangered, VU= vulnerable, NT= near threatened. For definitions refer to the methods section.

(*Dendroica petechia*) with the group "*aestiva*" as a widespread migrant, and the resident populations of the "*erithacoroides*" group inhabiting mangroves exclusively.

Some individuals of a few species of summer residents may remain on their breeding grounds during the winter. Individuals of Groove-billed Ani (*Crotophaga sulcirostris*) were recorded by the author in December and February of 2004 and 2005 in Alamos, Presa Chiculi, Presa Mocúzari, and Granados-Huásabas. An Elf Owl specimen (*Micrathene whitneyi*) at the British Museum was collected in November 1895, and subsequent observations indicate its presence from November to March (Moore 1938, Russell & Monson 1998). Museum specimens of the Lesser Nighthawk (*Chordeiles acutipennis*) were collected during November and January by Brown in 1905, Wright in 1929 and 1930, and Philips in 1952; Russell and Monson (1998) mention records for December 1982, and the author recorder the species in February 2004, all of them south of Hermosillo. A specimen of the Whip-poor-will (*Caprimulgus vociferus*) collected by Frazar in Alamos (February 1888) is referenced by van Rossem (1945) and Russell and Monson (1998); the author observed the species in Baviácora, Sonora River in January 2005. The Brown-crested Flycatcher (*Myiarchus tyrannulus*) was seen in January and February at Rancho Lo de Campa and Moctezuma by A. Moorhouse (Russell & Monson 1998), and were also recorded by the author and colleagues in central and southern Sonora. Summer Tanager (*Piranga rubra*) winters in Sonora (specimens collected by A. R. Phillips (Canadian Museum of Nature, without number) and observations during Christmas Bird Counts by Scott B. Terrill and Linda S. Terrill, Eduardo Gómez-Limón and the author support its presence during the winter). Incidental reports from local inhabitants also suggest the presence of the Military Macaw (*Ara militaris*), in Cajón de Onapa and other protected canyons north of Sahuaripa during the winter.

On the other hand, non-breeding individuals of wintering species might stay and live all-year long within Sonoran territories; the compiled information shows that at least 20 wintering species are regularly recorded during the summer, including some ducks, wading birds, gulls, terns, and a few landbirds (Appendix A1).

Seven aquatic species are considered accidental in Sonora, with just one or two known records extending farther north or south of their normal range. A total of 25 migratory species are vagrants and have been recorded in Sonora fewer than five times far from their normal distributional ranges; fifteen of them are wood-warblers that breed in the boreal region and southeastern United States, and typically winter in eastern Mexico and Central America (Kelly & Hutto 2005).

With respect to habits, 149 are aquatic species, 370 terrestrial, and 14 mostly aerial (swallows and swifts). Among the aquatic species, 67 are marine (five pelagic, 57 coastal, and five occasionally occupy interior freshwaters), 59 are essentially freshwater species (16 exclusively interior freshwater inhabitants, eight estuarine species, and 35 estuarine and interior species), and 23 species use indistinctly both, coastal and interior freshwaters. From the 370 terrestrial species, 29 are distributed at low elevations (generally below 1,100 m, under the lower limit of lowland oak woodlands), 69 are highland species (over elevations of 1,100 m), and 272 have a wider distribution on the elevation gradient. Twenty-eight of the highland species show elevational movements, moving down in elevation during the winter; these movements downslope could help them avoid cold weather, and/or to live temporally in places with greater abundance of food (Howell & Webb 1995); most of them have been recorded primarily in riparian environments.

The introduction of exotic species has resulted in the establishment of several species that, for the most part, are adapted to environments created by humans. Such is the case of the Rock Pigeon (*Columba livia*), the Eurasian Collared-Dove (*Streptopelia decaocto*) (E. Gómez-Limón, A. Flesh, and O. Hinojosa, pers. comm. 2006), the European Starling (*Sturnus vulgaris*), and the House Sparrow (*Passer domesticus*). Populations of the Ring-necked Pheasant (*Phasianus colchicus*) are also established in vicinity of the USA-Mexico border in the northwestern section of Sonora, probably as a consequence of releases in the United States related to hunting activities during the late 1960s and early 1970s (AZGFD 2006).

As some species are favored and become established in new areas, there are others that suffer the consequences of changes in their natural environments. The best known case is the extinct Imperial Woodpecker, which was an inhabitant of the highland coniferous forest and required big standing trees for feeding and nesting; their last known records from Sonora are observational records from Rancho Las Tinajas between February and May 1993 in the western slopes of the Sierra Madre Occidental (Lammertink *et al.* 1996). Although it is not known about other Sonoran species becoming extinct, there is evidence that indicates the extirpation of some. The Green Parakeet (*Aratinga holochlora*) is known only by the eight specimens collected by M.A. Frazar in May of 1888 from which the description of the subspecies *brewsteri* was based; they might have been part of the now extirpated northern population. Similar cases are the Bat Falcon (*Falco rufigularis*) which was recorded for the last time in 1949 and was extirpated by over collecting on the local population near Guirocoba, the Red-headed Tanager (*Piranga erythrocephala*) collected by M. Frazar in May 1888 and W.H. Burt in 1933, and the Vermiculated Screech-Owl (*Megascops guatemalae*) reported for the last time in 1958. All these species are characteristic of tropical or highland forests and most probably environmental alteration led to their local extirpation in the northern edge of their distribution. Other species hardly ever recorded are the Rufous-capped Brush-finch (*Atlapetes pileatus*), and the Yellow-winged Cacique (*Cacicus melanicterus*).

Fortunately, there are recent records and evidence of the presence of species that had not been recorded after 1950, such as the Solitary Eagle (*Harpyhaliaetus solitarius*), Masked Tityra (*Tytira semifasciata*), Laughing Falcon (*Herpetotheres cachinnans*), and Pale-billed Woodpecker (*Campephilus guatemalensis*) in southern Sonora, by A. Flesh (pers. comm. 2006).

Species with restricted distributions and those that are more sensitive to environmental change are always of concern. When restricted or sensitive bird species are known to have declined or their habitats are threatened, they require special attention. Three important official instruments at national and international levels have identified species in need of attention and protection: the Red list of Threatened Species of the International

Union for Conservation of Nature and Natural Resources (IUCN 2006) at global level, the Neotropical Migratory Bird Conservation Act (NMBCA 2000) in the United States, and Norma Oficial Mexicana NOM-059-ECOL-2001 (Diario Oficial de la Federación 2002) in México.

Under the criteria of the IUCN, the Red list of Threatened Species includes 99 globally threatened species for Mexico. From those 28 are found in Sonora: one critically endangered [the extinct Imperial Woodpecker], one endangered [the Thick-billed Parrot, *Rynchopsitta pachyrhyncha*], eight vulnerable, and 18 near threatened (Appendix A1). The Neotropical Migratory Bird Conservation Act intends to preserve healthy populations of Neotropical migratory birds by supporting conservation initiatives in the United States and Latin America. Out of 338 species of interest for the Act, 85% (288) species have been recorded in Sonora at least during the winter months. This percentage indicates the high significance of the area for the conservation of those birds, particularly short-distance migratory species. For Mexico, the NOM-059-ECOL-2001 defines those extinct, endangered, threatened, and protected plant and wildlife species for the country based on an adaptation of those criteria used by IUCN. From a total of 274 species included, 23% (63) species are present in Sonora: one extinct [the Imperial Woodpecker], nine endangered, 17 threatened, and 36 protected (Table A4 and Appendix A1).

When geographical distribution is taken into account, it is clear that some species are “endemic” or circumscribed to small (and sometimes very small) ranges. Their conservation is the responsibility of the region or countries to which they are restricted. The importance of these endemics to conservation is essential and their survival in natural conditions can be guaranteed only through active management and protection that may also benefit other species. Mexico harbors 91 such species that live exclusively within its political boundaries, and 26 of them are distributed in parts of Sonora; no bird species is endemic to the state. The species considered “quasiendemics” are those that extend slightly into a neighboring country due to the continuity of habitats or physiographic features, but most of their distribution is included in one country; 43

species are Mexican quasiendemics, and 13 of them are present in Sonora and are shared with the United States.

The concept of endemism is applied generally to resident species and, in some way, implies that they have a determined and fixed distribution. However, some migratory species can be restricted to small areas during their breeding or wintering periods, and conservation actions have to be implemented in those areas to assure their maintenance in the future. These species that are endemic to a region or country during a part of the year have been proposed as "semiendemics" (Gómez de Silva 1996). These should probably be re-labeled "seasonally endemic" because they are truly endemic during one season, and they deserve the same conservation attention that true endemics attain. Forty-eight species are semiendemic to Mexico, and 38 inhabit some habitats in the state of Sonora (Table A4 and Appendix A1).

Endemic species are defined by political boundaries, and for the state of Sonora in the northern limits Mexico, they are not necessarily the ones of highest conservation concern. Biological species do not recognize these limits and for that reason, quasiendemic and semiendemic species have to be regarded as priorities in international conservation actions, as well as at the regional level of the Southwestern United States and Northwestern Mexico.

Discussion

The location of the state of Sonora north of the Tropic of Cancer, where dry descendent atmospheric currents favor the presence of deserts, acts as the northern limit for the tropical forests. The northernmost extensions of the tropical deciduous forest occur in southern and southeastern Sonora, and concurrently, they are the northernmost limit of 96 species of bird found in Sonora. On the other hand, the deserts, grasslands, and highland scrublands in north and northeastern Sonora, act as the southern limit for 26 species of temperate North American avifauna. This is considered also an important wintering area for species breeding in the prairies of central United Sates and Southern Canada, and the coniferous forest, woodlands and semidesert shrub steppe in the mountainous region in western United States and Canada (Rich *et al.* 2004). It is clear therefore, the additive effects the Neartic and Neotropical regions have on the avifauna of Sonora, being as a result, the fifth richest state in Mexico, only after Oaxaca (725), Veracruz (708), Chiapas (655), and Guerrero (545) (Navarro-Sigüenza & Sánchez-González 2003).

The information compiled herein indicates that the avifauna in Sonora includes 533 species, nine more that the number reported by the most recent reference of the birds of Sonora (Russell and Monson 1998). The difference is due to the addition of new data and unknown or probably disregarded records from specimens in collections. I agree with the caution Russell and Monson use when considering the incorporation of hypothetical species when no specimens are available to document the presence of the species in the state of Sonora, and consider that specimens are an objective, required, and appropriate requirement. Nevertheless, I question the validity of the location of certain museum specimens, and at the same time exclude two of the species included by Russell and Monson (Sandwich Tern) because the record is supported only by one isolated observation, and the known distribution area is far enough removed from Sonora to shed doubt on the correctness of the identification. Future surveys and further information might confirm its status.

I present some observations about a series of thirteen species that, from my point of view, deserve further words of detail and clarification.

California Quail (*Callipepla californica*): there is a specimen in the United States National Museum of Natural History (USNM 311736) labeled as collected in “Sonora” by W.W. Brown on May 17, 1905. Although there are no specimens of any other species collected on the same date by him, previous and later dates show he was working at that time in the vicinities of Guaymas, La Chumata, and Opodepe, not even close to the Colorado River, where it would be more feasible to find it. Therefore, this has to be a misidentified specimen, if in fact it was collected within the state of Sonora.

Yellow-billed Loon (*Gavia adamsii*): A skull of a specimen found dead was collected on February 25, 2000 in Isla Tiburón, and is deposited at the Museo de Zoología, Facultad de Ciencias, UNAM (MZFC 15727). This specimen is evidence for this species to be an accidental for Sonora; it is the southernmost record of the species in Mexico, and the only one for the state. Two previous records come from Islas Los Coronados and the northern section of the Gulf of Baja California (Rojas-Soto *et al.* 2002). Not included previously by Russell and Monson (1998) as a species for Sonora.

Masked Booby (*Sula dactylatra*): Two specimens of the Masked Booby are deposited in United States Museums; the first one collected by T.E. Lawlor at Isla San Pedro Nolasco on July 18, 1967 is located at the Museum of Zoology at the University of Michigan (UMMZ 212595), and the second collected by C. Jones at Playa Tortilla in Bahía San Carlos, Guaymas on March 28, 1973 cataloged at the Denver Museum of Natural History (DMNH 36619). It is a pelagic accidental species for the state of Sonora, not previously included as part of the state avifauna.

Red-footed Booby (*Sula sula*): This booby is not included as part of the avifauna for Sonora (Russell and Monson 1998), but is represented by three specimens; two of them labeled as collected in “Guaymas” on September 21, 1875 (no collector indicated) at the Academy of Natural Sciences of Philadelphia (ANSP 33348 and 33349), and another probably collected in April of 1875 (no date on the label) by T.H. Streets on Tiburon Island at the United States National Museum of Natural History (USNM No numbered). Despite of the lack of recent records, it seems to have been accidental in Sonora. There are recent records for the state of Sinaloa (M. González-Bernal, pers. comm. 2006).

Black Rail (*Laterallus jamaicensis*): This secretive species of poorly known status in Mexico is not included by Russell and Monson (1998) in the “Birds of Sonora”, but has been recorded recently by Hinojosa-Huerta *et al.* (2004) when call-back surveys allowed them to document and verify its presence in the marshes and wetlands of the Colorado River Delta in Sonora. Although Howell and Webb (1995) point out that it is a species that probably breeds along the Colorado River in Baja California Norte and Sonora, they also indicate they might have been extirpated due to habitat loss. There is only one recent record for northwestern Baja California (Erickson *et al.* 1992). This species might be recolonizing the wetlands in the Colorado Delta due to their recent recovery as a result of management activities (Hinojosa-Huerta, comm. pers. 2006).

Northern Jacana (*Jacana spinosa*): The only evidence of this species was a skeleton in the Los Angeles County Museum labeled “Sonora”, apparently obtained in 1961. Due to the vagueness of the location, and the absence of additional records, it was considered as a hypothetical species for Sonora. Although the distributional map shows their northern limits in southern Sinaloa, 12 individuals were observed by the author at Presa El Chiculi, Yaqui River, near Ciudad Obregón on February 23, 2005. This record modifies the hypothetical status of the species for Sonora. It has been also recorded recently for the state of Sinaloa, near the limits with Sonora (M. González-Bernal, pers. comm. 2006).

Arctic Tern (*Sterna paradisaea*): a specimen at the Museum of Zoology of Louisiana State University obtained at Bahía Kino on January 2, 1960 by A.L. Gardner is labeled with this name (LSUMZ 43623). According to the time of migration, I have serious doubts about the correct identification of this specimen. Normally, fall migration occurs during August to September, and these terns do not come back from the southern seas until April (Villaseñor-Gómez 1993, Villaseñor-Gómez & Phillips 1994). I have included this species in the Appendix A1 because of the extant specimen, but I would consider this species with caution as a hypothetical for the state.

Bridled Tern (*Sterna anaethetus*): A published record from Puerto Lobos at Bahía Tepoca indicated the observation of this tern on August 20, 1884 by Stephens (1885). No further observations or specimens exist on this species for the state. It might be a misidentified individual, because the northern distributional limit on the Pacific coast of Mexico for this summer resident species is located in the state of Nayarit (Howell & Webb 1985).

Sandwich Tern (*Sterna sandvicensis*): An observation made on April 4, 1987 by H. Hobart at Puerto Lobos was published by Russell and Monson (1998). Sandwich terns are wintering visitors in the southern Pacific coast of Mexico (Oaxaca), and they have been registered as casuals up to the coast of Jalisco. Taking into account how far away Puerto Lobos is from that area, I believe this is not a species that should be included as part of the avifauna of Sonora; further data are needed to consider this tern even as a hypothetical species for the state.

Eurasian Collared-Dove (*Streptopelia decaocto*): This introduced dove was recently observed in Rancho San Sebastian, San Miguel River by E. Gómez-Limón (November 15, 2005). Other observation include a pair at Quitovac Cienega in June 2006 and a single bird at Ejido Los Yaquis in July 2006 (A.D. Flesch, unpubl. data), and other records in the Colorado River Delta (O. Hinojosa, unpubl. data). It is considered a species with an expanding distribution that can be found in Mexico.

Orange-fronted Parakeet (*Aratinga canicularis*): A specimen collected by W.J. Schaldach on January 2, 1964 at 15 km SW of "Puerto Loberas" [Puerto Lobos] and deposited at the University of Arizona (UAZ 8963) is the only documented record for the state. A recent observation by the author on February 2, 2004 at Tetapeche, Mayo River indicates the possibilities of recording this parakeet farther north from their known northern limits in the state of Sinaloa. They may also represent escaped individuals that have survived and established in the area.

Mangrove Warbler (*Dendroica petechia erithacoroides*): This form of Yellow Warbler inhabits and breeds exclusively in the mangrove thickets of the Pacific coast of Mexico. Russell and Monson indicate that "Extensive banding in the mangroves near Punta Chueca indicates that this population is a summer visitant. These warblers arrive in spring about 11 April… Departure is in late September" (Russell & Monson 1998). During the years of work, they were able to observe only one individual in winter. Other winter records from Bahía Kino, San Carlos, and Guaymas extend from November to January. During the field work done by the author and collaborators, we registered this form in every visit to estuaries with mangroves: on February 6-8, 2004, more than 15 individuals were detected at Esteros Santa Cruz, Paraíso, and Santa Rosa, near Bahía

Kino and Punta Chueca. The following year, on February 22, we detected 5 individuals in short mangrove thickets at Estero El Soldado, San Carlos. These records indicate the subspecies is likely a permanent resident, instead of summer resident.

Although van Rossem includes the islands in his distributional survey on the birds of Sonora (van Rossem 1945), they were not included later by Russell and Monson (1998). A further important contribution of the present review is the updated compilation on 237 species that inhabit fourteen islands and rocky islets in Sonora in the Gulf of California (Appendix A2). These islands constitute an important area for breeding sea birds and also harbor unique subspecies of their own. The two major islands, Isla Lobos and Isla Tiburón, because of their size and their proximity to mainland are also the ones with more species, (121 and 140, respectively); the other twelve islands, smaller in size, with less diversity, and farther away from the continental Mexico, harbor a total of 97 species.

The importance of these islands, however, rest on the fact that they include breeding sites for almost 90 aquatic species; sizeable populations of petrels, boobies, pelicans, and terns inhabit the area, and specifically, more than 90% of the world's populations of Heermann's (*Larus heermanni*) and Yellow-footed Gulls (*Larus livens*), Elegant Terns (*Sterna elegans*), and Craveri's Murrelets (*Synthliboramphus craveri*) depend on these islands for breeding (Howell & Webb 1995). For their biological importance as breeding areas for marine mammals and birds, and in terms of their reptile, mammal, and bird's endemic species and subspecies (Case *et al.* 2002), the Biosphere Reserve "Isla San Pedro Mártir" and the Gulf of California Protected Islands for Flora and Fauna were inscribed as a World Heritage Area by the IUCN in 2004 [Islands and Protected Areas of the Gulf of California (Mexico) ID No. 1182. IUCN World Heritage Evaluation Report, May 2005].

The diversity of environments within the elevation gradient, the sharp latitudinal transitions in vegetation in Sonora, and the isolation processes occurred within the system of islands in the Gulf of California for extended periods of time have resulted in the rich fauna that we find today. Although we have a good amount of information and a very good idea on the status of avifauna in Sonora, there is also the need to describe more finely the patterns of geographical and temporal distribution at the level of subspecies, as well as the habitat use of the avian species during the year. This will allow us to define the most important habitats for conservation, as well as the needs of particular species.

It is also important to increase the efforts and give continuity to surveys and monitoring activities in order to describe at least some basic demographic parameters that might give indications on the status of the populations of species of concern in the near future.

I am certain that there is still information gathered previously through birdwatching and banding activities in different areas of Sonora, and its systematic inclusion in an interactive database, as the one I have produced for this exercise, will enrich our knowledge and serve many other practical purposes in the near future.

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Appendix A1. Bird species recorded for the state of Sonora, Mexico. Includes information on the number of records from scientific literature, museum specimens, observations, and banding activities in the compiled database; relative abundance information was modified from Russell and Monson (1998). The endemic, quasiendemic, and semiendemic species for Mexico (END), information on habitat and distribution (HABITAT-DISTR), the species of interests for the Neotropical Migratory Bird Conservation Act (NMBCA), and the species officially considered under any given conservation or protection status in Mexico (NOM), and the species included in the Red list of Threatened Species of the International Union for Conservation of Nature and Natural Resources (IUCN) are indicated.

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
ANSERIFORMES **ANATIDAE: Swans, Geese and Ducks**														
Black-bellied Whistling-Duck *(Dendrocygna autumnalis)*	14	7	2		23	SR		*uc*				Aq, F, C I	X	
Fulvous Whistling-Duck *(Dendrocygna bicolor)*	8				8	R	*r*					Aq, F, C I	X	
Greater White-fronted Goose *(Anser albifrons)*	13	4			17	M			*uc*	*r*		Aq, F, I	X	
Snow Goose *(Chen caerulescens)*	19	6			25	M			*uc*	*r*		Aq, F, C I	X	
Brant *(Branta bernicla)*	20	1	2		23	M			*uc*			Aq, M, C (S)		T
Canada Goose *(Branta canadensis)*	12	2	2		16	M			*uc*			Aq, F, C I		
Tundra Swan *(Cygnus columbianus)*	4				4	M			*r*			Aq, F, I		Edg
Wood Duck *(Aix sponsa)*	15		3		18	M			*r*			Aq, F, I	X	
Gadwall *(Anas strepera)*	8	2	18		28	M			*uc*	*fc*		Aq, F, I	X	
Eurasian Wigeon *(Anas penelope)***	1				1	M			*acc*			Aq, M, C		

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
American Wigeon *(Anas americana)*	15	5	24		44	M			*c*	*c*		Aq, F, C I	X	
Mallard *(Anas platyrhynchos)*	20	3	175		198	PM	*uc*		*uc*			Aq, F, I	X	
Blue-winged Teal (*Anas discors)*	6	1	2		9	M			*r*	*r*		Aq, F, I	X	
Cinnamon Teal *(Anas cyanoptera)*	21	3	16		40	M[b]			*uc*	*fc*		Aq, F, C I	X	
Northern Shoveler *(Anas clypeata)*	23	4	4		31	M[b]			*fc*	*c*		Aq, F, C I	X	
Northern Pintail *(Anas acuta)*	23	5	10		38	M[b]			*uc*	*fc*		Aq, F, C I	X	
Green-winged Teal *(Anas crecca)*	21	18	12		51	M			*fc*	*fc*		Aq, F, C I	X	
Canvasback *(Aythya valisineria)*	8	1			9	M			*r*			Aq, F, C I	X	
Redhead *(Aythya americana)*	20	9	1		30	M			*c*	*c*		Aq, M F, C I	X	
Ring-necked Duck *(Aythya collaris)*	6	1	2		9	M[b]			*r*	*r*		Aq, F, C I	X	
Greater Scaup *(Aythya marila)* **	1				1	M			*acc*			Aq, M, C (S)		
Lesser Scaup *(Aythya affinis)*	18	5	13		36	M			*mc*			Aq, M F, C I	X	
Harlequin Duck *(Histrionicus histrionicus)*	3				3	M			*acc*			Aq, M, C (S)		
Surf Scoter *(Melanitta perspicillata)*	9	1			10	M			*uc*			Aq, M, C		
White-winged Scoter *(Melanitta fusca)*	3				3	M			*r*			Aq, M, C (S)		

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
Black Scoter *(Melanitta nigra) ***	1				1	M			*acc*			Aq, M, C (S)		
Long-tailed Duck *(Clangula hyemalis)*	4	1			5	M			*r*			Aq, M, C		
Bufflehead *(Bucephala albeola)*	16	2	8		26	M			*uc*			Aq, M F, C I		
Common Goldeneye *(Bucephala clangula)*	12				12	M			*r*			Aq, F, C		
Hooded Merganser *(Lophodytes cucullatus)*	2				2	M			*acc*			Aq, F, I	X	
Common Merganser *(Mergus merganser)*	15		28		43	M			*uc*			Aq, M F, C I		
Red-breasted Merganser *(Mergus serrator)*	22	2	2		26	M			*c*	*c*		Aq, M F, C I	X	
Ruddy Duck *(Oxyura jamaicensis)*	16	4	1		21	PM		*r*	*c*	*fc*		Aq, F, C I	X	
GALLIFORMES **CRACIDAE:** **Curassows and Guans**														
Rufous-bellied Chachalaca *(Ortalis wagleri)*	10	33	9		52	R	*uc*				End	T, L (N)		
PHASIANIDAE: **Partridges, Grouse and Pheasants**														
Ring-necked Pheasant *(Phasianus colchicus) ***	1				1	R	*r*					T		
ODONTOPHORIDAE: **Turkey and Quail**														
Wild Turkey *(Meleagris gallopavo)*	16	9	1		26	R	*c*					T, H		P
Scaled Quail *(Callipepla squamata)*	8	6			14	R	*r*					T, H (S)		

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
Elegant Quail *(Callipepla douglasii)*	24	323	9		356	R	*c*				End	T (N)		
Gambel's Quail *(Callipepla gambelii)*	53	392	142	1	588	R	*ab*					T		
Northern Bobwhite *(Colinus virginianus)*	17	268	1		286	R	*r*					T, L		NT
Montezuma Quail *(Cyrtonyx montezumae)*	28	85	6		119	R	*c*					T, H		P
GAVIIFORMES GAVIIDAE: Loons														
Red-throated Loon *(Gavia stellata)*	8				8	M			*r*			Aq, M, C		
Pacific Loon *(Gavia pacifica)*	9	10			19	M			*fc*			Aq, M, C		
Common Loon *(Gavia immer)*	18				18	M			*c*			Aq, M, C I		
Yellow-billed Loon *(Gavia adamsii)*	1	1			2	M				*acc*		Aq, M, C		
PODICIPEDIFORMES PODICIPEDIDAE: Grebes														
Least Grebe *(Tachybaptus dominicus)*	8	9	1		18	R	*uc*					Aq, F, I (N)		P
Pied-billed Grebe *(Podilymbus podiceps)*	10	1	4		15	M			*uc*	*uc*		Aq, F, C I	X	
Horned Grebe *(Podiceps auritus)*	12	1			13	M			*uc*			Aq, F, C		
Eared Grebe *(Podiceps nigricollis)*	27	11	3		41	M			*c*	*c*		Aq, F, C I	X	

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
Western Grebe *(Aechmophorus occidentalis)*	7				7	M			*uc*			Aq, F, C I	X	
Clark's Grebe *(Aechmophorus clarkii)*	3				3	M			*r*			Aq, F, C I	X	
PROCELLARIIFORMES PROCELLARIIDAE: Shearwaters and Petrels														
Northern Fulmar *(Fulmarus glacialis)* **	4	1			5	M						Aq, M, P		
Sooty Shearwater *(Puffinus griseus)*	6	1			7	M						Aq, M, P		NT
Black-vented Shearwater *(Puffinus opisthomelas)*	5				5	R	*r*				Sem	Aq, M, P		Edg, NT
HYDROBATIDAE: Storm-Petrels														
Black Storm-Petrel *(Oceanodroma melania)*	12	8			20	R	*c*				Sem	Aq, M, P		T
Least Storm-Petrel *(Oceanodroma microsoma)*	10				10	M				*c*	Sem	Aq, M, P		T
PELECANIFORMES PHAETHONTIDAE: Tropicbirds														
Red-billed Tropicbird *(Phaethon aethereus)*	14	24			38	R	*uc*					Aq, M, C		T
SULIDAE: Boobies and Gannets														
Masked Booby *(Sula dactylatra)*		2			2	R	*uc*					Aq, M, C		
Blue-footed Booby *(Sula nebouxii)*	22	9	1		32	R	*c*					Aq, M, C		

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
Brown Booby *(Sula leucogaster)*	25	20			45	R	*ab*					Aq, M, C		
Red-footed Booby *(Sula sula)*		3			3	R	*uc*					Aq, M, C		
PELECANIDAE: Pelicans														
American White Pelican *(Pelecanus erythrorhynchos)*	19		15		34	M			*uc*	*uc*		Aq, M F, C I	X	
Brown Pelican *(Pelecanus occidentalis)*	18	10	23		51	R	*ab*					Aq, M F, C	X	
PHALACROCORACIDAE: Cormorants														
Brandt's Cormorant *(Phalacrocorax penicillatus)*	9	1	1		11	R	*uc*					Aq, M, C		
Neotropic Cormorant *(Phalacrocorax brasilianus)*	11	6	35		52	R	*uc*					Aq, F, I (N)	X	
Double-crested Cormorant *(Phalacrocorax auritus)*	25	10	16		51	R	*uc*					Aq, M F, C I	X	
ANHINGIDAE: Darters														
Anhinga *(Anhinga anhinga)*	5				5	R	*uc*					Aq, F, I (N)	X	
FREGATIDAE: Frigatebirds														
Magnificent Frigatebird *(Fregata magnificens)*	16	10	7		33	R	*ab*					Aq, M, C		
CICONIIFORMES ARDEIDAE: Bitterns and Herons														
American Bittern *(Botaurus lentiginosus)*	10	2			12	M			*r*	*r*		Aq, F, C I	X	T

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
Least Bittern *(Ixobrychus exilis)*	18	15			33	SR		*uc*				Aq, F, C	X	
Bare-throated Tiger-Heron *(Tigrisoma mexicanum)*	7	16	1		24	R	*uc*					Aq, F, I (N)		P
Great Blue Heron *(Ardea herodias)*	42	8	186		236	R	*fc*					Aq, F, C I	X	
Great Egret *(Ardea alba)*	24	1	165		190	R	*uc*					Aq, F, C I	X	
Snowy Egret *(Egretta thula)*	25	8	14		47	R	*uc*					Aq, F, C I	X	
Little Blue Heron *(Egretta caerulea)*	19	7	2		28	R	*r*					Aq, F, C I	X	
Tricolored Heron *(Egretta tricolor)*	22	4	2		28	R	*uc*					Aq, F, C I	X	
Reddish Egret *(Egretta rufescens)*	23	8	7		38	R	*uc*					Aq, F, C	X	P
Cattle Egret *(Bubulcus ibis)*	16		4		20	R	*fc*					Aq, F, C I	X	
Green Heron *(Butorides virescens)*	22	26	57		105	PM	*fc*		*r*			Aq, F, C I	X	
Black-crowned Night-Heron *(Nycticorax nycticorax)*	28	8	9		45	R	*uc*					Aq, F, C I	X	
Yellow-crowned Night-Heron *(Nyctanassa violacea)*	15	7	4		26	R	*uc*					Aq, F, C	X	
THRESKIORNITHIDAE: Ibises and Spoonbills														
White Ibis *(Eudocimus albus)*	22	7	1		30	R	*r*					Aq, F, C	X	
White-faced Ibis *(Plegadis chihi)*	21	9	2		32	M			*uc*	*c*		Aq, F, I	X	

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
Roseate Spoonbill *(Platalea ajaja)*	18	7			25	SR		*r*				Aq, F, C I	X	
CICONIIDAE: Storks														
Wood Stork *(Mycteria americana)*	19	1			20	SR		*r*				Aq, F, C I	X	P
CATHARTIDAE: American Vultures														
Black Vulture *(Coragyps atratus)*	32	9	166		207	R	*c*					T	X	
Turkey Vulture *(Cathartes aura)*	58	5	295		358	PM	*c*		*c*	*c*		T	X	
FALCONIFORMES ACCIPITRIDAE: Kites, Eagles, Hawks, and allies														
Osprey *(Pandion haliaetus)*	30	8	52		90	R	*fc*					T, C I	X	
White-tailed Kite *(Elanus leucurus)*	9		2		11	PM	*uc*					T, H		
Bald Eagle *(Haliaeetus leucocephalus)*	25		1		26	PM	*r*		*r*			T		Edg
Northern Harrier *(Circus cyaneus)*	23	11	16		50	M			*fc*	*fc*		T	X	
Sharp-shinned Hawk *(Accipiter striatus)*	28	22	33	5	88	PM	*fc*		*fc*	*fc*		T	X	P
Cooper's Hawk *(Accipiter cooperii)*	30	26	45	1	102	PM	*fc*		*c*	*c*		T	X	P
Northern Goshawk *(Accipiter gentilis)*	9	2	1		12	R	*r*					T, H		T
Crane Hawk *(Geranospiza caerulescens)*	3	13	2		18	R	*r*					T, L (N)		T

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
Gray Hawk *(Asturina nitida)*	20	66	14	1	101	R	*c*					T, L		
Common Black-Hawk *(Buteogallus anthracinus)*	24	21	9		54	R	*fc*					T	X	P
Great Black-Hawk *(Buteogallus urubitinga)*	4	4	12		20	R	*r*					T, L (N)		P
Harris's Hawk *(Parabuteo unicinctus)*	15	30	10		55	R	*c*					T, L		P
Solitary Eagle *(Harpyhaliaetus solitarius)*	5	5			10	R	*r*					T, L (N)		Edg, NT
Short-tailed Hawk *(Buteo brachyurus)*	7				7	R	*uc*					T		
Swainson's Hawk *(Buteo swainsoni)*	14	5	1		20	PM		*uc*		*r*		T	X	P
White-tailed Hawk *(Buteo albicaudatus)*	19	2	3		24	R	*uc*					T		P
Zone-tailed Hawk *(Buteo albonotatus)*	29	22	3		54	PM		*fc*		*r*		T, H, Ad		P
Red-tailed Hawk *(Buteo jamaicensis)*	53	20	155		228	R	*fc*					T	X	
Ferruginous Hawk *(Buteo regalis)*	7	1	4		12	M			*uc*			T, L	X	P, NT
Rough-legged Hawk *(Buteo lagopus)*	7				7	M			*r*			T, L (S)		P
Golden Eagle *(Aquila chrysaetos)*	13	2	2		17	R	*r*					T		T
FALCONIDAE: Caracaras and Falcons														
Crested Caracara *(Caracara cheriway)*	38	35	50		123	R	*c*					T, L		

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
Laughing Falcon *(Herpetotheres cachinnans)*	6	10			16	R	*r*					T,L (N)		
American Kestrel *(Falco sparverius)*	36	73	113		222	PM	*fc*		*c*	*c*		T	X	
Merlin *(Falco columbarius)*	12	9	11		32	M			*r*	*r*		T	X	
Aplomado Falcon *(Falco femoralis)* **	3	1			4	R	*r*					T, L (N)		T
Bat Falcon *(Falco rufigularis)*	7	11			18	R	*r*					T, L (N)		
Peregrine Falcon *(Falco peregrinus)*	15	7	7		29	PM	*fc*		*uc*	*uc*		T	X	P
Prairie Falcon *(Falco mexicanus)*	17	5	1		23	M			*r*	*uc*		T	X	T
GRUIFORMES RALLIDAE: Rails, Gallinules, and Coots														
Black Rail *(Laterallus jamaicensis)*	2				2	R	*r*					Aq, F, I	X	NT
Clapper Rail *(Rallus longirostris)*	18	48			66	PM	*c*		*c*			Aq, F, C		P
Virginia Rail *(Rallus limicola)*	11	1			12	M			*r*	*r*		Aq, F, C I	X	P
Sora *(Porzana carolina)*	8	3			11	M			*uc*			Aq, F, C I	X	
Purple Gallinule *(Porphyrio martinicus)*	1	2			3	R	*r*					Aq, F, I (N)	X	
Common Moorhen *(Gallinula chloropus)*	8	3			11	R	*uc*					Aq, F, C I	X	
American Coot *(Fulica americana)*	26	5	8		39	R	*fc*					Aq, M F, C I	X	

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
GRUIDAE: **Cranes**														
Sandhill Crane *(Grus canadensis)*	11				11	M			*uc*			Aq, I	X	P
CHARADRIIFORMES **CHARADRIIDAE:** **Plovers and Lapwings**														
Black-bellied Plover *(Pluvialis squatarola)*	9	4	1		14	M			*c*	*c*		Aq, M, C	X	
Snowy Plover *(Charadrius alexandrinus)*	24	16			40	M	*?*		*c*	*c*		Aq, M, C	X	
Wilson's Plover *(Charadrius wilsonia)*	27	40	2		69	R	*c*					Aq, M, C	X	
Semipalmated Plover *(Charadrius semipalmatus)*	10	8			18	M			*fc*	*fc*		Aq, M, C I	X	
Piping Plover *(Charadrius melodus)*	15				15	M			*r*	*r*		Aq, M, C	X	Edg, NT
Killdeer *(Charadrius vociferus)*	26	17	134		177	R	*fc*					T	X	
Mountain Plover *(Charadrius montanus)*	7	6			13	M			*r*			Aq, I	X	T, VU
HAEMATOPODIDAE: **Oystercatchers**														
American Oystercatcher *(Haematopus palliatus)*	28	25			53	R	*fc*					Aq, M, C	X	
Black Oystercatcher *(Haematopus bachmani)* **	5				5	R	*r*					Aq, M, C		
RECURVIROSTRIDAE: **Stilts and Avocets**														
Black-necked Stilt *(Himantopus mexicanus)*	25	10	1		36	M[b]			*fc*	*fc*		Aq, M F, C I	X	

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
American Avocet *(Recurvirostra americana)*	21	4			25	M^b			*c*	*c*		Aq, M F, C I	X	
JACANIDAE: Jacanas														
Northern Jacana *(Jacana spinosa)* **		1	2		3	R	*r*					Aq, F, C (N)		
SCOLOPACIDAE: Sandpipers, Phalaropes, and Allies														
Greater Yellowlegs *(Tringa melanoleuca)*	12	8	23		43	M^b			*uc*	*uc*		Aq, F, C I	X	
Lesser Yellowlegs *(Tringa flavipes)*	7	2			9	M			*r*	*r*		Aq, F, C I	X	
Solitary Sandpiper *(Tringa solitaria)*	6				6	M			*uc*	*r*		Aq, F, C I	X	
Willet *(Catoptrophorus semipalmatus)*	22	14	7		43	M^b			*c*	*c*		Aq, M, C I	X	
Wandering Tattler *(Heteroscelus incanus)*	11	1			12	M			*uc*	*uc*		Aq, M, C	X	
Spotted Sandpiper *(Actitis macularia)*	24	11	170		205	M			*c*	*c*		Aq, M F, C I	X	
Upland Sandpiper *(Bartramia longicauda)* **	4				4	M				*r*		Aq, I	X	
Whimbrel *(Numenius phaeopus)*	14	2	3		19	M^b			*c*	*c*		Aq, M, C	X	
Long-billed Curlew *(Numenius americanus)*	23	9	10		42	M			*c*	*c*		Aq, M F, C I	X	NT
Marbled Godwit *(Limosa fedoa)*	16	10	4		30	M^b			*ab*	*ab*		Aq, M F, C	X	
Ruddy Turnstone *(Arenaria interpres)*	12	12			24	M			*c*	*c*		Aq, M, C	X	
Black Turnstone *(Arenaria melanocephala)*	12	12			24	M^b			*fc*	*fc*		Aq, M, C		

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
Surfbird *(Aphriza virgata)*	3	8			11	M[b]			*c*	*fc*		Aq, M, C	X	
Red Knot *(Calidris canutus)*	18	14			32	M			*fc*	*fc*		Aq, M, C	X	
Sanderling *(Calidris alba)*	11	12			23	M			*c*	*c*		Aq, M, C	X	
Semipalmated Sandpiper *(Calidris pusilla)*	2				2	M				*r*		Aq, M, C	X	
Western Sandpiper *(Calidris mauri)*	20	22	2		44	M			*ab*	*ab*		Aq, M, C I	X	
Least Sandpiper *(Calidris minutilla)*	20	22	21		63	M			*c*	*c*		Aq, M F, C I	X	
Baird's Sandpiper *(Calidris bairdii)* **	4				4	M			*r*	*r*		Aq, F, I	X	
Pectoral Sandpiper *(Calidris melanotos)* **	4				4	M				*r*		Aq, M F, C I	X	
Dunlin *(Calidris alpina)*	9	20			29	M			*fc*	*fc*		Aq, M, C		
Stilt Sandpiper *(Calidris himantopus)* **	2				2	M				*r*		Aq, F, I	X	
Short-billed Dowitcher *(Limnodromus griseus)*	13	2	1		16	M[b]			*uc*	*uc*		Aq, M, C	X	
Long-billed Dowitcher *(Limnodromus scolopaceus)*	16	18	1		35	M			*fc*	*fc*		Aq, F, C I	X	
Wilson's Snipe *(Gallinago delicata)*	17	17	32		66	M			*uc*			Aq, F, C I	X	
Wilson's Phalarope *(Phalaropus tricolor)*	6	4			10	M			*r*	*uc*		Aq, M F, C I	X	
Red-necked Phalarope *(Phalaropus lobatus)*	12	2			14	M			*r*	*c*		Aq, M F, C I	X	

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
Red Phalarope *(Phalaropus fulicarius)*	4				4	M			*r*	*r*		Aq, M, C	X	
LARIDAE: Gulls and Terns														
Pomarine Jaeger *(Stercorarius pomarinus)* **	3				3	M			*r*			Aq, M, C		
Parasitic Jaeger *(Stercorarius parasiticus)*	4				4	M			*r*			Aq, M, C		
Laughing Gull *(Larus atricilla)*	20	7			27	M[b]			*r*	*r*		Aq, M F, C I	X	
Franklin's Gull *(Larus pipixcan)*	4				4	M				*r*		Aq, M F, C I	X	
Bonaparte's Gull *(Larus philadelphia)*	21	6			27	M			*c*	*c*		Aq, M F, C I	X	
Heermann's Gull *(Larus heermanni)*	25	43	5		73	R	*c*				Sem	Aq, M, C		P, NT
Ring-billed Gull *(Larus delawarensis)*	27	9	26		62	M[b]			*c*	*c*		Aq, M F, C I	X	
California Gull *(Larus californicus)*	24		10		34	M[b]			*c*	*uc*		Aq, M, C	X	
Herring Gull *(Larus argentatus)*	16	3			19	M			*fc*	*fc*		Aq, M, C	X	
Thayer's Gull *(Larus thayeri)*	5				5	M			*r*			Aq, M, C		
Yellow-footed Gull *(Larus livens)*	17	13	3		33	R	*c*				Sem	Aq, M, C		P
Western Gull *(Larus occidentalis)*	21				21	M			*r*	*r*		Aq, M, C	X	
Glaucous-winged Gull *(Larus glaucescens)*	15				15	M			*r*	*r*		Aq, M, C	X	

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
Glaucous Gull *(Larus hyperboreus)*	4				4	M			*r*	*r*		Aq, M, C		
Sabine's Gull *(Xema sabini)* **	5				5	M				*r*		Aq, M, C	X	
Black-legged Kittiwake *(Rissa tridactyla)*	2				2	M			*r*			Aq, M, C		
Gull-billed Tern *(Sterna nilotica)*	6				6	SR		*r*				Aq, M, C	X	
Caspian Tern *(Sterna caspia)*	11	1	18		30	M[b]			*c*	*c*		Aq, M, C I	X	
Royal Tern *(Sterna maxima)*	17	26	4		47	R	*uc*					Aq, M, C	X	
Elegant Tern *(Sterna elegans)*	16	40	1		57	R	*fc*				Sem	Aq, M, C	X	P, NT
Common Tern *(Sterna hirundo)*	13	3			16	M[b]			*r*	*r*		Aq, M, C	X	
Arctic Tern *(Sterna paradisaea)*		1			1	M				*r*		Aq, M, C		
Forster's Tern *(Sterna forsteri)*	12	16			28	M			*c*	*c*		Aq, M, C	X	
Least Tern *(Sterna antillarum)*	44	8			52	SR		*uc*		*r*		Aq, M, C	X	P
Bridled Tern *(Sterna anaethetus)*	1				1	SR		*acc*				Aq, M, C (N)		
Black Tern *(Chlidonias niger)*	14	1			15	M				*uc*		Aq, M F, C I	X	
Black Skimmer *(Rynchops niger)*	11	12	1		24	M[b]			*r*	*r*		Aq, M, C	X	
ALCIDAE: Auks and Murres														

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
Craveri's Murrelet *(Synthliboramphus craveri)*	21	28			49	R	*uc*				Sem	Aq, M, C		T, VU
COLUMBIFORMES **COLUMBIDAE: Pigeons and Doves**														
Rock Pigeon *(Columba livia)*			1		1	R	*c*					T		
Red-billed Pigeon *(Patagioenas flavirostris)*	22	33	16		71	R	*fc*					T, L (N)	X	
Band-tailed Pigeon *(Patagioenas fasciata)*	35	12	3		50	R	*fc*					T, H	X	
Eurasian Collared-Dove *(Streptopelia decaocto)*			1		1	R	*r*					T		
White-winged Dove *(Zenaida asiatica)*	44	49	534	2	629	R	*ab*					T	X	
Mourning Dove *(Zenaida macroura)*	50	34	562	1	647	R	*ab*					T	X	
Inca Dove *(Columbina inca)*	31	94	74	6	205	R	*c*					T		
Common Ground-Dove *(Columbina passerina)*	28	71	41	3	143	R	*c*					T, L		
Ruddy Ground-Dove *(Columbina talpacoti)*	6		2		8	R	*uc*					T, L (N)		
White-tipped Dove *(Leptotila verreauxi)*	10	27	70	14	121	R	*fc*					T, L (N)		
PSITTACIFORMES **PSITTACIDAE:** **Parakeets, Macaws, and Parrots**														
Green Parakeet *(Aratinga holochlora)*	1	8			9	R					End	T,L (N)		T
Orange-fronted Parakeet *(Aratinga canicularis)*		1	1		2	R						T, L (N)		P

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
Military Macaw *(Ara militaris)*	18	16			34	SR[a]		*uc*				T, L (N)		Edg, VU
Thick-billed Parrot *(Rhynchopsitta pachyrhyncha)*	7				7	SR		*uc*			End	T, H		Edg, EN
Mexican Parrotlet *(Forpus cyanopygius)*	10	84	1		95	SR		*uc*			End	T, L (N)		P
White-fronted Parrot *(Amazona albifrons)*	27	138	24		189	R	*fc*					T, L (N)		
Lilac-crowned Parrot *(Amazona finschi)*	10	49	5		64	R	*r*				End	T, L (N)		T, VU
CUCULIFORMES CUCULIDAE: Cuckoos, roadrunners, and Anis														
Yellow-billed Cuckoo *(Coccyzus americanus)*	19	51			70	SR		*c*		*c*		T	X	
Mangrove Cuckoo *(Coccyzus minor)*	8				8	SR		*uc*				T, L (N)	X	
Squirrel Cuckoo *(Piaya cayana)*	5	16	4		25	R	*uc*					T, L (N)		
Lesser Roadrunner *(Geococcyx velox)*	8	9			17	R	*r*					T (N)		
Greater Roadrunner *(Geococcyx californianus)*	31	40	77	1	149	R	*c*					T		
Groove-billed Ani *(Crotophaga sulcirostris)*	8	18	7		33	SR[a]		*uc*				T, L (N)		
STRIGIFORMES TYTONIDAE: Barn Owls														
Barn Owl *(Tyto alba)*	15	5			20	R	*uc*					T		

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
STRIGIDAE: **Typical Owls**														
Flammulated Owl *(Otus flammeolus)*	9	3			12	SR		*uc*			Sem	T, H		
Western Screech-Owl *(Megascops kennicottii)*	18	117	6		141	R	*c*					T		
Whiskered Screech-Owl *(Megascops trichopsis)*	16	10			26	R	*c*					T, H		
Vermiculated Screech-Owl *(Megascops guatemalae)*	4	10			14	R	*r*					T, L (N)		
Great Horned Owl *(Bubo virginianus)*	35	24	14		73	R	*c*					T		
Northern Pygmy-Owl *(Glaucidium gnoma)*	20				20	R	*uc*					T, H		
Colima Pygmy-Owl *(Glaucidium palmarum)*	12	31			43	R	*r*				End	T, L (N)		
Ferruginous Pygmy-Owl *(Glaucidium brasilianum)*	22	71	7		100	R	*uc*					T		
Elf Owl *(Micrathene whitneyi)*	24	26			50	SR[a]		*c*			Sem	T	X	
Burrowing Owl *(Athene cunicularia)*	20	16	1		37	R	*uc*					T	X	
Mottled Owl *(Ciccaba virgata)*	3	19			22	R	*r*					T, L (N)		
Spotted Owl *(Strix occidentalis)*	8	4			12	R	*r*					T, H		T, NT
Long-eared Owl *(Asio otus)*	8				8	M			*r*			T, L		
Short-eared Owl *(Asio flammeus)*	8	1			9	M			*r*			T, L	X	P

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
Northern Saw-whet Owl *(Aegolius acadicus)*	1				1	R	*r*					T, H		
CAPRIMULGIFORMES **CAPRIMULGIDAE: Goatsuckers**														
Lesser Nighthawk *(Chordeiles acutipennis)*	37	73	2		112	SR[a]		*c*				T, L	X	
Common Nighthawk *(Chordeiles minor)*	13	7			20	SR		*fc*				T, H	X	
Common Pauraque *(Nyctidromus albicollis)*	6				6	R	*r*					T, L (N)		
Common Poorwill *(Phalaenoptilus nuttallii)*	31	32			63	R	*uc*					T	X	
Eared Poorwill *(Nyctiphrynus mcleodii)*	4				4	R	*r*				End	T (N)		P
Buff-collared Nightjar *(Caprimulgus ridgwayi)*	33	50			83	SR		*fc*				T, L		
Whip-poor-will *(Caprimulgus vociferus)*	22	5	1		28	SR[a]		*c*				T, H	X	
APODIFORMES **APODIDAE:** **Swifts**														
Black Swift *(Cypseloides niger)*	3				3	SR		*r*				Ae	X	
Chestnut-collared Swift *(Streptoprocne rutila)*	2				2	SR		*r*				Ae (N)		
White-naped Swift *(Streptoprocne semicollaris)*	3	1			4	R	*r*				End	Ae (N)		P
Vaux's Swift *(Chaetura vauxi)*	9	3			12	M				*r*		Ae	X	
White-throated Swift *(Aeronautes saxatalis)*	16	3	5		24	R	*fc*					Ae, H	X	

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
TROCHILIDAE: Hummingbirds														
Broad-billed Hummingbird *(Cynanthus latirostris)*	52	193	163	6	414	R	*c*				Sem	T	X	
White-eared Hummingbird *(Hylocharis leucotis)*	10	32	8		50	R	*uc*					T, H		
Berylline Hummingbird *(Amazilia beryllina)*	8	22			30	R	*uc*					T, Ad (N)		
Cinnamon Hummingbird *(Amazilia rutila)* **	1				1	R	*r*					T (N)		
Violet-crowned Hummingbird *(Amazilia violiceps)*	28	102	50	12	192	R	*c*				Sem	T	X	
Blue-throated Hummingbird *(Lampornis clemenciae)*	13	10			23	SR		*uc*			Sem	T, H	X	
Magnificent Hummingbird *(Eugenes fulgens)*	18	39			57	R	*uc*					T, H	X	
Plain-capped Starthroat *(Heliomaster constantii)*	6	27	9		42	R	*uc*					T, Ad (N)		
Lucifer Hummingbird *(Calothorax lucifer)*	5	1			6	SR		*r*			Sem	T, H		
Black-chinned Hummingbird *(Archilochus alexandri)*	17	32	16		65	SR		*uc*		*uc*	Sem	T	X	
Anna's Hummingbird *(Calypte anna)*	16	10	4		30	M			*uc*			T	X	
Costa's Hummingbird *(Calypte costae)*	26	89	87	5	207	R	*fc*					T	X	
Calliope Hummingbird *(Stellula calliope)*	10	4	1		15	M				*r*	Sem	T	X	
Broad-tailed Hummingbird *(Selasphorus platycercus)*	14	14	6		34	SR		*uc*		*fc*	Sem	T, H	X	

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
Rufous Hummingbird *(Selasphorus rufus)*	21	43	5		69	M				*fc*		T	X	
Allen's Hummingbird *(Selasphorus sasin)*	10	6			16	M				*r*	Sem	T	X	
TROGONIFORMES **TROGONIDAE: Trogons**														
Mountain Trogon *(Trogon mexicanus)*	4				4	R	*uc*					T, H (N)		
Elegant Trogon *(Trogon elegans)*	36	98	11		145	R	*fc*					T, H, Ad	X	
Eared Quetzal *(Euptilotis neoxenus)*	6				6	R	*uc*				Qen	T, H (N)		T, NT
CORACIIFORMES **MOMOTIDAE: Motmots**														
Russet-crowned Motmot *(Momotus mexicanus)*	9	43			52	R	*uc*				Qen	T, L (N)		
ALCEDINIDAE: Kingfishers														
Belted Kingfisher *(Ceryle alcyon)*	21	17	89		127	M			*fc*	*fc*		T, L	X	
Green Kingfisher *(Chloroceryle americana)*	38	115	182	20	355	R	*fc*							
PICIFORMES **PICIDAE: Woodpeckers**														
Lewis's Woodpecker *(Melanerpes lewis)*	14	4	6		24	M			*r*			T		
Acorn Woodpecker *(Melanerpes formicivorus)*	31	120	68		219	R	*c*					T, H		
Gila Woodpecker *(Melanerpes uropygialis)*	54	287	1434	11	1786	R	*ab*					T, L		

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
Williamson's Sapsucker *(Sphyrapicus thyroideus)*	13	3	4		20	M			*r*	*r*		T		
Yellow-bellied Sapsucker *(Sphyrapicus varius)*	3	21			24	M			*r*			T	X	
Red-naped Sapsucker *(Sphyrapicus nuchalis)*	20	14	89	8	131	M			*uc*	*uc*		T	X	
Ladder-backed Woodpecker *(Picoides scalaris)*	42	196	405	8	651	R	*fc*					T		
Hairy Woodpecker *(Picoides villosus)*	17	4	5		26	R	*r*					T, H		
Arizona Woodpecker *(Picoides arizonae)*	31	56	25		112	R	*fc*				Qen	T, H		
Gray-crowned Woodpecker *(Piculus auricularis)*	5				5	R	*r*				End	T, L (N)		
Northern Flicker *(Colaptes auratus)*	41	56	319		416	R	*fc*					T		
Gilded Flicker *(Colaptes chrysoides)*	29	108	64		201	R	*c*					T, L		
Lineated Woodpecker *(Dryocopus lineatus)*	8	37			45	R	*r*					T (N)		
Pale-billed Woodpecker *(Campephilus guatemalensis)*	3	29			32	R	*r*					T, L (N)		P
Imperial Woodpecker *(Campephilus imperialis)*	6	3			9	R	*uc*					T, H (N)		Ex, CR
PASSERIFORMES DENDROCOLAPTIDAE: Woodcreepers														
Ivory-billed Woodcreeper *(Xiphorhynchus flavigaster)*	9	27			36	R	*uc*					T, L (N)		
White-striped Woodcreeper *(Lepidocolaptes leucogaster)*	10	36	12	2	60	R	*c*				End	T, H, Ad (N)		

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
TYRANNIDAE: Tyrant Flycatchers														
Northern Beardless-Tyrannulet *(Camptostoma imberbe)*	16	52	94	1	163	R	*c*					T, L	X	
Tufted Flycatcher *(Mitrephanes phaeocercus)*	6	41	15		62	R	*uc*					T, H, Ad (N)		
Olive-sided Flycatcher *(Contopus cooperi)*	8	3			11	M				*r*		T, L	X	NT
Greater Pewee *(Contopus pertinax)*	26	45	7		78	R	*c*					T, H, Ad	X	
Western Wood-Pewee *(Contopus sordidulus)*	29	83	7	2	121	SR		*c*		*c*		T, H	X	
Willow Flycatcher *(Empidonax traillii)*	16	21	4	2	43	M			*r*	*uc*		T, L	X	
Least Flycatcher *(Empidonax minimus)*	6	1		1	8	M			*r*	*r*		T, L	X	
Hammond's Flycatcher *(Empidonax hammondii)*	16	18	9	12	55	M			*r*	*uc*		T	X	
Gray Flycatcher *(Empidonax wrightii)*	33	63	89	85	270	M			*c*	*uc*	Sem	T	X	
Dusky Flycatcher *(Empidonax oberholseri)*	18	41	51	51	161	M			*fc*	*fc*	Sem	T, L	X	
Pine Flycatcher *(Empidonax affinis)*	1	2			3	R	*r*				Qen	T (N)		
Pacific-slope Flycatcher *(Empidonax difficilis)*	11	126	31	11	179	M			*fc*	*uc*		T	X	
Cordilleran Flycatcher *(Empidonax occidentalis)*	2		8	8	18	PM		*c*	*r*	*uc*		T	X	
Western Flycatcher (*E. difficilis* or *occidentalis*)	21		7	1	29				*uc*	*uc*		T	X	

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
Buff-breasted Flycatcher *(Empidonax fulvifrons)*	9	21	5	2	37	R	*uc*					T, H, Ad	X	
Black Phoebe *(Sayornis nigricans)*	39	76	582	19	716	R	*fc*					T		
Eastern Phoebe *(Sayornis phoebe)*	7	8	11		26	M			*r*	*r*		T	X	
Say's Phoebe *(Sayornis saya)*	35	32	139		206	PM	*uc*		*fc*	*fc*		T	X	
Vermilion Flycatcher *(Pyrocephalus rubinus)*	41	147	174		362	R	*c*					T	X	
Bright-rumped Attila *(Attila spadiceus)*	7	4	1		12	R	*r*					T, L (N)		
Dusky-capped Flycatcher *(Myiarchus tuberculifer)*	32	109	94	4	239	R	*fc*					T, H, Ad	X	
Ash-throated Flycatcher *(Myiarchus cinerascens)*	59	210	265	4	538	R	*c*					T	X	
Nutting's Flycatcher *(Myiarchus nuttingi)*	14	87	30		131	R	*c*					T, L		
Brown-crested Flycatcher *(Myiarchus tyrannulus)*	29	76	52		157	SR[a]		*fc*				T	X	
Great Kiskadee *(Pitangus sulphuratus)*	6	16	29		51	R	*uc*					T, L (N)		
Social Flycatcher *(Myiozetetes similis)*	12	58	29		99	R	*fc*					T, L (N)		
Sulphur-bellied Flycatcher *(Myiodynastes luteiventris)*	28	63	1		92	SR		*c*				T, L (N)	X	
Tropical Kingbird *(Tyrannus melancholicus)*	23	50	6		79	SR		*c*				T, L	X	
Cassin's Kingbird *(Tyrannus vociferans)*	47	110	67		224	PM		*c*	*c*	*c*	Sem	T	X	

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
Thick-billed Kingbird *(Tyrannus crassirostris)*	16	64			80	SR		*c*			Sem	T	X	
Western Kingbird *(Tyrannus verticalis)*	25	19	10		54	SR		*uc*		*c*		T, L	X	
Scissor-tailed Flycatcher *(Tyrannus forficatus)*	3				3	M				*vag*		T, L	X	
Gray-collared Becard *(Pachyramphus major)*	6				6	R	*r*					T, H, Ad (N)		
Rose-throated Becard *(Pachyramphus aglaiae)*	23	105	7	1	136	SR		*fc*				T		
Masked Tityra *(Tityra semifasciata)*	1	1			2	R	*r*					T, L (N)		
LANIIDAE: Shrikes														
Loggerhead Shrike *(Lanius ludovicianus)*	49	73	165	17	304	PM	*uc*		*c*	*c*		T	X	
VIREONIDAE: Vireos														
White-eyed Vireo *(Vireo griseus) ***	1	1			2	R	*vag*					T, L	X	
Mangrove Vireo *(Vireo pallens)*	1	1			2	R	*r*					T, L (N)		P
Bell's Vireo *(Vireo bellii)*	20	46	6	1	73	PM	*?*	*c*	*uc*	*uc*		T, L	X	NT
Black-capped Vireo *(Vireo atricapilla)*	3				3	M			*r*		Sem	T	X	Edg, VU
Gray Vireo *(Vireo vicinior)*	18	20			38	M			*uc*		Sem	T, L (S)	X	
Plumbeous Vireo *(Vireo plumbeus)*	8	18	21	2	49	SR		*fc*				T	X	

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
Cassin's Vireo *(Vireo cassinii)*	13	25	17	6	61	M			*fc*		Sem	T	X	
Solitary Vireo complex *(Vireo "solitarius"* complex)	11	1			12							T	X	
Hutton's Vireo *(Vireo huttoni)*	28	25	14	4	71	R	*fc*					T, H, Ad		
Golden Vireo *(Vireo hypochryseus)*	3	8			11	R	*r*				End	T (N)		
Warbling Vireo *(Vireo gilvus)*	29	89	20		138	PM		*uc*	*uc*	*fc*		T, Ad	X	
Red-eyed Vireo *(Vireo olivaceus)*	1				1	M				*vag*		T	X	
Yellow-green Vireo *(Vireo flavoviridis)*	8	22			30	SR		*uc*				T (N)	X	
CORVIDAE: Jays, Magpies, and Crows														
Steller's Jay *(Cyanocitta stelleri)*	30	67	3		100	R	*fc*					T, H, Ad		
Black-throated Magpie-Jay *(Calocitta colliei)*	20	70	24		114	R	*mc*				End	T, L (N)		
Purplish-backed Jay *(Cyanocorax beecheii)*	10	59	2		71	R	*uc*				End	T, L (N)		T
Western Scrub-Jay *(Aphelocoma californica)*	12				12	R	*r*					T, H (S)		
Mexican Jay *(Aphelocoma ultramarina)*	29	86	51		166	R	*c*					T, H		
Pinyon Jay *(Gymnorhinus cyanocephalus)*	6				6	R	*vag*					T, H (S)		VU
Clark's Nutcracker *(Nucifraga columbiana)*	4	1			5	R	*vag*					T, H (S)		Edg

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
American Crow *(Corvus brachyrhynchos)*	3				3	M			*vag*			T, L (S)		
Sinaloa Crow *(Corvus sinaloae)*		46	14		60	R	*c*				End	T, L (N)		
Chihuahuan Raven *(Corvus cryptoleucus)*	39	3	11		53	R	*uc*					T		
Common Raven *(Corvus corax)*	45	29	567		641	R	*c*					T		
ALAUDIDAE: Larks														
Horned Lark *(Eremophila alpestris)*	25	53	83		161	R	*c*					T		
HIRUNDINIDAE: Swallows														
Purple Martin *(Progne subis)*	25	82			107	SR		*uc*		*r*		Ae	X	
Sinaloa Martin *(Progne sinaloae)*	9	2			11	SR		*uc*			Sem	Ae		P
Tree Swallow *(Tachycineta bicolor)*	12	13	2		27	M			*uc*	*c*		Ae	X	
Mangrove Swallow *(Tachycineta albilinea)*	26	8			34	R	*uc*					Ae (N)		
Violet-green Swallow *(Tachycineta thalassina)*	37	41	101		179	PM	*c*		*uc*	*c*		Ae	X	
Northern Rough-winged Swallow *(Stelgidopteryx serripennis)*	33	28	32		93	PM	*c*		*uc*	*c*		Ae	X	
Bank Swallow *(Riparia riparia)*	8				8	M				*uc*		Ae	X	
Cliff Swallow *(Petrochelidon pyrrhonota)*	17	21	11		49	SR		*fc*		*fc*		Ae	X	
Barn Swallow *(Hirundo rustica)*	18	1			19	SR		*fc*		*fc*		Ae	X	

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
PARIDAE: **Titmice**														
Mexican Chickadee *(Poecile sclateri)*	14	1	8		23	R	*uc*				Qen	T, H, Ad		
Bridled Titmouse *(Baeolophus wollweberi)*	41	86	81		208	R	*c*					T, H, Ad		
Juniper Titmouse *(Baeolophus ridgwayi)*	5	2			7	R	*r*					T, H (S)		
REMIZIDAE: **Verdins**														
Verdin *(Auriparus flaviceps)*	52	183	857	21	1113	R	*c*					T, L		
AEGITHALIDAE: **Bushtits**														
Bushtit *(Psaltriparus minimus)*	24	90	5		119	R	*fc*					T, H, Ad		
SITTIDAE: **Nuthatches**														
Red-breasted Nuthatch *(Sitta canadensis)*	4	1			5	M			*r*			T, H		
White-breasted Nuthatch *(Sitta carolinensis)*	35	49	48		132	R	*c*					T, H, Ad		
Pygmy Nuthatch *(Sitta pygmaea)*	9				9	R	*uc*					T, H		
CERTHIIDAE: **Creepers**														
Brown Creeper *(Certhia Americana)*	27	36	11	1	75	R	*c*					T, H, Ad		
TROGLODYTIDAE: **Wrens**														
Spotted Wren *(Campylorhynchus gularis)*	7	39			46	R	*uc*				End	T (N)		

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
Cactus Wren *(C. brunneicapillus)*	38	259	594	19	910	R	*ab*					T, L		
Rock Wren *(Salpinctes obsoletus)*	25	26	62		113	R	*c*					T		
Canyon Wren *(Catherpes mexicanus)*	28	58	149	5	240	R	*fc*					T		
Sinaloa Wren *(Thryothorus sinaloa)*	10	85	93	52	240	R	*mc*				End	T, L (N)		
Happy Wren *(Thryothorus felix)*	9	21	51	33	114	R	*uc*				End	T, L (N)		
Bewick's Wren *(Thryomanes bewickii)*	42	66	167	12	287	R	*mc*					T		
House Wren *(Troglodytes aedon)*	32	49	200	34	315	PM	*uc*		*c*	*c*		T	X	
Winter Wren *(Troglodytes troglodytes)*	2		3		5	M			*r*			T		
Sedge Wren *(Cistothorus platensis)* **	1				1	M						T, L	X	
Marsh Wren *(Cistothorus palustris)*	14	5	5		24	M			*uc*	*uc*		T	X	
CINCLIDAE: Dippers														
American Dipper *(Cinclus mexicanus)*	1				1	R	*r*					T, H		P
REGULIDAE: Kinglets														
Golden-crowned Kinglet *(Regulus satrapa)*	6				6	M			*r*	*r*		T, Ad		
Ruby-crowned Kinglet *(Regulus calendula)*	28	44	758	107	937	M			*c*	*c*		T, H, Ad	X	

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
SYLVIIDAE: Gnatcatchers														
Blue-gray Gnatcatcher *(Polioptila caerulea)*	44	74	719	75	912	PM	*mc*		*fc*	*fc*		T	X	
Black-tailed Gnatcatcher *(Polioptila melanura)*	32	107	405	17	561	R	*c*					T, L		
Black-capped Gnatcatcher *(Polioptila nigriceps)*	15	80	162	40	297	R	*c*				End	T		
TURDIDAE: Bluebirds, Thrushes, and Robins														
Eastern Bluebird *(Sialia sialis)*	13	55	19		87	R	*c*					T, H	X	
Western Bluebird *(Sialia mexicana)*	16	17			33	PM	*uc*		*uc*			T	X	
Mountain Bluebird *(Sialia currucoides)*	13	5	3		21	M			*uc*			T	X	
Townsend's Solitaire *(Myadestes townsendi)*	13	5	3		21	PM	*uc*		*r*			T	X	P
Brown-backed Solitaire *(Myadestes occidentalis)*	3	22	2		27	R	*fc*					T, H, Ad (N)		P
Orange-billed Nightingale-Thrush *(Catharus aurantiirostris)*	5	1	5	5	16	R	*uc*					T, H, Ad (N)		
Russet Nightingale-Thrush *(Catharus occidentalis)* **	1				1	R	*uc*				End	T, H, Ad (N)		
Swainson's Thrush *(Catharus ustulatus)*	17	29	2		48	M				*fc*		T	X	
Hermit Thrush *(Catharus guttatus)*	21	64	40	33	158	M			*c*	*c*		T	X	
Wood Thrush *(Hylocichla mustelina)* **	1				1	M				*vag*		T, L	X	

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
White-throated Robin *(Turdus assimilis)*	7	13			20	R	*uc*					T (N)		
Rufous-backed Robin *(Turdus rufopalliatus)*	12	54	5	3	74	R	*mc*				Qen	T, L (N)		
American Robin *(Turdus migratorius)*	26	16	18		60	PM	*c*		*c*			T, H	X	
Varied Thrush *(Ixoreus naevius)* **	1				1	M			*vag*			T (S)		
Aztec Thrush *(Ridgwayia pinicola)*	2				2	R	*r*				End	T, H (N)		P
MIMIDAE: Mockingbirds and Thrashers														
Gray Catbird *(Dumetella carolinensis)* **	1				1	M			*r*			T	X	
Northern Mockingbird *(Mimus polyglottos)*	38	96	466	6	606	PM	*ab*		*c*	*c*		T		
Sage Thrasher *(Oreoscoptes montanus)*	14	14			28	M			*uc*			T, L	X	
Brown Thrasher *(Toxostoma rufum)*	7	1	1		9	M			*r*			T, L		
Bendire's Thrasher *(Toxostoma bendirei)*	24	43	26	2	95	PM	*uc*		*uc*	*uc*	Sem	T, L		VU
Curve-billed Thrasher *(Toxostoma curvirostre)*	69	273	349	11	702	R	*c*					T		
Crissal Thrasher *(Toxostoma crissale)*	22	15	2		39	R	*uc*					T		
Le Conte's Thrasher *(Toxostoma lecontei)*	12	22			34	R	*uc*					T, L (S)		
Blue Mockingbird *(Melanotis caerulescens)*	13	40			53	R	*uc*				End	T, H, Ad (N)		

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
STURNIDAE: Starlings														
European Starling *(Sturnus vulgaris)*	16		19		35	R	*uc*					T, L		
MOTACILLIDAE: Wagtails and Pipits														
White Wagtail *(Motacilla alba)* **	2				2	M				*vag*		T, H		
American Pipit *(Anthus rubescens)*	11	15	35		61	M			*uc*	*uc*		T	X	
Sprague's Pipit *(Anthus spragueii)*	3	3			6	M			*r*			T, L	X	VU
BOMBYCILLIDAE: Waxwings														
Cedar Waxwing *(Bombycilla cedrorum)*	15	34	7		56	M			*c*	*uc*		T	X	
PTILOGONATIDAE: Silky-flycatchers														
Gray Silky-flycatcher *(Ptilogonys cinereus)*	9				9	R	*r*				Qen	T, H, Ad (N)		
Phainopepla *(Phainopepla nitens)*	37	100	201		338	R	*fc*					T		
PEUCEDRAMIDAE: Peucedramo														
Olive Warbler *(Peucedramus taeniatus)*	14	6	10		30	R	*fc*					T, H		
PARULIDAE: Wood-Warblers														
Tennessee Warbler *(Vermivora peregrina)*	3	1			4	M				*vag*		T, L	X	
Orange-crowned Warbler *(Vermivora celata)*	41	123	260	62	486	M			*fc*	*uc*		T	X	

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
Nashville Warbler *(Vermivora ruficapilla)*	19	35	9	4	67	M			*r*	*fc*		T	X	
Virginia's Warbler *(Vermivora virginiae)*	8	7			15	M				*uc*	Sem	T, L	X	
Lucy's Warbler *(Vermivora luciae)*	12	55	5		72	PM		*c*	*r*	*c*	Sem	T	X	
Crescent-chested Warbler *(Parula superciliosa)*	10	18	1		29	R	*r*					T, H (N)		
Northern Parula *(Parula americana)*	5	3			8	M				*r*		T	X	
Tropical Parula *(Parula pitiayumi)*	14	63			77	SR		*uc*				T (N)		
Yellow Warbler *(Dendroica petechia)*	45	140	18	1	204	PM	*c*	*c*		*c*		T	X	
Chestnut-sided Warbler *(Dendroica pensylvanica)* **	1				1	M				*vag*		T	X	
Magnolia Warbler *(Dendroica magnolia)*	2	1			3	M				*vag*		T, L	X	
Cape May Warbler *(Dendroica tigrina)* **	1				1	M				*vag*		T	X	
Black-throated Blue Warbler *(Dendroica caerulescens)*	3				3	M				*vag*		T, L	X	
Yellow-rumped Warbler *(Dendroica coronata)*	52	80	723	18	873	M			*fc*	*fc*		T	X	
Black-throated Gray Warbler *(Dendroica nigrescens)*	37	76	90	13	216	M			*c*	*c*	Sem	T	X	
Black-throated Green Warbler *(Dendroica virens)*	3	2			5	M			*vag*			T, L	X	
Townsend's Warbler *(Dendroica townsendi)*	28	15	6		49	M				*uc*		T, H	X	

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
Hermit Warbler *(Dendroica occidentalis)*	15	17	5		37	M				*fc*		T	X	
Blackburnian Warbler *(Dendroica fusca)* **	1				1	M				*vag*		T	X	
Yellow-throated Warbler *(Dendroica dominica)* **	1				1	M				*vag*		T	X	
Grace's Warbler *(Dendroica graciae)*	10	19			29	SR		*c*				T, H	X	
Palm Warbler *(Dendroica palmarum)*	2				2	M			*vag*	*vag*		T, L	X	
Bay-breasted Warbler *(Dendroica castanea)* **	1				1	M				*vag*		T	X	
Black-and-white Warbler *(Mniotilta varia)*	3	3	13	1	20	M			*uc*	*uc*		T, L	X	
American Redstart *(Setophaga ruticilla)*	13	3	6	1	23	M[b]			*r*	*uc*		T	X	
Prothonotary Warbler *(Protonotaria citrea)* **	2				2	M				*vag*		T, L	X	
Ovenbird *(Seiurus aurocapilla)*	8	4			12	M			*vag*	*vag*		T	X	
Northern Waterthrush *(Seiurus noveboracensis)*	15	1	6	2	24	M			*r*	*Fc*		T, L	X	
Louisiana Waterthrush *(Seiurus motacilla)*	3	6		1	10	M			*r*	*r*		T	X	
Kentucky Warbler *(Oporornis formosus)*	2	1			3	M				*vag*		T	X	
MacGillivray's Warbler *(Oporornis tolmiei)*	18	53	33	14	118	M			*fc*	*c*		T	X	
Common Yellowthroat *(Geothlypis trichas)*	34	66	308	34	442	PM		*c*	*c*	*fc*		T, L	X	

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
Hooded Warbler *(Wilsonia citrina)*	3				3	M				*vag*		T	X	
Wilson's Warbler *(Wilsonia pusilla)*	36	99	138	42	315	M			*c*	*ab*		T	X	
Red-faced Warbler *(Cardellina rubrifrons)*	7	2	2		11	SR		*uc*			Sem	T, H	X	
Painted Redstart *(Myioborus pictus)*	26	86	23		135	PM	*c*		*uc*	*c*		T, H, Ad	X	
Slate-throated Redstart *(Myioborus miniatus)*	5	6	1		12	R	*uc*					T, H, Ad (N)		
Fan-tailed Warbler *(Euthlypis lachrymosa)*	8	45			53	SR		*uc*				T, L (N)		
Rufous-capped Warbler *(Basileuterus rufifrons)*	17	45	6	1	69	R	*fc*				Qen	T (N)		
Yellow-breasted Chat *(Icteria virens)*	28	57	7	2	94	PM		*c*	*r*	*c*		T, L	X	
THRAUPIDAE: Tanagers														
Hepatic Tanager *(Piranga flava)*	35	72	27		134	R	*c*					T, H, Ad	X	
Summer Tanager *(Piranga rubra)*	31	90	11		132	SR[a]		*c*		*c*		T	X	
Scarlet Tanager *(Piranga olivacea)*	1	1	1		3	M				*vag*		T, L	X	
Western Tanager *(Piranga ludoviciana)*	33	83	10		126	M			*c*	*R*		T	X	
Flame-colored Tanager *(Piranga bidentata)*	11	4			15	R	*uc*					T, H (N)		
Red-headed Tanager *(Piranga erythrocephala)*	1	7			8	R	*r*				End	T, H (N)		

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
EMBERIZIDAE: **Emberizid Sparrows**														
Blue-black Grassquit *(Volatinia jacarina)*	10	4			14	R	*uc*					T, L (N)		
Rufous-capped Brush-Finch *(Atlapetes pileatus)* **	1				1	R	*r*				End	T, H (N)		
Rusty-crowned Ground-sparrow *(Melozone kieneri)*	9	39			48	R	*uc*				End	T (N)		
Green-tailed Towhee *(Pipilo chlorurus)*	35	57	397	171	660	M			*ab*	*ab*		T	X	
Spotted Towhee *(Pipilo maculatus)*	39	40	57	2	138	PM	*c*		*uc*	*uc*		T, H	X	
Canyon Towhee *(Pipilo fuscus)*	55	166	176	18	415	R	*ab*					T		
Abert's Towhee *(Pipilo aberti)*	10				10	R	*r*					T, L (S)		
Rufous-winged Sparrow *(Aimophila carpalis)*	36	309	104	62	511	R	*fc*				Qen	T, L	X	
Cassin's Sparrow *(Aimophila cassinii)*	16	10	2		28	PM	*fc*		*uc*	*uc*		T		
Botteri's Sparrow *(Aimophila botterii)*	19	21			40	R	*fc*					T	X	
Rufous-crowned Sparrow *(Aimophila ruficeps)*	26	66	48		140	R	*c*					T	X	
Rusty Sparrow *(Aimophila rufescens)*	16	78			94	R	*c*					T (N)		
Five-striped Sparrow *(Aimophila quinquestriata)*	11	132	9		152	R	*fc*				Sem	T		
Striped Sparrow *(Oriturus superciliosus)* **	3				3	R	*r*				End	T, H (N)		

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
Chipping Sparrow *(Spizella passerina)*	32	87	240	82	441	PM	*uc*		*c*	*c*		T	X	
Clay-colored Sparrow *(Spizella pallida)*	16	47	29	7	99	M			*fc*	*c*	Sem	T	X	
Brewer's Sparrow *(Spizella breweri)*	35	38	41	6	120	M			*c*	*c*		T	X	NT
Black-chinned Sparrow *(Spizella atrogularis)*	7	5	3		15	PM	*r*		*uc*			T	X	
Vesper Sparrow *(Pooecetes gramineus)*	38	54	17		109	M			*c*	*c*		T	X	
Lark Sparrow *(Chondestes grammacus)*	20	36	148	7	211	PM	*r*		*c*	*c*		T	X	
Black-throated Sparrow *(Amphispiza bilineata)*	34	110	136	9	289	R	*c*					T		
Sage Sparrow *(Amphispiza belli)*	8	13			21	M			*uc*			T, L		
Lark Bunting *(Calamospiza melanocorys)*	23	21	3		47	M			*c*	*c*		T	X	
Savannah Sparrow *(Passerculus sandwichensis)*	43	202	18		263	PM	*uc*		*uc*	*uc*		T	X	
Grasshopper Sparrow *(Ammodramus savannarum)*	17	38	3		58	PM	*c*		*c*	*?*		T	X	
Baird's Sparrow *(Ammodramus bairdii)*	9	1			10	M			*r*		Sem	T (S)		
Fox Sparrow *(Passerella iliaca)*	6	1	3	3	13	M			*r*			T, L		
Song Sparrow *(Melospiza melodia)*	27	68	651	105	851	PM	*fc*		*uc*	*uc*		T, L		
Lincoln's Sparrow *(Melospiza lincolnii)*	32	47	108	146	333	M			*c*			T, L	X	

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
Swamp Sparrow *(Melospiza georgiana)*	7	3	2	8	20	M			*r*	*r*		T, L	X	
White-throated Sparrow *(Zonotrichia albicollis)*	7	3	2	3	15	M			*r*			T		
White-crowned Sparrow *(Zonotrichia leucophrys)*	42	113	127	186	468	M			*ab*	*c*		T	X	
Golden-crowned Sparrow *(Zonotrichia atricapilla)*	7				7	M			*r*			T		
Dark-eyed Junco *(Junco hyemalis)*	25	17	40		82	M			*c*			T, H (S)		
Yellow-eyed Junco *(Junco phaeonotus)*	13	13	20		46	R	*mc*				Qen	T, H		
McCown's Longspur *(Calcarius mccownii)*	7				7	M			*uc*			T (S)		
Chestnut-collared Longspur *(Calcarius ornatus)*	9				9	M			*uc*			T		NT
CARDINALIDAE: Cardinals, Grosbeaks, and Allies														
Northern Cardinal *(Cardinalis cardinalis)*	49	265	351	101	766	R	*fc*					T, L		
Pyrrhuloxia *(Cardinalis sinuatus)*	39	118	124	19	300	R	*fc*					T, L		
Yellow Grosbeak *(Pheucticus chrysopeplus)*	13	46			59	SR		*c*			Qen	T (N)		
Rose-breasted Grosbeak *(Pheucticus ludovicianus)*	6	1			7	M				*?*		T, L	X	
Black-headed Grosbeak *(Pheucticus melanocephalus)*	48	128	43	12	231	PM		*c*	*uc*	*c*	Sem	T, Ad	X	
Blue Grosbeak *(Passerina caerulea)*	27	86	12	5	130	PM		*c*	*uc*	*c*		T	X	

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
Lazuli Bunting *(Passerina amoena)*	29	59	20	6	114	M			*uc*	*c*	Sem	T	X	
Indigo Bunting *(Passerina cyanea)*	15				15	M			*?*	*r*		T	X	
Varied Bunting *(Passerina versicolor)*	23	131	21	26	201	SR		*fc*				T	X	
Painted Bunting *(Passerina ciris)*	10	39			49	M				*uc*		T, L	X	NT
Dickcissel *(Spiza americana)*	9				9	M				*r*		T, L	X	
ICTERIDAE: Blackbirds, Orioles, and Allies														
Red-winged Blackbird *(Agelaius phoeniceus)*	22	67	69		158	PM	*uc*		*fc*			T, L	X	
Eastern Meadowlark *(Sturnella magna)*	20	8	6		34	PM	*c*		*c*			T	X	
Western Meadowlark *(Sturnella neglecta)*	23	53	45		121	PM	*uc*		*c*	*c*		T	X	
Yellow-headed Blackbird *(Xanthocephalus xanthocephalus)*	22	13	5		40	M			*c*	*c*		T, L	X	
Rusty Blackbird *(Euphagus carolinus)* **	2				2	M			*vag*			T		
Brewer's Blackbird *(Euphagus cyanocephalus)*	16	30	26		72	M			*c*			T	X	
Great-tailed Grackle *(Quiscalus mexicanus)*	46	124	104		274	R	*c*					T, L		
Bronzed Cowbird *(Molothrus aeneus)*	16	66	3		85	PM	*c*		*uc*			T	X	
Brown-headed Cowbird *(Molothrus ater)*	32	80	33		145	PM	*c*		*ab*			T	X	

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
Black-vented Oriole *(Icterus wagleri)*	19	79	2		100	R	*mc*					T (N)		
Orchard Oriole *(Icterus spurius)*	7	11			18	SR		*mc*				T, L	X	
Hooded Oriole *(Icterus cucullatus)*	32	101	9	1	143	PM	*mc*		*c*	*c*	Sem	T	X	
Streak-backed Oriole *(Icterus pustulatus)*	31	127	158	23	339	R	*ab*					T, L (N)		
Bullock's Oriole *(Icterus bullockii)*	18	51	12		81	M		*r*	*uc*	*c*	Sem	T	X	
Baltimore Oriole *(Icterus galbula)*	13	1			14	M				*?*		T, L	X	
Scott's Oriole *(Icterus parisorum)*	35	12	7		54	PM		*mc*	*uc*	*uc*	Sem	T	X	
Yellow-winged Cacique *(Cacicus melanicterus)*	4				4	R	*r*				Qen	T, L (N)		
FRINGILLIDAE: Fringillid Finches														
Scrub Euphonia *(Euphonia affinis)*	4	2			6	R	*r*					T, L (N)		
Elegant Euphonia *(Euphonia elegantissima)*	4	8			12	R	*uc*					T (N)		
Purple Finch *(Carpodacus purpureus)*	2				2	M			*r*			T, L (S)		
Cassin's Finch *(Carpodacus cassinii)*	6	2			8	M			*r*			T, H (S)		NT
House Finch *(Carpodacus mexicanus)*	54	236	727	6	1023	R	*ab*					T		
Red Crossbill *(Loxia curvirostra)*	13	2	2		17	R	*uc*					T, H		

SPECIES	Lit	Mus	Obs	Ban	Num Rec	S S	Relative Abundance				END	HABITAT-DISTR	NMBCA	NOM IUCN
							R	SR	W	T				
Pine Siskin *(Carduelis pinus)*	10	23	4		37	M			*uc*			T, H		
Black-headed Siskin *(Carduelis notata)*	7	14	1		22	R	*uc*					T, H (N)		
Lesser Goldfinch *(Carduelis psaltria)*	31	98	206	9	344	R	*c*					T	X	
Lawrence's Goldfinch *(Carduelis lawrencei)*	10	10	21	11	52	M			*uc*			T, L (S)		
American Goldfinch *(Carduelis tristis)*	5				5	M			*uc*			T, L (S)	X	
Hooded Grosbeak *(Coccothraustes abeillei)*	1				1	R	*r*				Qen	T, H (N)		
Evening Grosbeak *(Coccothraustes vespertinus)*	7	1			8	R	*r*					T, H (N)		
PASSERIDAE: Old World Sparrows														
House Sparrow *(Passer domesticus)*	12	2	32		46	R	*c*					T		

Lit: Records from scientific literature; **Mus**: records from specimens in museums; **Obs**: records from observations during field work; **Ban**: banded specimens; **Num Rec**: number of records in database; **S S**: seasonal status [R= permanent resident, SR= summer resident (a superscript "a" indicates individuals remaining during the winter in the area), PM= partial migrant, M= migrant ((a superscript "b" indicates individuals remaining during the summer in the area)]; **Abundance (R & M 1988)**: terms used to define relative abundance [*ab*= abundant, *c* = common, *fc*= fairly common, *uc*= uncommon, *r*= rare, *vag*= vagrant, *acc*, accidental] according to seasonal status [R= resident, SR= summer resident, W= wintering, T= transient] (modified from Russell and Monson 1998); **END**: category of endemism [End= endemic species to Mexico, Qen= quasiendemic species to Mexico, Sem= semiendemic species to Mexico]; **HABITAT-DISTR**: Aq: aquatic, T: terrestrial, Ae= aerial, M: marine, F: freshwater, C: costal, I: interior, P: pelagic, H: highland species generally above 1200 m in elevation, L: Lowland species generally below 1200 m in elevation; (when H or L are not included, it is implied the species has a wide distribution within the elevation gradient), Ad: species with seasonal altitudinal displacements, (S): the species is in the southern limit of their distribution, (N): the species is in the northern limit of its distribution; **NMBCA:** species of interest for the Neotropical Migratory Bird Conservation Act; **NOM**: Species included in the Norma Oficial Mexicana NOM-059-ECOL-2001 [Ex= Extinct, T= threatened, Edg= endangered, P= Protected]; **IUCN**: species included in the Red list of Threatened Species of the International Union for Conservation of Nature and Natural Resources [CR= critically endangered, EN= endangered, VU= vulnerable, NT= near threatened] (IUCN 2006). The species followed by "**" are considered "hypothetical" by Russell and Monson (1998).

Appendix A2. Insular avifauna of the State of Sonora, Mexico.

SPECIES	ISLANDS *													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Brant (*Branta bernicla*)														X
Gadwall (*Anas strepera*)				X										
American Wigeon (*Anas americana*)				X										
Mallard (*Anas platyrhynchos*)				X										
Blue-winged Teal (*Anas discors*)				X										
Cinnamon Teal (*Anas cyanoptera*)				X										
Northern Shoveler (*Anas clypeata*)														X
Green-winged Teal (*Anas crecca*)														X
Canvasback (*Aythya valisineria*)														X
Redhead (*Aythya americana*)														X
Ring-necked Duck (*Aythya collaris*)														X
Lesser Scaup (*Aythya affinis*)														X
Surf Scoter (*Melanitta perspicillata*)								X						X
Long-tailed Duck (*Clangula hyemalis*)														X
Bufflehead (*Bucephala albeola*)														X
Common Merganser *(Mergus merganser)*				X				X						
Red-breasted Merganser *(Mergus serrator)*								X						X
Gambel's Quail *(Callipepla gambelii)*					X									X
Red-throated Loon *(Gavia stellata)*														X
Pacific Loon (*Gavia pacifica*)								X						X
Common Loon (*Gavia immer*)														X
Yellow-billed Loon (*Gavia adamsii*)														X
Pied-billed Grebe (*Podilymbus podiceps*)				X										
Eared Grebe (*Podiceps nigricollis*)								X		X	X			X
Northern Fulmar (*Fulmarus glacialis*)														X

SPECIES	ISLANDS *													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Sooty Shearwater (*Puffinus griseus*)														X
Black-vented Shearwater (*Puffinus opisthomelas*)											X			X
Black Storm-Petrel *(Oceanodroma melania)*								X						
Least Storm-Petrel *(Oceanodroma microsoma)*								X						X
Red-billed Tropicbird *(Phaethon aethereus)*								X	X	X				X
Masked Booby *(Sula dactylatra)*											X			
Blue-footed Booby *(Sula nebouxii)*	X								X	X	X			X
Brown Booby *(Sula leucogaster)*								X	X	X	X			X
Red-footed Booby *(Sula sula)*														X
American White Pelican *(Pelecanus erythrorhynchos)*				X										
Brown Pelican *(Pelecanus occidentalis)*	X					X				X	X			X
Brandt's Cormorant *(Phalacrocorax penicillatus)*								X		X	X			X
Neotropic Cormorant *(Phalacrocorax brasilianus)*				X										
Double-crested Cormorant *(Phalacrocorax auritus)*	X								X	X				X
Magnificent Frigatebird *(Fregata magnificens)*	X	X					X	X	X	X	X			X
Great Blue Heron *(Ardea herodias)*	X		X	X	X						X			X
Great Egret *(Ardea alba)*			X	X										
Snowy Egret *(Egretta thula)*	X		X	X										X
Little Blue Heron *(Egretta caerulea)*			X											X
Tricolored Heron *(Egretta tricolor)*	X		X											
Reddish Egret *(Egretta rufescens)*	X	X	X											X
Cattle Egret *(Bubulcus ibis)*	X		X											
Green Heron *(Butorides virescens)*			X	X	X									
Black-crowned Night-Heron *(Nycticorax nycticorax)*	X		X											
Yellow-crowned Night-Heron *(Nyctanassa violacea)*	X		X			X								X
White Ibis *(Eudocimus albus)*	X		X											X
Roseate Spoonbill *(Platalea ajaja)*		X	X											

SPECIES	ISLANDS *													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Black Vulture *(Coragyps atratus)*				X										X
Turkey Vulture *(Cathartes aura)*				X										X
Osprey *(Pandion haliaetus)*				X			X	X			X		X	X
Northern Harrier *(Circus cyaneus)*								X						X
Sharp-shinned Hawk *(Accipiter striatus)*				X										
Cooper's Hawk *(Accipiter cooperii)*				X										X
Northern Goshawk *(Accipiter gentilis)*				X										
Gray Hawk *(Asturina nitida)*				X										
Common Black-Hawk *(Buteogallus anthracinus)*				X										
White-tailed Hawk *(Buteo albicaudatus)*				X										
Red-tailed Hawk *(Buteo jamaicensis)*				X				X						X
Golden Eagle *(Aquila chrysaetos)*														X
Crested Caracara *(Caracara cheriway)*				X										
American Kestrel *(Falco sparverius)*				X										X
Merlin *(Falco columbarius)*				X										
Peregrine Falcon *(Falco peregrinus)*	X			X				X	X	X				X
Prairie Falcon *(Falco mexicanus)*														X
Clapper Rail *(Rallus longirostris)*			X		X									
Snowy Plover *(Charadrius alexandrinus)*														X
Wilson's Plover *(Charadrius wilsonia)*							X	X						X
Semipalmated Plover *(Charadrius semipalmatus)*														X
Killdeer *(Charadrius vociferous)*				X				X						
American Oystercatcher *(Haematopus palliatus)*	X	X	X		X		X	X	X	X				X
American Avocet *(Recurvirostra americana)*														X
Willet *(Catoptrophorus semipalmatus)*					X			X			X			X
Wandering Tattler *(Heteroscelus incanus)*	X										X			
Spotted Sandpiper *(Actitis macularia)*				X				X		X	X			X

SPECIES	ISLANDS *													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Whimbrel (*Numenius phaeopus)*														X
Long-billed Curlew *(Numenius americanus)*														X
Marbled Godwit *(Limosa fedoa)*					X									
Ruddy Turnstone *(Arenaria interpres)*		X									X			
Black Turnstone *(Arenaria melanocephala)*						X		X			X			X
Surfbird *(Aphriza virgata)*														X
Red Knot *(Calidris canutus)*		X												
Sanderling *(Calidris alba)*					X									
Western Sandpiper *(Calidris mauri)*					X									X
Least Sandpiper *(Calidris minutilla)*														X
Short-billed Dowitcher *(Limnodromus griseus)*					X									
Long-billed Dowitcher *(Limnodromus scolopaceus)*					X									
Wilson's Snipe *(Gallinago delicata)*				X										
Wilson's Phalarope *(Phalaropus tricolor)*														X
Red-necked Phalarope *(Phalaropus lobatus)*						X		X						X
Red Phalarope *(Phalaropus fulicarius)*											X			
Bonaparte's Gull *(Larus Philadelphia)*								X	X	X				X
Heermann's Gull *(Larus heermanni)*	X							X	X	X				X
Ring-billed Gull *(Larus delawarensis)*								X		X	X			X
California Gull *(Larus californicus)*								X		X	X			X
Herring Gull *(Larus argentatus)*														X
Yellow-footed Gull *(Larus livens)*	X				X			X	X	X	X			X
Western Gull *(Larus occidentalis)*	X							X		X	X			X
Caspian Tern *(Sterna caspia)*														X
Royal Tern *(Sterna maxima)*					X				X					X
Elegant Tern *(Sterna elegans)*	X				X			X	X	X				X
Least Tern *(Sterna antillarum)*					X									

SPECIES	ISLANDS *													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Black Skimmer *(Rynchops niger)*			X											
Craveri's Murrelet *(Synthliboramphus craveri)*	X					X		X	X	X	X	X		X
White-winged Dove *(Zenaida asiatica)*			X	X				X			X			X
Mourning Dove *(Zenaida macroura)*				X				X		X				X
Inca Dove *(Columbina inca)*				X										
Common Ground-Dove *(Columbina passerine)*														X
White-tipped Dove *(Leptotila verreauxi)*				X										
Greater Roadrunner *(Geococcyx californianus)*				X										
Barn Owl *(Tyto alba)*	X													
Western Screech-Owl *(Megascops kennicottii)*														X
Great Horned Owl *(Bubo virginianus)*														X
Burrowing Owl *(Athene cunicularia)*								X			X			X
Long-eared Owl *(Asio otus)*														X
Short-eared Owl *(Asio flammeus)*														X
Common Poorwill *(Phalaenoptilus nuttallii)*									X					X
Broad-billed Hummingbird *(Cynanthus latirostris)*				X	X									
Violet-crowned Hummingbird *(Amazilia violiceps)*				X										
Black-chinned Hummingbird *(Archilochus alexandri)*														X
Costa's Hummingbird *(Calypte costae)*								X			X		X	X
Rufous Hummingbird *(Selasphorus rufus)*								X						X
Allen's Hummingbird *(Selasphorus sasin)*														X
Belted Kingfisher *(Ceryle alcyon)*				X										X
Green Kingfisher *(Chloroceryle americana)*				X				X						
Gila Woodpecker *(Melanerpes uropygialis)*				X										X
Red-naped Sapsucker *(Sphyrapicus nuchalis)*				X										
Ladder-backed Woodpecker *(Picoides scalaris)*				X				X						X
Northern Flicker *(Colaptes auratus)*				X										

SPECIES	ISLANDS *													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Gilded Flicker *(Colaptes chrysoides)*														X
White-striped Woodcreeper *(Lepidocolaptes leucogaster)*				X										
Northern Beardless-Tyrannulet *(Camptostoma imberbe)*				X										
Tufted Flycatcher *(Mitrephanes phaeocercus)*				X										
Western Wood-Pewee *(Contopus sordidulus)*														X
Willow Flycatcher *(Empidonax traillii)*				X	X									X
Hammond's Flycatcher *(Empidonax hammondii)*				X										
Gray Flycatcher *(Empidonax wrightii)*				X										X
Dusky Flycatcher *(Empidonax oberholseri)*				X										
Pacific-slope Flycatcher *(Empidonax difficilis)*				X										X
Cordilleran Flycatcher *(Empidonax occidentalis)*				X										
Western Flycatcher *(E. difficilis* or *E. occidentalis)*					X									X
Buff-breasted Flycatcher *(Empidonax fulvifrons)*				X										
Black Phoebe *(Sayornis nigricans)*				X										X
Say's Phoebe *(Sayornis saya)*				X										X
Vermilion Flycatcher *(Pyrocephalus rubinus)*				X										
Dusky-capped Flycatcher *(Myiarchus tuberculifer)*				X										
Ash-throated Flycatcher *(Myiarchus cinerascens)*				X				X			X			X
Great Kiskadee *(Pitangus sulphuratus)*					X									
Tropical Kingbird *(Tyrannus melancholicus)*				X	X									X
Cassin's Kingbird *(Tyrannus vociferans)*				X										
Rose-throated Becard *(Pachyramphus aglaiae)*				X										
Loggerhead Shrike *(Lanius ludovicianus)*				X										X
Mangrove Vireo *(Vireo pallens)*					X									
Gray Vireo *(Vireo vicinior)*								X						X
Plumbeous Vireo *(Vireo plumbeus)*				X										
Cassin's Vireo *(Vireo cassinii)*				X										

SPECIES	ISLANDS *													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Black-throated Magpie-Jay *(Calocitta colliei)*				X										
Common Raven *(Corvus corax)*				X				X		X	X			X
Purple Martin *(Progne subis)*														X
Tree Swallow *(Tachycineta bicolor)*											X			
Mangrove Swallow *(Tachycineta albilinea)*														X
Violet-green Swallow *(Tachycineta thalassina)*				X										X
Verdin *(Auriparus flaviceps)*	X			X				X						X
Brown Creeper *(Certhia americana)*				X										
Cactus Wren *(Campylorhynchus brunneicapillus)*				X										X
Rock Wren *(Salpinctes obsoletus)*							X	X	X	X				X
Canyon Wren *(Catherpes mexicanus)*				X										X
Sinaloa Wren *(Thryothorus sinaloa)*				X										
Happy Wren *(Thryothorus felix)*				X										
House Wren *(Troglodytes aedon)*				X										X
Marsh Wren *(Cistothorus palustris)*						X								
Ruby-crowned Kinglet *(Regulus calendula)*				X										X
Blue-gray Gnatcatcher *(Polioptila caerulea)*				X				X						
Black-tailed Gnatcatcher *(Polioptila melanura)*														X
Black-capped Gnatcatcher *(Polioptila nigriceps)*				X	X									
Orange-billed Nightingale-Thrush *(Catharus aurantiirostris)*				X										
Hermit Thrush *(Catharus guttatus)*				X										
Northern Mockingbird *(Mimus polyglottos)*				X	X			X		X				X
Sage Thrasher *(Oreoscoptes montanus)*														X
Bendire's Thrasher *(Toxostoma bendirei)*														X
Curve-billed Thrasher *(Toxostoma curvirostre)*				X	X			X						X
American Pipit *(Anthus rubescens)*														X
Phainopepla *(Phainopepla nitens)*														X

SPECIES	ISLANDS *													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Orange-crowned Warbler *(Vermivora celata)*				X							X			X
Nashville Warbler *(Vermivora ruficapilla)*				X										
Yellow Warbler *(Dendroica petechia)*				X	X									X
Yellow-rumped Warbler *(Dendroica coronata)*				X										
Black-throated Gray Warbler *(Dendroica nigrescens)*				X										X
Black-and-white Warbler *(Mniotilta varia)*				X										X
American Redstart *(Setophaga ruticilla)*				X										
Northern Waterthrush *(Seiurus noveboracensis)*				X										
Louisiana Waterthrush *(Seiurus motacilla)*				X										
MacGillivray's Warbler *(Oporornis tolmiei)*				X										
Common Yellowthroat *(Geothlypis trichas)*				X										
Wilson's Warbler *(Wilsonia pusilla)*				X										
Rufous-capped Warbler *(Basileuterus rufifrons)*				X										
Yellow-breasted Chat *(Icteria virens)*				X					X					
Hepatic Tanager *(Piranga flava)*				X										
Green-tailed Towhee *(Pipilo chlorurus)*				X				X						X
Spotted Towhee *(Pipilo maculatus)*				X										
Canyon Towhee *(Pipilo fuscus)*				X										X
Rufous-winged Sparrow *(Aimophila carpalis)*				X										
Botteri's Sparrow *(Aimophila botterii)*														X
Chipping Sparrow *(Spizella passerina)*				X							X			
Clay-colored Sparrow *(Spizella pallida)*				X										
Brewer's Sparrow *(Spizella breweri)*								X						X
Black-throated Sparrow *(Amphispiza bilineata)*								X			X		X	X
Lark Bunting *(Calamospiza melanocorys)*														X
Savannah Sparrow *(Passerculus sandwichensis)*						X	X	X						X
Grasshopper Sparrow *(Ammodramus savannarum)*														X

SPECIES	ISLANDS *													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Fox Sparrow *(Passerella iliaca)*				X										
Song Sparrow *(Melospiza melodia)*				X										
Lincoln's Sparrow *(Melospiza lincolnii)*				X					X					X
Swamp Sparrow *(Melospiza georgiana)*				X										
White-throated Sparrow *(Zonotrichia albicollis)*				X										
White-crowned Sparrow *(Zonotrichia leucophrys)*				X										X
Northern Cardinal *(Cardinalis cardinalis)*				X										X
Pyrrhuloxia *(Cardinalis sinuatus)*				X							X			X
Rose-breasted Grosbeak *(Pheucticus ludovicianus)*														X
Black-headed Grosbeak *(Pheucticus melanocephalus)*				X										
Blue Grosbeak *(Passerina caerulea)*				X										
Lazuli Bunting *(Passerina amoena)*				X										X
Varied Bunting *(Passerina versicolor)*				X										
Western Meadowlark *(Sturnella neglecta)*				X										
Great-tailed Grackle *(Quiscalus mexicanus)*														X
Bronzed Cowbird (Molothrus aeneus)														X
Hooded Oriole *(Icterus cucullatus)*				X										X
Streak-backed Oriole *(Icterus pustulatus)*				X										X
Scott's Oriole *(Icterus parisorum)*														X
House Finch *(Carpodacus mexicanus)*				X				X		X				X
Lesser Goldfinch (*Carduelis psaltria*)				X										X
Lawrence's Goldfinch (*Carduelis lawrencei*)				X										
House Sparrow (*Passer domesticus*)				X										
Number of Species	22	6	16	121	24	7	6	50	17	24	31	1	3	140

[*: 1. Isla Alcatraz ; 2. Isla de Pájaros; 3. Isla Huivulai; 4. Isla Lobos; 5. Isla Masocarit; 6. Isla Patos; 7. Isla Pelícano; 8. Isla San Esteban; 9. Isla San Jorge; 10. Isla San Pedro Mártir; 11. Isla San Pedro Nolasco; 12. Isla Tassen; 13. Isla Turner; 14. Isla Tiburón].

Appendix B

THE STATE OF SONORA: CLIMATE AND VEGETATION

Climate

Climate in most of the state of Sonora is dry, with high temperatures and scarce precipitation; however, the presence of the Sierra Madre Occidental modifies this pattern, so that less extreme temperatures and more abundant rainfall occur in the mountains. With the exception of the San Luis Colorado section in northern part of the state with Mediterranean climate, precipitation is concentrated mostly during the summer months, and normally the winters are dry. According to the climate classification of Köppen, modified by Enriqueta García (García 1973), there are seven types of climate types in the state (Figure B1):

1. Very dry Climate

This climate type covers 46% of the state, in a band along the coastal line in the complete extension of the state, from Sinaloa to the United States border, from sea level to 800m in elevation. In this area, the precipitation is low (normally less than 400 mm a year), and mean annual temperature between 18 and 26°C. The climate is extreme, with the difference between the hottest month and the coldest month being greater than 14°C. It is also known as "Desert climates".

2. Dry Climate

Dry climate covers 20% of the state, over a band extending in a northwest-southwest direction, at elevations ranging form 600 to 1,400m above sea level (normally below 1,000m). It includes three subgroups: Warm climate (Clima Cálido), with temperatures between 22 and 26°C from the center to the south of the state; Semiwarm Climate (Clima Semicálido), with temperatures between 18 and 22°C from the center to the north; and Temperate Climate (Clima

Templado), with temperatures between 12 and 18 °C, in the northeast. Total annual precipitation is between 350 and 500 mm.

3. Semidry Climate

This climate type is present in 28% of the state, on areas in the north and central-eastern portions, where the mean annual temperature goes from 12 to 26°C, and annual precipitation goes from 400 up to 700 mm. The climate is considered transitional between the dry and the temperate climates. According to the temperature, this type can be divided in three subgroups: Warm climate (Clima Cálido), with temperatures between 22 and 26°C in latitudes from 100 to 600m above sea level; Semiwarm Climate (Clima Semicálido), with temperatures between 18 and 22°C in places below 1,200m above sea level and between the 28 and 31° of latitude; and Temperate Climate (Clima Templado), with temperatures between 12 and 18°C, in places with elevation between 1,000 and 2,400m above sea level.

4. Temperate Climate

Only 4% of the state is under a temperate climate, mostly in the eastern sections of Sonora, near the border with the state of Chihuahua, between 1000 and 2000m above sea level, with annual mean temperature between 12 and 18°C, and annual precipitation between 600 and 1,000 mm.

5. Semicold Climate

This climate type is represented in eastern Sonora at elevations between, 2,000 and 2,600m above sea level, on the 0.2% of the state extension; annual mean temperature is between 5 and 12°C, and precipitation can go from 500 up to 1,000 mm.

6. Semiwarm climate

This climate prevails over 1.5% of the state, in the southeastern section over the Sierras. It consists of an annual mean temperature between 18 and 22°C, and precipitation between 600 and 1,000 mm.

7. Warm climate

It is represented in a minimal extension of Sonora (0.3%), in the southeastern section where the limits of Sonora, Chihuahua, and Sinaloa are located. In general, annual mean temperature is between 22 and 26°C, and precipitation between 700 and 1,000 mm.

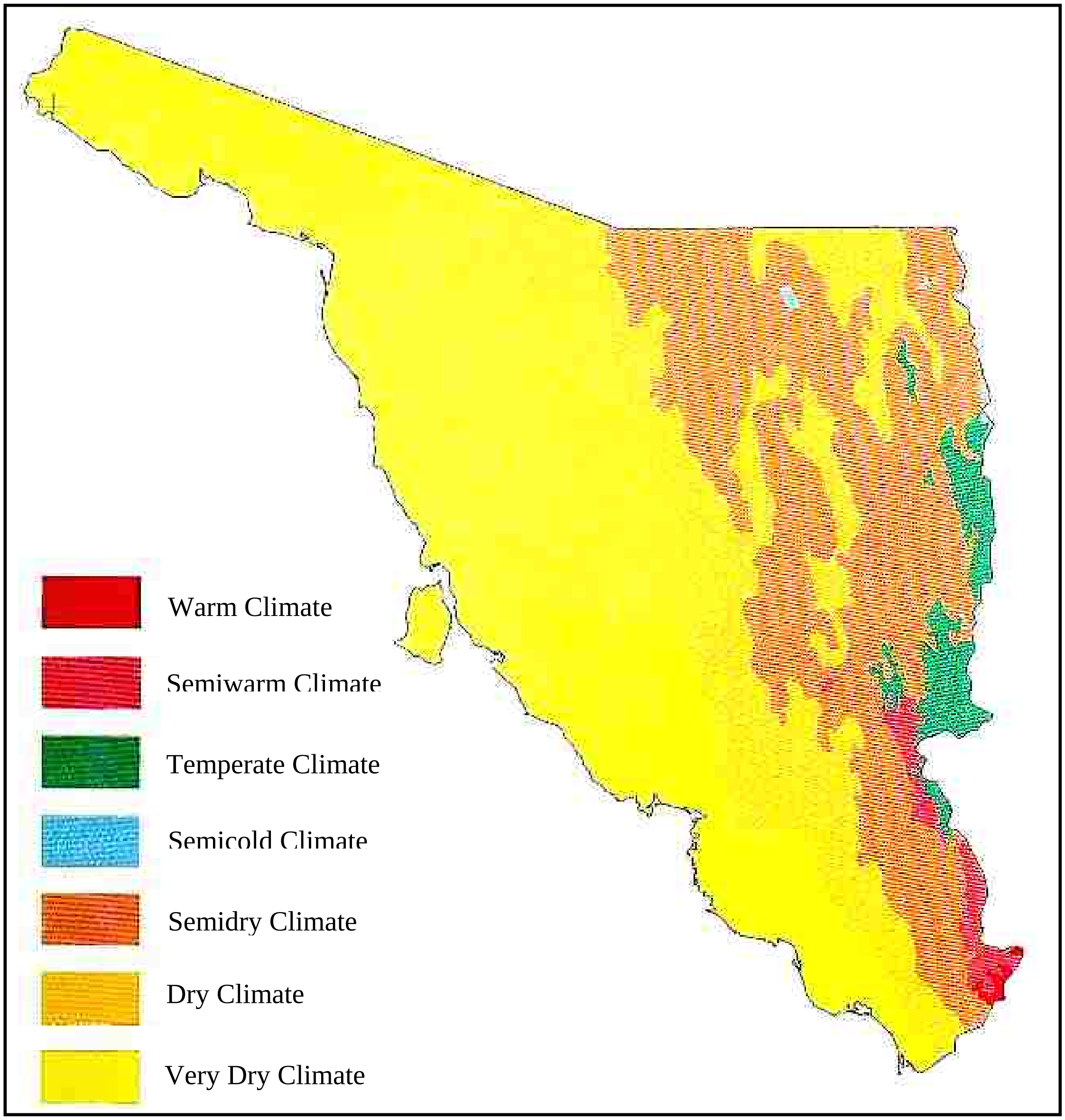

Figure B1. Climate types in Sonora

(Source: INEGI 2000)

Vegetation

The description of the vegetation types in this paper follows the classification used by Instituto Nacional de Estadística, Geografía e Informática (INEGI 2000), and includes additional information from several other important sources (Miranda & Hernández-Xolocotzin 1963, Hastings *et al.* 1972, Rzedowski 1986, Turner *et al.* 1986, Brown 1994, Martin *et al.* 1998). The different classification schemes have been integrated into INEGI's categorization, considering that it has been the scheme used to produce the available cartography for México on a variety of subjects.

1. Forests

Forests include those continuous tracts of vegetation with tall trees dominating the landscape. They comprise the following: Pine forests ("Madrean Montana Conifer Forest" (Brown 1994)); Pine-Oak forests, Oak forests, Oak-Pine forests, and Juniper forests ("Madrean Evergreen Woodland" (Brown 1994)); and Tropical deciduous forests ("Sinaloan Deciduous Forest" (Brown 1994), and "Selva Baja Caducifolia" (Miranda & Hernández-Xolocotzin 1963)).

1.1. Pine Forests (Bosques de Pino)

Pine forests are located in the highest parts of the Sierra Madre Occidental, in places with temperate and subhumid climates, with annual mean temperature from 12 to 16°C, and precipitation of 600 to 800 mm. Their canopy is 15 to 18m high, and it is composed mostly of Durango pine (*Pinus durangensis*), Chihuahua pine (*P. leiophylla* var. *chihuahuana*), apache pine (*P. engelmannii*), Arizona pine (*P. ponderosa* var. *arizonica*), and oaks (*Quercus sideroxyla*). In an intermediate stratum (6 to 8m), we find oaks (*Quercus fulva, Quercus sideroxyla)*, Arizona pine, and juniper (*Juniperus* sp.). A lower stratum (3 to 5m) is formed by Texas madrone (*Arbutus xalapensis*), juniper, Arizona pine, and Arizona white oak (*Quercus arizonica*). The understory contains ceanothuses (*Ceanothus* sp.), depressed oak (*Quercus depressipes*), and bracken fern (*Pteridium aquilinum*), among other species.

In the most humid sites, Durango pine, Douglas fir (*Pseudotsuga menziesii*), true fir (*Abies durangensis*), Arizona pine, bigthoot maple (*Acer grandidentatum*), and Arizona alder (*Alnus oblongifolia*) are present; in exposed locations, pino triste (*Pinus lumholtzii*) has also been reported (Rzedowski 1986). These humid highland forests are considered under the term "Mixed Conifer Forest" by Gentry (Martin *et al.* 1998). Pine forests show some levels of disturbance due mostly to the extraction of pines, and oak wood for cellulose and fuel; some oak species are overgrazed by free ranging cattle.

1.2. Pine – Oak Forests (Bosques de Pino – Encino)

They are located in some areas of the Sierra Madre Occidental near the border with the state of Chihuahua, normally bellow the Pine Forest, where the climate is temperate and subhumid, the annual mean temperature between 12 and 18°C, and rainfall of 600 to 800 mm. Those communities dominated by pine species are established on moderate slopes between 1,900 and 2,300m, and include apache pine, Durango pine, Chihuahua pine, southwestern white pine (*P. ayacahuite* var. *brachyptera*), Arizona pine, and Douglas fir in the 18-25m stratum; Arizona white Oak, *Q. coccolobifolia*, *Q. fulva*, silver-leaf Oak (*Q. hypoleucoides*), Mexican blue oak (*Q. oblongifolia*), netleaf oak (*Q. rugosa*), *Q. sideroxyla*, *Q. viminea*, Texas madrone, and Arizona madrone (*Arbutus arizonica*) in the 6-15m stratum; pointleaf manzanita (*Arctostaphylos pungens*), firecracker bush (*Bouvardia ternifolia*), and ceanothus in the understory. At lower elevations the pine-oak forests grades inconspicuously into oak woodlands.

Some secondary arboreal communities are simpler, shorter (< 4m), and less diverse, basically with a canopy constituted by Durango pine, Chihuahua pine, and one-seed juniper **(***Juniperus monosperma*), and an understory with Arizona madrone, Texan madrone, and pointleaf manzanita; these simplified communities are the result of excessive pine logging. On the other hand, these forests have been subjected to periodic fires in those areas with extensive cattle-grazing.

1.3. Oak Forests (Encinares)

These types of forests are the most extensive in Sonora, and they occur in elevations ranging from 1,100 to 2,200m in the north, and as low as 800m in the southeast. They are located in places with semidry climates at the sierras nearby Nogales (where the annual mean temperature varies from 15.3 to 17.7°C, and the rainfall reaches 428 to 516 mm a year), as well as in more humid temperate to semitropical climates in the south (annual rainfall mean ≈ 800 mm and temperature between 12-18°C).

They are formed by open, and deciduous oak woodlands (5 to 8 m tall) with abundant grasses [sideoats grama (*Bouteloua curtipendula*), hairy grama (*B. hirsuta*), slender grama (*B. filiformis*), plains lovegrass (*Eragrostis intermedia*), Texas bluestem (*Andropogon cirratus*), mountain muhly (*Muhlenbergia montana*), blue grass (*M. emersleyi*), and tanglehead grass (*Heteropogon contortus*), growing in dry conditions. Among the dominant oak species are Arizona white oak, Emory oak (*Q. emoryi*), Mexican blue oak, and Chihuahua oak (*Q. chihuahuensis*). Commonly, two species of junipers are also present (alligatorbark juniper [*Juniperus deppeana*], and one-seed juniper**)**. Shrubby species constitute an intermediate stratum (1-2 m), which may contain species typical of temperate forests (such as smooth bouvardia [*Bouvardia glaberrima*], hopseed bush (*Dodonaea viscosa*), and fragrant sumac [*Rhus aromatica*]), xeric scrublands (leaf succulent agaves [*Agave* sp.], babybonnets [*Coursetia* sp.], desert spoon [*Dasylirion* sp.], franseria [*Franseria* sp.], beargrass (*Nolina* sp.), prickly pear (*Opuntia* spp.), and mesquite), as well as some other species associated to tropical deciduous forest (fernleaf acacia [*Acacia pennatula*], zorrillo [*Cestrum lanatum*], and uvalama [*Vitex mollis*]).

In canyons and protected slopes at high elevations, they can include associations of cusi oak (*Quercus albocincta*), *Q. tuberculata*, *Q. fulva*, hand basin Oak (*Q. pennivenia*), *Q. sipuraca*, Toumei oak (*Q. chuchiuchupensis=toumeyi*), Santa Clara oak (*Q. santaclarensis*), and Mexican white oak (*Q. epileuca*); or netleaf oak, silver-leaf ak, *Q. coccolobifolia*, Texas madrone, with pointleaf manzanita, and Fendler ceanothus (*Ceanothus fendleri*), as well as southwestern white pine, and Chihuahua pine in the higher areas.

The term “Chaparral” has been used at times to refer to those associations of small oak species (3m high) present at low elevations in some areas of Sonora, because of their physiognomic similarity with “true” Chaparral in California and northern Baja California. However, true Chaparral includes species well suited to live under mediterranean climates, with cool and wet winters (October-April), and hot and dry summers (May-September); therefore, they include species adapted to seasonal drought and fire. In order to make a distinction among them, I have decided to refer to them as “lowland oaklands” in this paper.

Logging activities are intense in some areas. Because of cattle overgrazing, forests nearby cities and towns are very disturbed, as indicated by the thin oak’s trunks, or by the dominance of hopseed bush, mimosa (*Mimosa* sp.), and kidneywood (*Eysenhardtia* sp.).

1.4. Oak – Pine Forests (Bosques de Encino – Pino)

These forests are found at elevations of 1,100 – 1,500m above sea level, in steep slopes of the Sierra Madre Occidental, under temperate climates, with mean annual temperature between 12 and 18°C, and rainfall between 500 and 800 mm. They are communities where oaks dominate over the pine species (generally of 10-12m), and they vary in their composition according to changes in relative humidity and topography, among other factors. At dryer and lower elevations we find Emory oak, Chihuahua oak, and Arizona white oak, associated with Mexican pinyon (*Pinus cembroides*), Chihuahua pine, apache pine, and alligatorbark juniper. At higher elevations with more humid conditions the associations change to *Quercus viminea*, *Q. fulva*, and Mexican blue oak, coupled with Chihuahua pine, ocote pine (*Pinus oocarpa*), Yécora pine (*Pinus yecorensis*),and Arizona pine. Logging is also important in these forests, and there are periodic fires set to promote the maintenance of grasses and shrubs to support widespread and extensive cattle grazing.

1.5. Juniper Forests (Bosques de Táscate)

They are located only in restricted and small areas in the highlands of the eastern part of the state, as a transitional community between pine forests and oak woodlands on one hand, and grasslands, xeric scrublands, or tropical deciduous forest on the other. They are very open evergreen communities of varied stature (0.5-6m), that include mainly one-seed juniper associated with blue grama (*Bouteloua gracilis*). It has been suggested that these forests do not constitute a climax community, but instead, they have a secondary origin. They are also know as “Bosque de Escuamifolios” (Miranda & Hernández-Xolocotzin 1963).

1.6. Tropical Deciduous Forest (Bosque Tropical Caducifolio)

This vegetation type is the richest, most diverse, and structurally more complex in Sonora, and represents the northernmost extension of the tropical forests in North America. More than 75% of the trees species lose their leaves and it may appear like arid lifeless vegetation during the dry season; with the rain, however, it grows into a continuous green carpet extending over sierras, hills, barrancas, bajadas, and valleys. These heterogeneous associations are found at a wide range of elevations (from 80 to 1,100m), in sites with semidry and warm climates in their northern distributions (central-eastern Sonora), and in more humid and warmer climates in the south, where they are taller and more exuberant during the dry season. In general, the mean temperature in its distribution ranges from 18 to 25°C, and the rainfall totals from 400 to 900 mm a year.

The composition of tropical deciduous forests is highly variable, depending on factors such as physiography, elevation, and type and degree of disturbance, and includes trees, succulent, and thorny species, being dominant different species of torotes (*Bursera* spp.) and mauto (*Lysiloma divaricata*). The canopy (5 to 12m) includes mauto, torotes (*Bursera laxiflora*, *B. gracilis*, and *B. odorata*), silk cotton tree or pochote (*Ceiba acuminata*), tree morning-glory or palo santo (*Ipomoea arborescens*), and organpipe catus (*Stenocereus thurberi*). In the middle stratum (2 to 5m), some of the most frequent species are palo Adán or Ocotillo (*Fouquieria diguetii*), southwestern coral bean (*Erythrina flabelliformis*), *Bursera nudiflora, Cordia* sp., Mexican alvaradoa (*Alvaradoa amorphoides*), sangrengado copalillo (*Jatropha cordata*), papache (*Randia thurberi*), rosary babybonnets (*Coursetia glandulosa*), and chirahui (*Acacia cymbispina*), in addition to other epiphytic plants and vines. In the understory we can find vara dulce (*Croton flavescens*), prickly pears, papache, canyon ragweed or chicura (*Ambrosia ambrosioides*), and sangrengado (*Jatropha cinerea*), as well as other bushes and grasses. In the southern portions of the state, other species with more restricted distribution are torote copal (*Bursera inopinata*), palo mulato (*B. grandifolia*), palo piojo (*Willardia mexicana*), palo joso (*Conzattia sericea*), palo colorado (*Caesalpinia platyloba*), *Caesalpinia standleyi*, senna (*Senna* spp.), powder puff (*Calliandra rupestris = emarginata*), and tabebuia (*Tabebuia* spp.).

In canyons and in the vicinity of rivers, communities are taller and include additional and more tropical elements, such as guamuchil (*Pithecellobium dulce*), garabato (*Celtis iguanea*), mesquite amargo (*Prosopis juliflora* var. *articulata*), senna, peacock flower (*Caesalpinia pulcherrima*), bolillo (*Leucaena lanceolata*), papache, figs (*Ficus* spp.), brazilwwod (*Haematoxylon brasiletto*), and palo barril (C*ochlospermum vitifolium*).

Secondary communities are not as complex and rich, and tend to be dominated by thorny species, including boat-thorn acacia or huinole (*Acacia cochliacanta*), uña de gato (*Mimosa laxiflora*), sangrengado copalillo, rosary babybonnets, palo Adán, vara dulce, vinorama (*Acacia constricta*), and papache. Extensive grassing is common and widespread in these tropical forests, some agriculture, and the extraction of fuel and plant products are the most important sources of disturbance.

2. Grasslands (Pastizales)

They are communities dominated by different species of grasses, besides herbs and shrubs, belonging mostly to the Composite and Legume families. They are established within the transitional zone between the xeric scrublands and forests in the northeastern part of the state, on valleys and sierras, at elevations ranging from 1,000 to 1,600m. They develop in places with semidry temperate to warm climates, with annual mean temperatures from 16 to 20°C, and annual precipitation between 400 a 500 mm.

Commonly, in their composition they include associations of native grama species of the genus *Bouteloua* (*B. rothrockii, B. curtipendula*, *B. chondrosioides*, *B. filiformis*, *B. hirsuta* and *B. gracilis*), as well as other species of grasses, such as threeawn (*Aristida* spp.), *Andropogon* sp., tanglehead grass, *Hilaria* sp., *Muhlenbergia* sp., and *Sporobolus* sp. Some native or introduced shrub species in the grasslands (as well as in the adjacent communities) are acacia (*Acacia* spp.), false mesquite (*Calliandra eriophylla),* croton (*Croton* sp.), ocotillo (*Fouquieria splendens)*, palo santo (*Ipomoea* sp.), ratany (*Krameria* sp.), wolfberry (*Lycium* sp.), velvet pod mimosa *(Mimosa dysocarpa)*, beargrass, and prickly pear. The main activity in these areas is livestock production. Some extensions have been invaded by viscid acacia (*Acacia neovernicosa)*, false mesquite, hackberry (*Celtis* sp.), condalia (*Condalia* sp.), and mesquite as a result of overgrazing, and native grasses have been substituted by invasive species of threeawn, and woollygrass *(Erioneuron)*. They are the equivalent to the "Semidesert Grasslands" and "Sonoran Savanna Grasslands" of Brown (Brown 1994).

3. Scrublands (Matorrales)

3.1. Subtropical Scrubland (Matorral Subtropical)

In Sonora this vegetation type occupies the transitional zone between xeric scrublands, grasslands, and oak forests. It is located at the western slopes of the Sierra Madre Occidental, at elevations ranging from 200 to 1,900m, on sierras, hills, and canyons. The climate on which the subtropical scrub develops is dry to semidry with fresh winters (mean annual temperature between 18 and 24°C, and annual rainfall from 350 to 600 mm). It shares some species with the Desert Scrublands, Mezquital, and Tropical Deciduous Forest.

In these communities there is a low proportion of thorny species and a higher number of non-deciduous plants, features that make subtropical scrubland different from the Tropical Deciduous Forest. Commonly, they have three strata: the canopy (3 to 6 m) can include species such as torote prieto (*Bursera laxiflora*), elephant tree (*B. microphylla*), fragrant bursera *(B. fagaroides*), ocotillo, littleleaf palo verde (*Cercidium microphyllum*), rosary babybonnets, hopseed bush, coral bean (*Erythrina* sp.), guayacán (*Guaiacum coulteri*), guasima (*Guazuma ulmifolia*), tree morning-glory, mauto, desert ironwood, hecho (*Pachycereus* spp.), mesquite, and organpipe cactus. The intermediate stratum (1-2m) contains acacia, croton, palo verde, Arizona kidneywood (*Eysenhardtia orthocarpa*), Brazilwood, sangrengado (*Jatropha* spp.), wolfberry, uña de gato, prickle pear, otatillo (*Parthenium tomentosum* var. *stramonium*), palo jocono (*Pithecellobium sonorae*), papache, and Mexican jumping bean (*Sapium biloculare*). In the understory (0.35-0.70m), the common plant species are indian mallows (*Abutilon incanum*), San Diego ragweed (*Ambrosia chenopodiifolia*), sideoats grama, slender grama, turflike grass (*Cathestecum erectum*), white brittlebush (*Encelia farinosa*), purple prickle pear (*Opuntia violaceae* var. *macrocentra*), and damiana (*Turnera diffusa*).

The local extraction of some native plant species as food, fuel, medicine, or materials for handcrafts, as well as the extensive cattle grazing has caused important changes in these communities; in those disturbed sites, the shrubby species of adjacent communities are well established (such as mesquite, palo verde, palo dulce, acacia, hopseed bush, and sangregado), meanwhile grasses are the dominant species in other more open communities on plane terrains.

3.2. Desert Scrublands (Matorrales Xerófilos)

They constitute the vegetative cover of considerable extensions of the aridlands on northwestern Mexico and Baja California, and, in general, they are included together under the denomination of "Sonoran Desertscrub" by Brown (Brown 1994). In Sonora, they are located in the coastal plains, hills and sierras, on sites with extreme oscillations in daily temperature, intense sunlight, low atmospheric humidity, and high levels of evapo-transpiration; the annual rainfall varies from 100 to 400 mm (in some cases close to 50 mm). They are highly variable communities in composition, complexity, and physiognomy, with species adapted to aridity (some of the strategies to cope with those conditions are succulence, microphilia or lack of leaves, tomentousness, thorniness, deciduousness, and ephemeral life cycles). These communities can be dominated by one or two species on a unique stratum, meanwhile others can be very rich and include up to four different strata.

These scrublands are important in terms of extensive cattle grazing, and the disturbance level is high in many sites. Some of the plants that are preferred by cattle are chirahui, palo verde, piojito, torote prieto, honey mesquite, and different species of grasses. Local inhabitants use mesquite, desert ironwood, guayacán, Brazilwood, tree morning-glory, and *Ziziphus sonorensis* as fuel.

According to the life forms, structure and species composition, a series of different types of Desert Scrubs can be defined. The features that help to define these groups are the proportion of succulent and subfrutescent species, thorniness, and the degree of deciduousness. The subtypes considered are: 1) "Sarcocaulescent" Scrubland, 2) "Crassicaulescent" Scrubland, 3) "Sarcocrassicaulecent" Scrubland, 4) Microphyll Scrubland, and 5) Thornscrub.

3.2.1. *Sarcocaulescent* Scrubland (Matorral Sarcocaule)

They are constituted mostly by shrubs with juicy and soft stems (subfrutescent), some of them with exfoliating papery bark. They are patchily distributed in the sierras and interior plains, as well as on the coastal plain of the state, from sea level to 1,100m of elevation. They are present in places with very dry and warm climates, with annual mean temperatures from 18 to 24°C, and less than 400 mm of rainfall a year.

The dominant species in the plains, sierras, and bajadas in the northern and northwestern part of its distribution are torotes, different species of sangrengado (*Jatropha cinerea*, *Jatropha cuneata*), desert ironwood, palo verde (*Cercidium floridum*, *Cercidium microphyllum*), ocotillo (*Fouquieria splendens*), honey mesquite (*Prosopis glandulosa* var. *torreyana*), elephant tree, creosotebush, *Citharexylum flabellifolium*, *Desmanthus fruticosus*, granadita (*Colubrina viridis*), teddy-bear cholla (*Opuntia bigelovii*), oregano (*Lippia palmeri*), ejotón (*Pithecellobium confine*), rama parda (*Ruellia californica*), and guayacán (*Viscainoa geniculata*); in the lower stratum we find California encelia (*Encelia californica*), white ragweed (*Ambrosia dumosa*), common needle-grass (*Aristida adscensionis*), woolly plantain (*Plantago insularis*), and parry dalea (*Dalea parryi*). In less arid conditions, we find desert oregano (*Aloysia* sp.), croton, desert spoon, Brazilwood, mauto, and zexmenia (*Zexmenia* sp.).

In the central region of the state, other plants substitute the codominant species creating different communities on hills and small elevations, generally over superficial soils. Nearby Guaymas, the dominant tree species are elephant tree, honey mesquite, ocotillo, and Willard's acacia (*Acacia willardiana*), and are accompanied by shrubs such as rosary babybonnets, sweet acacia (*Acacia farnesiana*), piojito (*Caesalpinia pumila*), cacti of the genera *Stenocereus* and *Pachycereus*, choyas (jumping cholla [*Opuntia fulgida*], cane Cholla [*O. spinosior*]), sixweeks grama (*Bouteloua barbata*), and big sandbur (*Cenchrus myosuroides*).

In the southwestern slopes of Sierra Madre Occidental and the coastal plains the composition and physiognomy of this vegetation are different. The species in the canopy (2-3m) are sangrengados (*Jatropha cordata*, *J. cuneata*, and *J. cinerea*), torotes (*Bursera laxiflora*, *B. odorata*, and *B. fagaroides*), chirahui, palo verde, Brazilwood, ocotillo, mauto, guayacán, and

Cordia sp. In the median stratum (1-2m) there are desert christmas cactus (*Opuntia leptocaulis*), palo jocono, sangrengados, papache, *Ziziphus sonorensis*, *Condalia coulteri*, palo colorado, tree morning-glory, and Mexican kidneywood (*Eysenhardtia polystachya*); due to disturbance, some species such as snake-eyes (*Phaulothamnus spinescens*), Coville's bundleflower (*Desmanthus covillei*), Sonoran caper (*Atamisquea emarginata*), and tasajo (*Stenocereus alamosensis*) can be present. The following species are part of the undersotry (0.15- 0.70m): prickly pear (*Opuntia* sp.), vara dulce, Berlandier wolfberry (*Lycium berlandieri*), xoconoxtle (*Pereskiopsis porteri)*, and grasses of the genera *Aristida*, *Bouteloua*, *Cathestecum*, *Muhlenbergia*, and *Setaria*.

3.2.2. *Crassicaulescent* Scrubland (Matorral Crasicaule)

In this vegetation, the dominant species are succulent elements that form those associations known as “Cardonales”, “Sahuarales”, and “Nopaleras”. They are found from sea level up to 150m of elevation, under very dry climatic conditions (annual mean temperature of 22 – 24°C, and less than 350 mm of rainfall). In the sierras near Sonoita, sahuaros (*Carnegiea gigantea*), palo verde, candelabro (*Myrtillocactus* sp.), teddy-bear cholla and, white brittlebush are dominant. On the coastal plains near Huatabampo, the most common species are hairbrush cactus (*Pachycereus pecten-aboriginum*), and organpipe cactus, in association with palo verde and sangregados. In the plains of the northeastern part of the state, this vegetation is dominated by an association of *Cercidium-Opuntia*, with other species such as saguaro, palo verde, mesquite, desert ironwood, ocotillo, and creosotebush.

3.2.3. *Sarcocrassicaulescent* Scrubland (Matorral Sarcocrasicaule)

In this type of scrublands, the succulent and the subfrutescent elements are present in similar proportions. They are located in small areas from sea level to 230m of elevation, under very dry conditions (mean annual temperature of 22°C, and rainfall between 180 and 200 mm). The dominant elements can be different cacti species (including some of the genus *Machaerocereus*), and other species of *Jatropha* and *Bursera*. One of the driest versions is located near Tastiota and Cerro Prieto, where this scrubland is dominated by elephant tree, sangrengado (*Jatropha cuneata*), and sour pitahaya (*Machaerocereus gummosus*). Around the

Presa Plutarco Elías Calles, and north and east from Sahuaripa, torote prieto and sangrengados are the dominant species.

A variation of this scrubland has been called "**Coastal thornscrub**", which is represented by associations of thorny shrubs, vines, small trees, and cacti on very plane landscapes near the coastline, known locally as "Pitahayeras. Among the trees and large cacti there are palo brea, palo jito (*Forchhammeria watsoni*), jaboncillo (*Fouquieria macdougalii*), guayacán, sangrengado copalillo, San Juanico (*Jacquinia macrocarpa*), sinita, honey mesquite, organpipe cactus, and saituna (*Ziziphus amole*). Common shrubs include Tucson burr ragweed (*Ambrosia cordifolia*), vara prieta (*Cordia parviflora*), sangrengado, thornbush, and cacachila (*Karwinskia humboldtiana*).

3.3. Microphyll Scrubland (Matorral Micrófilo)

They are shrubby communities of small-leaved species that grow on sandy deserts, in the most arid regions of Mexico. They are widely distributed in Sonora, in the Northern portion of the state, at elevations ranging from sea level to 1,200m, under dry and generally warm climatic conditions (mean temperatures between 20 and 24°C and less than 400 mm of rain during the year). They are represented by diverse plant associations, in which the percentage of thorny species can be very different. However, some species that are dominant and characterize this vegetation type are creosotebush, palo verde (*Cercidium microphyllum*, *C. floridum*, and *C. praecox*), desert ironwood, ocotillo, acacia, honey mesquite, San Diego ragweed, white ragweed, and white brittlebush.

Structurally, they have three strata; the canopy (2-3m) includes the species listed previously, as well as sahuaro, sinita, elephant tree, sangrengado, thornbush, and kidneywood. The median stratum (1-1.5m), includes also viscid acacia, catclaw (*Acacia greggii*), sangregados (*Jatropha cardiophylla*, *J. cuneata*, *J. cinerea*, and *J. cordata*), cholla (*Opuntia cholla*), desert christmas cactus, mimosa, jojoba, piojito, sinita, Mexican crucillo (*Condalia warnockii*), graythorn (*Condalia lycioides*), tepeguaje (*Lysiloma watsonii*), granjeno (*Celtis pallida*), yellow trumpet flower (*Tecoma stans*), and hopseed bush.

In the lower stratum (0.5m) the dominant species belong to the Families Compositae family (California encelia and white brittlebush), Fabaceae (false mesquite, desert senna (*Senna covesii*), mimosa and dalea (*Dalea* sp.)), Poaceae, (sideoats grama, other species of *Bouteloua*, common needle-grass, and turflike grass), Chenopodiaceae (fourwing saltbush [*Atriplex canescens*], and seablite (*Suaeda* sp.)), besides several sangrengado species. Many disturbed and overgrazed sites are characterized by an evidently scarce vegetative cover, visible erosion, and low plant diversity.

3.4. Thornscrub (Mesquital)

Mesquite species are dominant in this type of scrubland, which covers hills and bajadas of the northern Sierras and plains, as well as in the coastal plains, from sea level to 1,200m in elevation. They develop under dry and warm climates (180 to 400 mm rainfall, annual mean temperatures between 18 and 24°C). They can be 3-5m tall, and have two or three strata, where the most common species are honey mesquite and velvet mesquite (*Prosopis velutina*), accompanied by other shrubs and grasses found in the adjacent Microphyll or Sarcocaulescent scrublands; however, there are a number of local versions in which the dominant species change. Rzedowski (1986) includes mesquital as part of “Bosque Espinoso”.

In the northern distributions, the dominant species can be acacia, ragweed, sahuaro, hackberry, blue palo verde (*Cercidium floridum*), condalia, encelia, euphorbia (*Euphorbia* sp.), sangrengado, sinita, thornbush, uña de gato, desert ironwood, and teddy-bear cholla.

In the center of the state, velvet mesquite and chirahui are the most important species on plains and hills, being associated with Sonora palo verde (*Cercidium sonorae*), Brazilwood, piojito, cacachila, and abundant grasses. Between Guaymas-Hermosillo-Santa Ana, there is an open mesquite scrub with littleleaf palo verde, desert ironwood, white brittlebush, organpipe cactus, sinita, cholla, desert senna, papache, and false mesquite.

On the river plains of the southern part of the state, honey mesquite is associated with thornbush, privet (*Forestiera* sp.), pearlberry (*Vallesia glabra*), condalia, chamiso salado (*Suaeda fruticosa*), and iodinebush (*Allenrolfea occidentalis*).

3.5. Sandy Desert Vegetation

This community type is formed by annual and perennial herbs, as well as some shrubby species, and occurs from sea level to 150m on the Desierto de Altar. In these places, the extreme temperatures, the low humidity, and the soil conditions limit the growth of some perennial species, and determine the low cover of this vegetation. Their composition and structure are simple, having a single stratum composed by a few species, most of them being ephemerals. Some of the species present in sandy dunes are sand verbena (*Abronia villosa*), white ragweed, California threeawn (*Aristida californica*), desert milkweed (*Asclepias subulata*), chamiso, flat-seeded spurge (*Chamaesyce platysperma*), desert dicoria (*Dicoria canescens*), spectacle pod (*Dithyrea californica*), drymary (*Drymaria viscose*), long-leaf ephedra (*Ephedra trifurca*), big galleta (*Hilaria rigida*), creosotebush, Arizona lupine (*Lupinus arizonicus*), desert primrose (*Oenothera deltoids*), honey mesquite, and Palmer's crinklemat (*Tiquilia palmeri*). These communities remain basically in its primary conditions, although some species have been used by Pápago indigenous people as food sources.

4. Halophyte vegetation

It can be found from sea level up to 150m of elevation, in areas with saline soils, where the vegetation cover comprises herbs, low shrubs, and some small succulent species. They form small bands and patches along the coast, and some extensions within the Desierto de Altar in the northwest of Sonora. They are established in places where the mean temperature is between 20 and 24°C, and the rainfall is less than 200 mm a year.

The associations can include a series of obligated and tolerant saline plants, belonging mostly to the familes Poaceae, Chenopodiaceae, and Frankeniaceae, such as pickleweed, lippia, seaheath (*Frankenia* sp.), alkali sacaton (*Sporobolus airoides*), chamiso, teddy-bear cholla, satlbush (*Atriplex barclayana*), iodinebush, inkweed (*Suaeda torreyana*), alkali blite (*Suaeda fruticosa*), maytenus (*Maytenus phyllanthoides*), *Lycium carinatum*, amole (*Stegnosperma halimifolium*), snake-eyes, and oregano.

5. Sonoran Oasis Woodlands

They are relict and restricted tropical woodlands growing within moist canyons with permanent springs near the coast of western Sonora. These sites are very diverse in plants species; however, they are represented by an association of palm species (*Brahea brandegeei*, *Sabal uresana*, and *Washingtonia robusta*), fig trees (*Ficus petiolaris*), and other tropical species such as vara prieta (*Cordia parvofolia*) and Brazilwood. Other species that are found at Cañón de Nacapule are Nacapule Jasmin (*Vallesia laciniata*), *Calliandra californica*, buckwheat (*Coccoloba goldmanii*), agaves (*Agave chrysoglossa* and *A. colorata*), Ratany, *Passiflora arida*, and *Passiflora mexicana*, among many others (Sánchez-Escalante 2004).

6. Mangroves

Mangroves in Sonora are communities of halophytes with small trees (<3m) formed in protected estuaries by black mangrove (*Avicennia germinans*), buttonwood (*Conocarpus erecta*), white mangrove (*Laguncularia racemosa*), and red mangrove (*Rhizophora mangle*), associated with iodinebush, pickleweed, and Mohave seablite. The northernmost distribution of mangroves in the Gulf of California occurs at 400 km north from the border with the state of Sinaloa, and they are rare or absent north of 29°N. In these northern areas they constitute relatively small patches of black mangrove. They are included under the denomination of "Sinaloan Maritime Scrubland" by Brown (Brown 1994).

7. Riparian vegetation

Riparian communities are rich and show impressive local variations depending on the elevation, the substrate, the surrounding vegetation, and the continuity of the water flow through out the year. They have been described in the fourth chapter of this volume.

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Appendix B1. Scientific names, common names and families of plants mentioned in the text.

Scientific Name	Common Name	Family
Abies durangensis	True Fir	Pinaceae
Abronia villosa	Sand Verbena	Nyctaginaceae
Abutilon incanum	Indian Mallow	Malvaceae
Acacia cochliacanta	Boat-thorn Acacia, Huinole	Fabaceae
Acacia constricta	Vinorama, Whitethorn Acacia	Fabaceae
Acacia cymbispina	Chirahui	Fabaceae
Acacia farnesiana	Sweet Acacia	Fabaceae
Acacia greggii	Catclaw, Uña de Gato	Fabaceae
Acacia neovernicosa	Viscid Acacia	Fabaceae
Acacia pennatula	Fernleaf Acacia	Fabaceae
Acacia spp.	Acacia	Fabaceae
Acacia willardiana	Willard's Acacia	Fabaceae
Acer grandidentatum	Bigthoot Maple	Aceraceae
Acer sp.	Alder	Aceraceae
Agave chrysoglossa	Agave	Agavaceae
Agave colorata	Agave	Agavaceae
Agave sp.	Agave	Agavaceae
Agonandra racemosa	Man Vine	Opiliaciae
Albizia sinaloensis	Sinaloa Silk Tree	Fabaceae
Allenrolfea occidentalis	Iodinebush	Chenopodiaceae
Alnus oblongifolia	Arizona Alder	Betulaceae
Aloysia sp.	Desert Oregano	Fabaceae
Alvaradoa amorphoides	Mexican Alvaradoa	Simaroubaceae
Ambrosia ambrosioides	Canyon Ragweed, Chicura	Asteraceae
Ambrosia chenopodiifolia	San Diego Ragweed, Chamizo	Asteraceae
Ambrosia cordifolia	Tucson Burr Ragweed	Asteraceae
Ambrosia dumosa	White Ragweed	Asteraceae
Ambrosia spp.	Ragweed	Asteraceae
Andropogon cirratus	Texas Bluestem	Poaceae
Andropogon sp.	Grass	Poaceae
Arbutus arizonica	Arizona Madrone	Ericaceae
Arbutus xalapensis	Texas Madrone	Ericaceae
Arctostaphylos pungens	Pointleaf Manzanita	Ericaceae
Aristida adscensionis	Common needle grass	Poaceae
Aristida californica	California Threeawn	Poaceae
Aristida spp.	Threeawn	Poaceae
Asclepias subulata	Desert milkweed	Asclepiadaceae
Atamisquea emarginata	Sonoran Caper, Palo zorrillo	Capparaceae
Atriplex barclayana	Saltbush	Chenopodiaceae
Atriplex canescens	Fourwing Saltbush, Chamiso	Chenopodiaceae
Atriplex lentiformis	Quail bush	Chenopodiaceae
Atriplex polycarpa	Saltbush	Chenopodiaceae
Avicennia germinans	Black mangrove	Avicenniaceae
Baccharis salicifolia	Mulefat, Seepwillow, Batamote	Asteraceae

Scientific Name	Common Name	Family
Bouteloua barbata	Sixweeks Grama	Poaceae
Bouteloua chondrosioides	Grama	Poaceae
Bouteloua curtipendula	Sideoats Grama	Poaceae
Bouteloua filiformis	Slender Grama	Poaceae
Bouteloua gracilis	Blue Grama	Poaceae
Bouteloua hirsuta	Hairy Grama	Poaceae
Bouteloua rothrockii	Rothrock Grama	Poaceae
Bouteloua spp.	Grama	Poaceae
Bouvardia glaberrima	Smooth Bouvardia	Rubiaceae
Bouvardia ternifolia	Firecracker Bush	Rubiaceae
Brahea brandegeei	Palm	Arecaceae
Bursera fagaroides	Fragrant Bursera, Torote	Burseraceae
Bursera gracilis	Torote	Burseraceae
Bursera grandifolia	Palo Mulato	Burseraceae
Bursera inopinata	Torote Copal	Burseraceae
Bursera laxiflora	Torote Prieto	Burseraceae
Bursera microphylla	Elephant Tree	Burseraceae
Bursera nudiflora	Torote	Burseraceae
Bursera odorata	Torote Blanco	Burseraceae
Bursera spp.	Torote	Burseraceae
Caesalpinia platyloba	Palo Colorado	Fabaceae
Caesalpinia pulcherrima	Peacock flower	Fabaceae
Caesalpinia pumila	Piojito	Fabaceae
Caesalpinia standleyi		Fabaceae
Calliandra californica		Fabaceae
Calliandra eriophylla	False Mesquite	Fabaceae
Calliandra rupestris=emarginata	Powder Puff	Fabaceae
Carnegiea gigantea	Sahuaro	Cactaceae
Cathestecum erectum	Turflike Grass	Poaceae
Cathestecum sp.	Grass	Poaceae
Ceanothus fendleri	Fendler Ceanothus	Rhamnaceae
Ceanothus sp.	Ceanothus	Rhamnaceae
Ceiba acuminata	Silk Cotton Tree, Pochote	Bombacaceae
Celtis iguanea	Garabato	Ulmaceae
Celtis pallida	Granjeno	Ulmaceae
Celtis sp.	Hackberry	Ulmaceae
Cenchrus myosuroides	Big Sandbur, Toboso	Poaceae
Cercidium floridum	Blue Palo Verde	Fabaceae
Cercidium microphyllum	Littleleaf Palo Verde	Fabaceae
Cercidium praecox	Palo brea	Fabaceae
Cercidium sonorae	Sonora Palo Verde	Fabaceae
Cercidium spp.	Palo Verde	Fabaceae
Cestrum lanatum	Zorrillo	Solanaceae
Chamaesyce platysperma	Flat-seeded Spurge	Euphorbiaceae
Citharexylum flabellifolium	Fiddlewood	Verbenaceae
Coccoloba goldmanii	Buckwheat	Polygonaceae
Cochlospermum vitifolium	Palo Barril	Bixaceae

Scientific Name	Common Name	Family
Colubrina viridis	Granadita	Rhamnaceae
Condalia coulteri	Condalia	Rhamnaceae
Condalia lycioides	Graythorn	Rhamnaceae
Condalia sp.	Condalia	Rhamnaceae
Condalia warnockii	Mexican Crucillo	Rhamnaceae
Conocarpus erecta	Buttonwood	Combretaceae
Conzattia sericea	Palo Joso	Fabaceae
Cordia parviflora	Vara Prieta	Boraginaceae
Cordia sp.	Cordia	Boraginaceae
Cornus sp.	Dogwood	Cornaceae
Coursetia glandulosa	Rosary Babybonnets	Fabaceae
Coursetia sp.	Babybonnets	Fabaceae
Crataegus sp.	Hawthorn	Rosaceae
Croton flavescens	Vara dulce	Euphorbiaceae
Croton sp.	Croton	Euphorbiaceae
Dalea parryi	Parry Dalea	Fabaceae
*Dalea*sp.	Dalea	Fabaceae
Dasylirion sp.	Desert Spoon, Sotol	Nolinaceae
Desmanthus covillei	Coville's bundleflower	Fabaceae
Desmanthus fruticosus	Bundleflower	Fabaceae
Dicoria canescens	Desert Dicoria	Asteraceae
Diospyros sonorae	Zapote	Ebenaceae
Dithyrea californica	Spectacle Pod	Brassicaceae
Dodonaea viscosa	Hopseed Bush	Sapindaceae
Drymaria viscose	Drymary	Caryophyllaceae
Elaeagnus angustifolia	Russian Olive	Elaeagnaceae
Encelia californica	California Encelia	Asteraceae
Encelia farinosa	White Brittlebush	Asteraceae
Encelia spp.	Encelia	Asteraceae
Ephedra trifurca	Long-leaf Ephedra	Ephedraceae
Eragrostis intermedia	Plains Lovegrass	Poaceae
Erioneuron spp.	Woollygrass	Poaceae
Erythrina flabelliformis	Southwestern Coral Bean	Fabaceae
Erythrina sp.	Coral Bean	Fabaceae
Euphorbia spp.	Euphorbia	Euphorbiaceae
Eysenhardtia orthocarpa	Arizona Kidneywood	Fabaceae
Eysenhardtia polystachya	Mexican Kidneywood	Fabaceae
Eysenhardtia sp.	Kidneywood	Fabaceae
Ficus petiolaris	Fug tree	Moraceae
Ficus spp.	Fig	Moraceae
Forchhammeria watsoni	Palo Jito	Capparaceae
Forestiera spp.	Privet	Oleaceae
Fouquieria diguetii	Palo Adán, Ocotillo	Fouquieriaceae
Fouquieria macdougalii	Jaboncillo	Fouquieriaceae
Fouquieria splendens	Ocotillo	Fouquieriaceae
Fouquieria spp.	Ocotillo	Fouquieriaceae
Frankenia sp.	Seaheath	Frankeniaceae

Scientific Name	Common Name	Family
Franseria sp.	Franseria	Asteraceae
Guaiacum coulteri	Guayacán	Zygophyllaceae
Guazuma ulmifolia	Guasima	Sterculiaceae
Haematoxylon brasiletto	Brazilwood, Palo Brasil	Fabaceae
Heteropogon contortus	Tanglehead Grass	Poaceae
Hilaria sp.	Grass	Poaceae
Hymenoclea monogyra	Jeco	Asteraceae
Ipomoea arborescens	Tree morning-glory, Palo Santo	Convolvulaceae
Ipomoea sp.	Palo Santo	Convolvulaceae
Jacquinia macrocarpa	San Juanico	Theophrastaceae
Jatropha cardiophylla	Sangrengado	Euphorbiaceae
Jatropha cinerea	Sangrengado	Euphorbiaceae
Jatropha cordata	Sangrengado Copalillo	Euphorbiaceae
Jatropha cuneata	Sangrengado	Euphorbiaceae
Jatropha spp.	Sangrengado	Euphorbiaceae
Juniperus deppeana	Alligatorbark Juniper	Cupressaceae
Juniperus monosperma	One Seed Juniper	Cupressaceae
Juniperus sp.	Juniper	Cupressaceae
Karwinskia humboldtiana	Cacachila	Rhamnaceae
Krameria erecta	Ratany	Krameriaceae
Krameria sp.	Ratany, Cosahui	Krameriaceae
Laguncularia racemosa	White Mangrove	Combretaceae
Larrea tridentata	Creosote Bush	Zygophyllaceae
Leucaena lanceolata	Bolillo	Fabaceae
Lippia palmeri	Oregano	Verbenaceae
Lophocereus schottii	Sinita	Cactaceae
Lupinus arizonicus	Arizona Lupine	Fabaceae
Lycium berlandieri	Berlandier Wolfberry	Solanaceae
Lycium carinatum	Wolfberry	Solanaceae
Lycium sp.	Wolfberry	Solanaceae
Lysiloma divaricata	Mauto	Fabaceae
Lysiloma watsonii	Tepeguaje	Fabaceae
Machaerocereus gummosus	Sour Pitahaya	Cactaceae
Maytenus phyllanthoides	Maytenus	Celastraceae
Mimosa dysocarpa	Velvet Pod Mimosa, Gatuño	Fabaceae
Mimosa laxiflora	Uña de gato	Fabaceae
Mimosa sp.	Mimosa	Fabaceae
Muhlenbergia emersleyi	Bull Grass	Poaceae
Muhlenbergia montana	Mountain Muhly	Poaceae
Muhlenbergia sp.	Grass	Poaceae
Myrtillocactus sp.	Candelabro	Cactaceae
Nolina sp.	Beargrass	Nolinaceae
Oenothera deltoides	Desert Primrose	Onagraceae
Olneya tesota	Desert Ironwood	Fabaceae
Opuntia bigelovii	Teddy-bear cholla	Cactaceae
Opuntia cholla	Cholla	Cactaceae
Opuntia fulgida	Jumping cholla	Cactaceae

Scientific Name	Common Name	Family
Opuntia leptocaulis	Desert Christmas Cactus	Cactaceae
Opuntia sp.	Prickly pear	Cactaceae
Opuntia spinosior	Cane Cholla	Cactaceae
Opuntia violaceae var. *macrocentra*	Purple Prickle Pear	Cactaceae
Pachycereus pecten-aboriginum	Hairbrush Cactus, Hecho	Cactaceae
Pachycereus pringlei	Elephant Cactus, Cardón	Cactaceae
Pachycereus spp.	Crardón	Cactaceae
Panicum sonorum	Sonoran Panic Grass	Poaceae
Parkinsonia aculeata	Jerusalem Thorn	Fabaceae
Parthenium tomentosum stramonium	Otatillo	Asteraceae
Passiflora arida	Pasiflora	Passifloraceae
Passiflora mexicana	Pasiflora	Passifloraceae
Pereskiopsis porteri	Xoconoxtle	Cactaceae
Phaulothamnus spinescens	Snake-eyes, Mal de Ojo	Phytolaccaceae
Phragmites australis	Reed	Poaceae
Pinus ayacahuite var. *brachyptera*	Southwestern White Pine	Pinaceae
Pinus cembroides	Mexican Pinyon	Pinaceae
Pinus durangensis	Durango Pine	Pinaceae
Pinus engelmannii	Apache Pine	Pinaceae
Pinus leiophylla var. chihuahuana	Chihuahua Pine	Pinaceae
Pinus lumholtzii	Pino Triste	Pinaceae
Pinus oocarpa	Ocote Pine	Pinaceae
Pinus ponderosa var. arizonica	Arizona Pine	Pinaceae
Pinus spp.	Pine	Pinaceae
Pinus yecorensis	Yécora pine	Pinaceae
Pisonia capitata	Pisonia	Nyctaginaceae
Pithecellobium confine	Ejotón	Fabaceae
Pithecellobium dulce	Guamuchil	Fabaceae
Pithecellobium sonorae	Palo jocono	Fabaceae
Plantago insularis	Woolly Plantain	Plantaginaceae
Platanus wrightii	Sycamore, Aliso	Platanaceae
Pleuraphis = Hilaria rigida	Big Galleta	Poaceae
Pluchea salicifolia	Mexican camphorweed	Asteraceae
Populus angustifolia	Narrowleaf Cottonwood	Salicaceae
Populus fremontii	Fremont Cottonwood	Salicaceae
Populus mexicana var. *dimorpha*	Mexican Cottonwood	Salicaceae
Populus tremuloides	Quaking Aspen	Salicaceae
Prosopis glandulosa var. *torreyana*	Honey Mesquite	Fabaceae
Prosopis juliflora var. *articulata*	Mesquite amargo	Fabaceae
Prosopis spp.	Mesquite	Fabaceae
Prosopis velutina	Velvet or Screwbean Mesquite	Fabaceae
Pseudotsuga menziesii	Douglas-Fir	Pinaceae
Psorothamnus spinosus	Smoke Tree	Fabaceae
Pteridium aquilinum	Bracken Fern	Dennstaedtiaceae
Quercus albocincta	Cusi oak	Fagaceae
Quercus arizonica	Arizona White Oak	Fagaceae
Quercus chihuahuensis	Chihuahua Oak	Fagaceae

Scientific Name	Common Name	Family
Quercus chuchiuchupensis = toumeyi	Toumei Oak	Fagaceae
Quercus coccolobifolia	Oak	Fagaceae
Quercus depressipes	Depressed Oak	Fagaceae
Quercus emoryi	Emory Oak	Fagaceae
Quercus epileuca	Mexican white Oak	Fagaceae
Quercus fulva	Oak	Fagaceae
Quercus hypoleucoides	Silver-leaf Oak	Fagaceae
Quercus oblongifolia	Mexican Blue Oak	Fagaceae
Quercus pennivenia	Hand Basin Oak	Fagaceae
Quercus rugosa	Netleaf Oak	Fagaceae
Quercus santaclarensis	Santa Clara Oak	Fagaceae
Quercus sideroxyla	Oak	Fagaceae
Quercus sipuraca	Oak	Fagaceae
Quercus tuberculata	Oak	Fagaceae
Quercus viminea	Oak	Fagaceae
Randia thurberi	Papache	Rubiaceae
Rhizophora mangle	Red Mangrove	Rhizophoraceae
Rhus aromatica	Fragrant Sumac	Anacardiaceae
Ruellia californica	Rama Parda	Acanthaceae
Sabal uresana	Sabal Palm	Arecaceae
Salicornia sp.	Pickleweed	Chenopodiaceae
Salix bondplandiana	Bonpland Willow	Salicaceae
Salix exigua	Coyote Willow	Salicaceae
Salix gooddingii	Goodding Willow	Salicaceae
Salix sp.	Willow	Salicaceae
Sambucus sp.	Elder	Salicaceae
Sapium biloculare	Mexican Jumping Bean	Euphorbiaceae
Scirpus sp.	Bulrush	Cyperaceae
Senna covesii	Desert Senna	Fabaceae
Senna spp.	Senna	Fabaceae
Setaria sp.	Bristlegrass	Poaceae
Sideroxylon tepicense	Tepic Zapote	Sapotaceae
Simmondsia chinensis	Jojoba	Simmondsiaceae
Sporobolus ariorides	Alkali Sacaton	Poaceae
Sporobolus sp.	Grass	Poaceae
Stegnosperma halimifolium	Amole	Phytolaccaceae
Stemmadenia tomentosa	Huevos	Apocynaceae
Stenocereus alamosensis	Tasajo	Cactaceae
Stenocereus sp.	Pitahaya	Cactaceae
Stenocereus thurberi	Organ Pipe Cactus, Pitahaya	Cactaceae
Suaeda fruticosa = ramosissima	Alkali Blite	Chenopodiaceae
Suaeda moquinii	Mohave Seablite	Chenopodiaceae
Suaeda sp.	Seablite	Chenopodiaceae
Suaeda torreyana	Inkweed	Chenopodiaceae
Tabebuia impetiginosa	Purple Tabebuia	Bignoniaceae
Tabebuia spp.	Tabebuia, Amapa	Bignoniaceae
Tamarix ramosissima	Saltcedar	Tamaricaceae

Scientific Name	Common Name	Family
Taxodium distichum var. *mexicana*	Baldcypress, Sabino	Cupressaceae
Tecoma stans	Yellow Trumpet Flower	Bignoniaceae
Tessaria sericea	Arroweed	Asteraceae
Tiquilia palmeri	Palmer's Crinklemat	Boraginaceae
Turnera diffusa	Damiana	Turneraceae
Typha spp.	Cattail	Typhaceae
Vallesia glabra	Pearlberry, Sitavaro	Apocynaceae
Vallesia laciniata	Nacapule Jasmin	Apocynaceae
Viscainoa geniculata	Guayacán	Zygophyllaceae
Vitex mollis	Uvalama	Verbenaceae
Washingtonia robusta	Palm	Arecaceae
Willardia Mexicana	Palo Piojo	Fabaceae
Zexmenia sp.	Zexmenia	Asteraceae
Ziziphus amole	Saituna	Rhamnaceae
Ziziphus sonorensis		Rhamnaceae

Appendix C. Mean number of individuals per count for the species recorded in the vegetation types sampled in Sonora (January-February 2004-2006) (25-m radius).

			HABITAT TYPE (VEGETATION)														
Species	**Status**	**Indiv**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**
Elegant Quail	R	9	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Gambel's Quail	R	79	0.043	0.000	0.000	0.000	0.130	0.120	0.000	0.000	0.000	0.224	0.014	0.060	0.000	0.000	0.000
Northern Bobwhite	R	6	0.003	0.000	0.000	0.000	0.000	0.160	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Black Vulture	R	70	0.038	0.145	0.000	0.000	0.022	0.000	0.000	0.000	0.741	0.013	0.000	0.000	0.055	0.000	0.000
Turkey Vulture	R	31	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.033	0.000	0.012	0.236	0.000	0.117
Sharp-shinned Hawk	PM	1	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.017
Cooper's Hawk	PM	2	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Red-tailed Hawk	R	8	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.024	0.018	0.000	0.033
American Kestrel	PM	5	0.003	0.000	0.000	0.000	0.007	0.000	0.000	0.022	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Killdeer	R	25	0.014	0.000	0.000	0.000	0.000	0.040	0.000	0.000	0.000	0.013	0.000	0.000	0.000	0.000	0.017
Northern Jacana	R	4	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Spotted Sandpiper	M	49	0.027	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Least Sandpiper	M	6	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Wilson's Snipe	M	6	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Band-tailed Pigeon	R	1	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.017
White-winged Dove	R	113	0.062	0.000	0.000	0.095	0.007	0.000	0.025	0.000	0.000	0.092	0.000	0.012	0.309	0.000	0.000
Mourning Dove	R	173	0.095	0.000	0.067	0.000	0.022	0.000	0.013	0.178	0.121	0.112	0.314	0.506	0.018	0.000	0.000
Inca Dove	R	34	0.019	0.000	0.000	0.000	0.000	0.040	0.000	0.000	0.000	0.086	0.000	0.000	0.000	0.000	0.000
Common Ground-Dove	R	24	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.012	0.000	0.000	0.000
White-tipped Dove	R	8	0.004	0.000	0.000	0.048	0.000	0.000	0.038	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Greater Roadrunner	R	15	0.008	0.000	0.000	0.000	0.007	0.040	0.013	0.000	0.017	0.007	0.000	0.024	0.036	0.000	0.000
Burrowing Owl	R	1	0.001	0.000	0.000	0.000	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

			HABITAT TYPE (VEGETATION)														
Species	**Status**	**Indiv**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**
Broad-billed Hummingbird	R	107	0.059	0.000	0.000	0.381	0.051	0.000	0.506	0.067	0.000	0.072	0.014	0.000	0.000	0.000	0.000
White-eared Hummingbird	R	4	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.026	0.033
Violet-crowned Hummingbird	R	16	0.009	0.000	0.000	0.000	0.000	0.000	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Williamson's Sapsucker	M	1	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.017
Plain-capped Starthroat	R	4	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Black-chinned Hummingbird	PM	7	0.004	0.000	0.000	0.000	0.000	0.000	0.025	0.000	0.000	0.020	0.000	0.000	0.000	0.000	0.000
Anna's Hummingbird	M	3	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Costa's Hummingbird	R	52	0.029	0.073	0.000	0.238	0.058	0.000	0.038	0.022	0.034	0.059	0.029	0.000	0.000	0.000	0.000
Calliope Hummingbird	M	1	0.001	0.000	0.000	0.000	0.000	0.040	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Broad-tailed Hummingbird	PM	3	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rufous Hummingbird	M	8	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Unknown Hummingbird	PM	17	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.000	0.000	0.000	0.000	0.017
Elegant Trogon	R	1	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Belted Kingfisher	M	3	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.017
Green Kingfisher	R	56	0.031	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Lewis's Woodpecker	M	3	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.036	0.000	0.000
Acorn Woodpecker	R	19	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.109	0.013	0.150
Gila Woodpecker	R	215	0.118	0.000	0.000	0.095	0.116	0.320	0.063	0.044	0.207	0.197	0.057	0.157	0.127	0.013	0.000
Red-naped Sapsucker	M	17	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.013	0.050
Ladder-backed Woodpecker	R	64	0.035	0.000	0.033	0.000	0.014	0.120	0.076	0.022	0.052	0.033	0.000	0.036	0.036	0.013	0.000
Hairy Woodpecker	R	2	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.033
Arizona Woodpecker	R	6	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.036	0.000	0.067
Northern Flicker	R	21	0.012	0.000	0.000	0.000	0.022	0.000	0.051	0.000	0.034	0.013	0.000	0.012	0.018	0.000	0.033
Gilded Flicker	R	25	0.014	0.000	0.000	0.000	0.000	0.240	0.000	0.000	0.086	0.020	0.000	0.133	0.000	0.000	0.000
Northern Beardless-Tyrannulet	R	15	0.008	0.000	0.000	0.048	0.000	0.000	0.025	0.000	0.000	0.000	0.000	0.000	0.018	0.000	0.000

			HABITAT TYPE (VEGETATION)														
Species	**Status**	**Indiv**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**
Tufted Flycatcher	R	2	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Greater Pewee	R	1	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Western Wood-Pewee	PM	1	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Willow Flycatcher	M	1	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Gray Flycatcher	M	29	0.016	0.000	0.000	0.000	0.000	0.040	0.000	0.111	0.000	0.013	0.000	0.000	0.000	0.000	0.000
Dusky Flycatcher	M	10	0.005	0.000	0.000	0.000	0.000	0.000	0.013	0.000	0.000	0.000	0.000	0.000	0.018	0.000	0.000
Pacific-slope Flycatcher	M	8	0.004	0.000	0.000	0.000	0.000	0.000	0.025	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cordilleran Flycatcher	PM	1	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Western Flycatcher	PM	5	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Buff-breasted Flycatcher	R	2	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.017
Empidonax sp.	PM	148	0.081	0.000	0.000	0.000	0.022	0.000	0.025	0.000	0.000	0.013	0.000	0.000	0.000	0.038	0.017
Black Phoebe	R	222	0.122	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.036	0.013	0.000
Eastern Phoebe	M	3	0.002	0.000	0.000	0.000	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Say's Phoebe	PM	29	0.016	0.000	0.000	0.000	0.007	0.000	0.000	0.000	0.000	0.013	0.014	0.036	0.000	0.000	0.017
Vermilion Flycatcher	R	50	0.027	0.000	0.000	0.000	0.000	0.000	0.000	0.022	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Dusky-capped Flycatcher	R	18	0.010	0.000	0.000	0.000	0.000	0.000	0.051	0.000	0.000	0.000	0.000	0.000	0.018	0.000	0.000
Ash-throated Flycatcher	R	83	0.046	0.018	0.000	0.143	0.159	0.000	0.203	0.000	0.017	0.158	0.029	0.012	0.036	0.000	0.000
Nutting's Flycatcher	R	6	0.003	0.000	0.000	0.000	0.000	0.000	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Brown-crested Flycatcher	PM	13	0.007	0.018	0.000	0.000	0.043	0.000	0.000	0.022	0.000	0.000	0.000	0.012	0.000	0.000	0.000
Great Kiskadee	R	5	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Social Flycatcher	R	1	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cassin's Kingbird	PM	8	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.020	0.000	0.000	0.000	0.000	0.000
Loggerhead Shrike	PM	24	0.013	0.000	0.000	0.000	0.014	0.040	0.000	0.000	0.017	0.033	0.000	0.084	0.000	0.000	0.000
Bell's Vireo	PM	3	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.000	0.000	0.000	0.000	0.000
Plumbeous Vireo	PM	4	0.002	0.000	0.000	0.000	0.000	0.000	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

			HABITAT TYPE (VEGETATION)														
Species	**Status**	**Indiv**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**
Cassin's Vireo	M	6	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Hutton's Vireo	R	5	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.038	0.033
Warbling Vireo	PM	7	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Black-throated Magpie-Jay	R	8	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mexican Jay	R	16	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.073	0.064	0.050
Common Raven	R	26	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.017	0.079	0.000	0.024	0.018	0.000	0.067
Horned Lark	R	11	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.039	0.029	0.036	0.000	0.000	0.000
Violet-green Swallow	PM	39	0.021	0.036	0.000	0.000	0.036	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.582	0.000	0.000
Northern Rough-winged Swallow	PM	1	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mexican Chickadee	R	13	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.128	0.050
Bridled Titmouse	R	51	0.028	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.127	0.231	0.117
Verdin	R	405	0.222	0.073	0.033	0.190	0.500	0.680	0.177	0.711	0.345	0.651	0.014	0.398	0.055	0.000	0.000
Bushtit	R	17	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.026	0.000
White-breasted Nuthatch	R	12	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.036	0.038	0.083
Brown Creeper	R	5	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.083
Cactus Wren	R	153	0.084	0.000	0.000	0.000	0.174	0.120	0.025	0.022	0.310	0.362	0.043	0.289	0.127	0.000	0.000
Rock Wren	R	16	0.009	0.000	0.033	0.000	0.014	0.000	0.013	0.000	0.000	0.000	0.000	0.000	0.018	0.115	0.017
Canyon Wren	R	7	0.004	0.000	0.000	0.143	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.018	0.013	0.000
Sinaloa Wren	R	19	0.010	0.000	0.000	0.000	0.000	0.000	0.051	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Happy Wren	R	6	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bewick's Wren	R	43	0.024	0.000	0.000	0.000	0.000	0.000	0.000	0.044	0.052	0.000	0.000	0.012	0.164	0.064	0.000
House Wren	PM	73	0.040	0.000	0.000	0.000	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.051	0.033
Marsh Wren	M	1	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ruby-crowned Kinglet	M	506	0.278	0.000	0.000	0.048	0.000	0.040	0.000	0.000	0.000	0.007	0.014	0.024	0.236	0.256	0.350

			HABITAT TYPE (VEGETATION)														
Species	**Status**	**Indiv**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**
Blue-gray Gnatcatcher	PM	440	0.242	0.018	0.000	0.238	0.304	0.000	0.544	0.200	0.069	0.033	0.000	0.036	0.182	0.000	0.000
Black-tailed Gnatcatcher	R	217	0.119	0.000	0.167	0.000	0.087	0.280	0.418	0.622	0.362	0.178	0.100	0.205	0.000	0.000	0.000
Black-capped Gnatcatcher	R	84	0.046	0.000	0.000	0.000	0.029	0.120	0.000	0.000	0.121	0.046	0.000	0.000	0.000	0.000	0.000
Eastern Bluebird	R	9	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.103	0.017
Hermit Thrush	M	8	0.004	0.000	0.000	0.048	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.017
American Robin	PM	22	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.367
Northern Mockingbird	PM	180	0.099	0.000	0.000	0.000	0.652	0.040	0.025	0.044	0.069	0.191	0.014	0.120	0.018	0.000	0.000
Bendire's Thrasher	PM	7	0.004	0.000	0.000	0.048	0.000	0.000	0.000	0.022	0.000	0.020	0.000	0.012	0.000	0.000	0.000
Curve-billed Thrasher	R	85	0.047	0.000	0.000	0.000	0.058	0.080	0.013	0.000	0.172	0.145	0.000	0.169	0.091	0.013	0.000
American Pipit	M	12	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Phainopepla	R	47	0.026	0.000	0.000	0.048	0.022	0.320	0.000	0.022	0.000	0.105	0.071	0.072	0.000	0.000	0.000
Olive Warbler	R	3	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.050
Orange-crowned Warbler	M	145	0.080	0.164	0.000	0.333	0.152	0.000	0.101	0.000	0.000	0.020	0.000	0.024	0.018	0.026	0.000
Nashville Warbler	M	14	0.008	0.000	0.000	0.190	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Lucy's Warbler	PM	3	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Crescent-chested Warbler	R	1	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.013	0.000
Yellow Warbler	PM	14	0.008	0.255	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Yellow-rumped Warbler	M	436	0.239	0.073	0.000	0.048	0.000	0.080	0.000	0.000	0.052	0.059	0.000	0.084	0.055	0.244	0.167
Black-throated Gray Warbler	M	36	0.020	0.000	0.000	0.048	0.007	0.000	0.051	0.000	0.000	0.000	0.000	0.000	0.018	0.013	0.000
Townsend's Warbler	M	2	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.033
Hermit Warbler	M	4	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.026	0.033
Black-and-white Warbler	M	6	0.003	0.000	0.000	0.000	0.000	0.000	0.063	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
American Redstart	M	2	0.001	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Northern Waterthrush	M	4	0.002	0.073	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MacGillivray's Warbler	M	12	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

			HABITAT TYPE (VEGETATION)														
Species	**Status**	**Indiv**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**
Common Yellowthroat	PM	170	0.093	0.527	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Grasshopper Sparrow	PM	1	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.017
Wilson's Warbler	M	68	0.037	0.000	0.000	0.048	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Painted Redstart	PM	12	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.077	0.000
Slate-throated Redstart	R	1	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rufous-capped Warbler	R	5	0.003	0.000	0.000	0.000	0.000	0.000	0.038	0.000	0.000	0.000	0.000	0.000	0.000	0.026	0.000
Yellow-breasted Chat	PM	3	0.002	0.000	0.000	0.000	0.022	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Hepatic Tanager	R	13	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.026	0.000
Summer Tanager	PM	1	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Green-tailed Towhee	M	174	0.096	0.036	0.000	0.000	0.022	0.040	0.025	0.133	0.086	0.013	0.014	0.108	0.000	0.000	0.000
Spotted Towhee	PM	17	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.018	0.013	0.183
Canyon Towhee	R	56	0.031	0.000	0.000	0.048	0.000	0.120	0.063	0.222	0.034	0.059	0.000	0.036	0.091	0.051	0.017
Rufous-winged Sparrow	R	74	0.041	0.000	0.000	0.000	0.000	0.040	0.000	0.000	0.069	0.145	0.000	0.253	0.036	0.000	0.000
Cassin's Sparrow	PM	1	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.000	0.000	0.000	0.000	0.000
Rufous-crowned Sparrow	R	50	0.027	0.000	0.000	0.000	0.000	0.000	0.203	0.044	0.000	0.007	0.000	0.048	0.255	0.013	0.000
Five-striped Sparrow	R	7	0.004	0.000	0.000	0.000	0.000	0.000	0.089	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Chipping Sparrow	PM	515	0.283	0.000	0.000	0.571	0.000	0.280	0.000	0.511	0.000	0.000	0.000	0.072	0.473	0.628	0.100
Clay-colored Sparrow	M	39	0.021	0.000	0.000	0.000	0.283	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Brewer's Sparrow	M	127	0.070	0.000	0.000	0.000	0.000	1.280	0.000	0.267	0.000	0.000	0.100	0.265	0.182	0.000	0.000
Black-chinned Sparrow	M	1	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Vesper Sparrow	M	5	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.000	0.012	0.000	0.000	0.033
Lark Sparrow	M	255	0.140	0.000	0.000	0.000	0.036	0.400	0.000	0.067	0.034	0.053	0.000	0.229	0.291	0.000	0.100
Black-throated Sparrow	R	46	0.025	0.000	0.233	0.000	0.080	0.000	0.000	0.000	0.190	0.013	0.014	0.024	0.018	0.000	0.000
Savannah Sparrow	PM	26	0.014	0.055	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.241	0.018	0.013	0.017
Song Sparrow	PM	351	0.193	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.017	0.000	0.000	0.000	0.000	0.000	0.000

			HABITAT TYPE (VEGETATION)														
Species	**Status**	**Indiv**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**
Lincoln's Sparrow	M	47	0.026	0.073	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
White-crowned Sparrow	M	172	0.094	0.036	0.000	0.000	0.029	0.240	0.000	0.333	0.000	0.000	0.143	0.012	0.000	0.000	0.000
Dark-eyed Junco	M	60	0.033	0.000	0.000	0.095	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.141	0.767
Yellow-eyed Junco	R	21	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.026	0.317
Northern Cardinal	R	134	0.074	0.018	0.000	0.190	0.043	0.040	0.076	0.067	0.052	0.138	0.000	0.012	0.018	0.013	0.000
Pyrrhuloxia	R	41	0.023	0.000	0.000	0.000	0.000	0.000	0.013	0.044	0.000	0.013	0.000	0.048	0.000	0.000	0.000
Black-headed Grosbeak	PM	10	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.073	0.000	0.000
Blue Grosbeak	PM	3	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Lazuli Bunting	M	5	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Varied Bunting	PM	4	0.002	0.000	0.000	0.000	0.000	0.000	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Red-winged Blackbird	PM	32	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Western Meadowlark	PM	21	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.241	0.000	0.000	0.000
Brewer's Blackbird	M	1	0.001	0.000	0.000	0.000	0.000	0.040	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Great-tailed Grackle	R	21	0.012	0.073	0.000	0.000	0.007	0.000	0.000	0.000	0.000	0.026	0.000	0.000	0.000	0.000	0.000
Streak-backed Oriole	R	34	0.019	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bullock's Oriole	M	1	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Scott's Oriole	PM	2	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.026	0.000
House Finch	R	222	0.122	0.036	0.000	0.143	0.268	0.080	0.000	0.044	0.207	0.243	0.229	0.060	0.018	0.090	0.033
Pine Siskin	M	1	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.013	0.000
Lesser Goldfinch	R	124	0.068	0.073	0.000	0.000	0.000	0.200	0.000	0.000	0.034	0.000	0.000	0.000	0.109	0.000	0.000
Lawrence's Goldfinch	M	5	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
House Sparrow	R	2	0.001	0.000	0.000	0.000	0.000	0.080	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Number of Counts			**1816**	**54**	**30**	**21**	**138**	**25**	**79**	**45**	**58**	**152**	**70**	**83**	**54**	**75**	**60**
Number of species detected			**168**	**24**	**6**	**24**	**40**	**32**	**38**	**27**	**29**	**49**	**19**	**44**	**47**	**39**	**44**
Mean number of species per count				**1.40**	**0.47**	**2.24**	**2.04**	**3.04**	**2.38**	**2.20**	**2.12**	**2.48**	**0.63**	**2.18**	**2.25**	**1.33**	**1.97**

			HABITAT TYPE (VEGETATION)														
Species	**Status**	**Indiv**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**
Number of Residents				**10**	**6**	**13**	**23**	**20**	**26**	**16**	**22**	**31**	**13**	**27**	**32**	**24**	**23**
Percentage of Residents				41.7	100	54.2	57.5	62.5	68.4	59.3	75.9	63.3	68.4	61.4	68.1	61.5	52.3
Number of Partial Migrants				**6**	**0**	**3**	**10**	**3**	**6**	**6**	**4**	**11**	**2**	**9**	**7**	**7**	**10**
Percentage of Partial Migrants				25.0	0.0	12.5	25.0	9.4	15.8	22.2	13.8	22.4	10.5	20.5	14.9	17.9	22.7
Number of Migrants				**8**	**0**	**8**	**7**	**9**	**6**	**5**	**3**	**7**	**4**	**8**	**8**	**8**	**11**
Percentage of Migrants				33.3	0.0	33.3	17.5	28.1	15.8	18.5	10.3	14.3	21.1	18.2	17.0	20.5	25.0
Number of Individuals detected			**8,237**	**107**	**17**	**74**	**491**	**145**	**255**	**177**	**210**	**595**	**88**	**357**	**253**	**214**	**229**
Mean number of Individuals per count			**4.54**	**1.98**	**0.57**	**3.52**	**3.56**	**5.80**	**3.23**	**3.93**	**3.62**	**3.91**	**1.26**	**4.30**	**4.69**	**2.85**	**3.82**

STATUS: R = Resident species, PM = Partial Migrant Species; M = Migrant Species. Indiv: Number of individuals detected.

[HABITAT TYPES (VEGETATION): A = All habitat types; B = Mangroves; C = Microphylous Scrubland; D = Oasis; E = Coastal Sarcocaulescent Scrubland; F = Subtropical Scrub; G = Tropical Deciduous Forest; H = Thornscrub; I = Sarcocrassicaulescent Scrubland; J = Sarcocaulescent Scrubland; K = Vegetation of sandy deserts; L = Grasslands; M = Low elevation Oaklands; N = High elevation oaklands; O = Highland Coniferous Forest].

Appendix D. Mean number of individuals per count for the species recorded in the riparian vegetations sampled in Sonora (January-February 2004-2006) (25-m radius).

			RIPARIAN HABITATS*									
Species	**Status**	**Indiv.**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Elegant Quail	R	9	0.010	0.000	0.011	0.000	0.000	0.000	0.037	0.000	0.000	0.000
Gambel's Quail	R	18	0.021	0.000	0.000	0.112	0.000	0.000	0.037	0.000	0.000	0.000
Northern Bobwhite	R	2	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.061
Turkey Vulture	R	5	0.006	0.000	0.000	0.011	0.038	0.000	0.000	0.000	0.000	0.000
Cooper's Hawk	PM	2	0.002	0.000	0.011	0.000	0.010	0.000	0.000	0.000	0.000	0.000
Red-tailed Hawk	R	3	0.003	0.000	0.000	0.000	0.000	0.032	0.000	0.004	0.043	0.000
American Kestrel	PM	3	0.003	0.000	0.000	0.000	0.000	0.000	0.005	0.004	0.043	0.000
Killdeer	R	21	0.024	0.000	0.000	0.000	0.000	0.000	0.028	0.057	0.087	0.000
Northern Jacana	R	4	0.005	0.070	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Spotted Sandpiper	M	48	0.055	0.018	0.066	0.022	0.058	0.032	0.056	0.078	0.087	0.000
Least Sandpiper	M	6	0.007	0.000	0.000	0.000	0.000	0.000	0.028	0.000	0.000	0.000
Wilson's Snipe	M	6	0.007	0.000	0.000	0.000	0.010	0.000	0.009	0.013	0.000	0.000
White-winged Dove	R	76	0.087	0.193	0.077	0.326	0.029	0.032	0.075	0.035	0.043	0.000
Mourning Dove	R	70	0.080	0.000	0.011	0.124	0.019	0.000	0.112	0.113	0.217	0.030
Inca Dove	R	20	0.023	0.263	0.000	0.022	0.000	0.000	0.000	0.013	0.000	0.000
Common Ground-Dove	R	23	0.026	0.281	0.022	0.045	0.000	0.032	0.000	0.000	0.000	0.000
White-tipped Dove	R	4	0.005	0.018	0.000	0.000	0.010	0.000	0.005	0.004	0.000	0.000
Greater Roadrunner	R	6	0.007	0.000	0.000	0.011	0.000	0.000	0.005	0.009	0.087	0.000
Broad-billed Hummingbird	R	37	0.042	0.123	0.088	0.112	0.010	0.065	0.014	0.026	0.000	0.000
Violet-crowned Hummingbird	R	15	0.017	0.000	0.033	0.000	0.067	0.000	0.014	0.009	0.000	0.000
Plain-capped Starthroat	R	4	0.005	0.018	0.000	0.000	0.000	0.097	0.000	0.000	0.000	0.000
Black-chinned Hummingbird	PM	2	0.002	0.000	0.000	0.000	0.000	0.000	0.005	0.004	0.000	0.000
Anna's Hummingbird	M	3	0.003	0.000	0.000	0.011	0.000	0.000	0.005	0.004	0.000	0.000

			RIPARIAN HABITATS*									
Species	**Status**	**Indiv.**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Costa's Hummingbird	R	18	0.021	0.000	0.033	0.022	0.000	0.000	0.023	0.035	0.000	0.000
Broad-tailed Hummingbird	PM	3	0.003	0.000	0.000	0.000	0.000	0.000	0.009	0.000	0.000	0.030
Rufous Hummingbird	M	8	0.009	0.000	0.000	0.011	0.010	0.000	0.005	0.022	0.000	0.000
Unknown Hummingbird	PM	15	0.017	0.000	0.000	0.000	0.000	0.000	0.019	0.048	0.000	0.000
Elegant Trogon	R	1	0.001	0.000	0.000	0.000	0.000	0.032	0.000	0.000	0.000	0.000
Belted Kingfisher	M	2	0.002	0.018	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000
Green Kingfisher	R	56	0.064	0.088	0.099	0.022	0.029	0.161	0.065	0.078	0.000	0.000
Lewis's Woodpecker	M	1	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.000
Acorn Woodpecker	R	3	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.091
Gila Woodpecker	R	115	0.132	0.158	0.066	0.022	0.096	0.032	0.112	0.217	0.478	0.061
Red-naped Sapsucker	M	13	0.015	0.000	0.033	0.000	0.019	0.000	0.009	0.017	0.043	0.030
Ladder-backed Woodpecker	R	37	0.042	0.053	0.033	0.034	0.019	0.000	0.065	0.048	0.043	0.000
Northern Flicker	R	6	0.007	0.000	0.000	0.000	0.000	0.000	0.023	0.004	0.000	0.000
Northern Beardless-Tyrannulet	R	11	0.013	0.088	0.022	0.000	0.010	0.000	0.000	0.009	0.043	0.000
Tufted Flycatcher	R	2	0.002	0.000	0.000	0.000	0.019	0.000	0.000	0.000	0.000	0.000
Greater Pewee	R	1	0.001	0.000	0.000	0.000	0.000	0.032	0.000	0.000	0.000	0.000
Western Wood-Pewee	PM	1	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.043	0.000
Willow Flycatcher	M	1	0.001	0.000	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000
Gray Flycatcher	M	21	0.024	0.000	0.000	0.034	0.058	0.032	0.019	0.022	0.000	0.061
Dusky Flycatcher	M	8	0.009	0.000	0.000	0.000	0.000	0.194	0.000	0.009	0.000	0.000
Pacific-slope Flycatcher	M	6	0.007	0.053	0.000	0.000	0.000	0.000	0.000	0.013	0.000	0.000
Cordilleran Flycatcher	PM	1	0.001	0.000	0.000	0.011	0.000	0.000	0.000	0.000	0.000	0.000
Western Flycatcher	PM	5	0.006	0.000	0.000	0.000	0.000	0.065	0.014	0.000	0.000	0.000
Buff-breasted Flycatcher	R	1	0.001	0.000	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000
Empidonax sp.	PM	137	0.157	0.140	0.154	0.067	0.308	0.000	0.154	0.161	0.304	0.000

			RIPARIAN HABITATS*									
Species	**Status**	**Indiv.**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Black Phoebe	R	218	0.250	0.088	0.231	0.146	0.346	0.484	0.346	0.209	0.217	0.030
Eastern Phoebe	M	2	0.002	0.000	0.022	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Say's Phoebe	PM	21	0.024	0.000	0.000	0.034	0.000	0.000	0.056	0.022	0.043	0.000
Vermilion Flycatcher	R	49	0.056	0.158	0.055	0.022	0.000	0.000	0.028	0.104	0.000	0.091
Dusky-capped Flycatcher	R	13	0.015	0.105	0.000	0.000	0.038	0.000	0.000	0.004	0.087	0.000
Ash-throated Flycatcher	R	11	0.013	0.035	0.000	0.079	0.000	0.000	0.000	0.009	0.000	0.000
Nutting's Flycatcher	R	5	0.006	0.018	0.000	0.000	0.010	0.097	0.000	0.000	0.000	0.000
Brown-crested Flycatcher	PM	4	0.005	0.000	0.000	0.045	0.000	0.000	0.000	0.000	0.000	0.000
Great Kiskadee	R	5	0.006	0.035	0.000	0.011	0.010	0.000	0.005	0.000	0.000	0.000
Social Flycatcher	R	1	0.001	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cassin's Kingbird	PM	5	0.006	0.018	0.033	0.000	0.000	0.032	0.000	0.000	0.000	0.000
Loggerhead Shrike	PM	8	0.009	0.018	0.000	0.000	0.019	0.000	0.005	0.017	0.000	0.000
Bell's Vireo	PM	2	0.002	0.035	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Plumbeous Vireo	PM	3	0.003	0.018	0.000	0.000	0.010	0.000	0.005	0.000	0.000	0.000
Cassin's Vireo	M	6	0.007	0.035	0.000	0.000	0.010	0.000	0.005	0.009	0.000	0.000
Warbling Vireo	PM	7	0.008	0.088	0.011	0.000	0.000	0.000	0.005	0.000	0.000	0.000
Black-throated Magpie-Jay	R	8	0.009	0.140	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mexican Jay	R	4	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.017	0.000	0.000
Common Raven	R	6	0.007	0.000	0.000	0.011	0.000	0.000	0.000	0.017	0.043	0.000
Northern Rough-winged Swallow	PM	1	0.001	0.000	0.000	0.000	0.000	0.000	0.005	0.000	0.000	0.000
Bridled Titmouse	R	19	0.022	0.000	0.000	0.000	0.000	0.000	0.009	0.022	0.000	0.364
Verdin	R	108	0.124	0.158	0.066	0.483	0.087	0.000	0.093	0.078	0.130	0.000
Bushtit	R	15	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.013	0.000	0.364
White-breasted Nuthatch	R	2	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.030
Cactus Wren	R	16	0.018	0.035	0.000	0.079	0.000	0.000	0.009	0.022	0.000	0.000

			RIPARIAN HABITATS*									
Species	**Status**	**Indiv.**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Rock Wren	R	1	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.030
Canyon Wren	R	2	0.002	0.000	0.000	0.000	0.010	0.000	0.005	0.000	0.000	0.000
Sinaloa Wren	R	15	0.017	0.053	0.000	0.000	0.019	0.097	0.009	0.022	0.000	0.000
Happy Wren	R	6	0.007	0.070	0.000	0.000	0.010	0.000	0.005	0.000	0.000	0.000
Bewick's Wren	R	23	0.026	0.000	0.000	0.000	0.000	0.000	0.033	0.070	0.000	0.000
House Wren	PM	65	0.075	0.193	0.044	0.022	0.173	0.161	0.075	0.035	0.000	0.030
Marsh Wren	M	1	0.001	0.000	0.000	0.011	0.000	0.000	0.000	0.000	0.000	0.000
Ruby-crowned Kinglet	M	446	0.511	0.105	0.220	0.079	0.702	0.032	0.757	0.652	0.826	0.242
Blue-gray Gnatcatcher	PM	318	0.365	0.667	0.396	0.079	0.490	0.194	0.360	0.378	0.696	0.000
Black-tailed Gnatcatcher	R	60	0.069	0.070	0.088	0.416	0.000	0.097	0.009	0.026	0.000	0.000
Black-capped Gnatcatcher	R	63	0.072	0.035	0.055	0.000	0.317	0.097	0.061	0.030	0.000	0.000
Hermit Thrush	M	6	0.007	0.000	0.000	0.000	0.019	0.000	0.014	0.004	0.000	0.000
Northern Mockingbird	PM	40	0.046	0.140	0.011	0.225	0.010	0.000	0.005	0.022	0.174	0.000
Bendire's Thrasher	PM	1	0.001	0.000	0.000	0.011	0.000	0.000	0.000	0.000	0.000	0.000
Curve-billed Thrasher	R	22	0.025	0.053	0.000	0.112	0.000	0.000	0.019	0.022	0.000	0.000
American Pipit	M	12	0.014	0.000	0.022	0.000	0.000	0.000	0.023	0.022	0.000	0.000
Phainopepla	R	7	0.008	0.000	0.000	0.079	0.000	0.000	0.000	0.000	0.000	0.000
Orange-crowned Warbler	M	92	0.106	0.140	0.088	0.247	0.115	0.097	0.079	0.091	0.043	0.000
Nashville Warbler	M	10	0.011	0.088	0.000	0.000	0.029	0.000	0.005	0.004	0.000	0.000
Lucy's Warbler	PM	3	0.003	0.035	0.000	0.000	0.000	0.032	0.000	0.000	0.000	0.000
Yellow-rumped Warbler	M	378	0.433	0.193	0.297	0.281	0.298	0.161	0.617	0.543	0.783	0.121
Black-throated Gray Warbler	M	28	0.032	0.140	0.000	0.011	0.019	0.065	0.056	0.013	0.000	0.000
Black-and-white Warbler	M	1	0.001	0.000	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000
American Redstart	M	1	0.001	0.000	0.000	0.000	0.000	0.000	0.005	0.000	0.000	0.000
MacGillivray's Warbler	M	12	0.014	0.193	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000

			RIPARIAN HABITATS*									
Species	**Status**	**Indiv.**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Common Yellowthroat	PM	141	0.162	0.228	0.121	0.067	0.250	0.097	0.192	0.174	0.043	0.000
Wilson's Warbler	M	67	0.077	0.298	0.011	0.011	0.077	0.194	0.107	0.048	0.000	0.000
Painted Redstart	PM	6	0.007	0.000	0.000	0.000	0.000	0.032	0.000	0.013	0.000	0.061
Slate-throated Redstart	R	1	0.001	0.000	0.000	0.000	0.000	0.032	0.000	0.000	0.000	0.000
Hepatic Tanager	R	11	0.013	0.000	0.011	0.000	0.019	0.000	0.019	0.017	0.000	0.000
Summer Tanager	PM	1	0.001	0.000	0.000	0.011	0.000	0.000	0.000	0.000	0.000	0.000
Green-tailed Towhee	M	143	0.164	0.053	0.143	0.225	0.375	0.226	0.065	0.191	0.130	0.000
Spotted Towhee	PM	4	0.005	0.000	0.000	0.000	0.000	0.000	0.009	0.009	0.000	0.000
Canyon Towhee	R	13	0.015	0.018	0.000	0.011	0.010	0.000	0.000	0.022	0.217	0.000
Rufous-winged Sparrow	R	24	0.028	0.211	0.000	0.022	0.000	0.000	0.000	0.043	0.000	0.000
Rufous-crowned Sparrow	R	12	0.014	0.000	0.000	0.067	0.000	0.000	0.000	0.000	0.000	0.182
Chipping Sparrow	PM	386	0.443	0.333	0.121	0.584	0.462	0.000	0.369	0.765	0.000	0.030
Brewer's Sparrow	M	44	0.050	0.000	0.044	0.000	0.000	0.000	0.000	0.174	0.000	0.000
Black-chinned Sparrow	M	1	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.000
Vesper Sparrow	M	1	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.000
Lark Sparrow	M	186	0.213	0.035	0.022	0.067	0.058	0.000	0.136	0.570	0.435	0.000
Black-throated Sparrow	R	11	0.013	0.035	0.000	0.000	0.000	0.000	0.000	0.039	0.000	0.000
Song Sparrow	PM	350	0.401	0.035	0.110	0.045	0.288	0.000	0.636	0.704	0.261	0.000
Lincoln's Sparrow	M	43	0.049	0.070	0.000	0.067	0.125	0.226	0.019	0.039	0.000	0.000
White-crowned Sparrow	M	134	0.154	0.000	0.088	0.169	0.154	0.000	0.145	0.243	0.348	0.000
Dark-eyed Junco	M	1	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.000
Northern Cardinal	R	86	0.099	0.211	0.044	0.079	0.135	0.129	0.061	0.126	0.130	0.000
Pyrrhuloxia	R	32	0.037	0.035	0.044	0.022	0.029	0.032	0.019	0.035	0.348	0.000
Black-headed Grosbeak	PM	6	0.007	0.000	0.000	0.000	0.000	0.000	0.005	0.022	0.000	0.000
Blue Grosbeak	PM	3	0.003	0.053	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

			RIPARIAN HABITATS*									
Species	**Status**	**Indiv.**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Lazuli Bunting	M	5	0.006	0.018	0.000	0.000	0.029	0.032	0.000	0.000	0.000	0.000
Varied Bunting	PM	3	0.003	0.000	0.011	0.000	0.010	0.032	0.000	0.000	0.000	0.000
Red-winged Blackbird	PM	32	0.037	0.018	0.000	0.000	0.000	0.000	0.126	0.017	0.000	0.000
Western Meadowlark	PM	1	0.001	0.000	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Great-tailed Grackle	R	12	0.014	0.211	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Streak-backed Oriole	R	33	0.038	0.035	0.011	0.011	0.048	0.032	0.047	0.048	0.087	0.000
Bullock's Oriole	M	1	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.000
House Finch	R	96	0.110	0.053	0.022	0.056	0.067	0.000	0.150	0.152	0.174	0.242
Lesser Goldfinch	R	107	0.123	0.000	0.022	0.090	0.115	0.000	0.168	0.196	0.174	0.000
Lawrence's Goldfinch	M	5	0.006	0.000	0.000	0.000	0.038	0.000	0.005	0.000	0.000	0.000
Number of Counts			**872**	**57**	**91**	**89**	**104**	**31**	**214**	**230**	**23**	**33**
Number of species detected			**134**	**64**	**46**	**56**	**62**	**37**	**75**	**83**	**34**	**20**
Mean number of species per count				**4.11**	**2.48**	**3.06**	**4.04**	**2.84**	**3.57**	**3.94**	**4.04**	**1.18**
Number of Residents				**34**	**22**	**30**	**28**	**18**	**33**	**40**	**18**	**12**
Percentage of Residents				53.1	47.8	53.6	45.2	48.6	44.0	48.2	52.9	60.0
Number of Partial Migrants				**15**	**12**	**12**	**11**	**8**	**20**	**16**	**8**	**4**
Percentage of Partial Migrants				23.4	26.1	21.4	17.7	21.6	26.7	19.3	23.5	20.0
Number of Migrants				**15**	**12**	**14**	**23**	**11**	**22**	**27**	**8**	**4**
Percentage of Migrants				23.4	26.1	25.0	37.1	29.7	29.3	32.5	23.5	20.0
Number of Individuals detected			**5,025**	**382**	**294**	**460**	**617**	**111**	**1,271**	**1,658**	**160**	**72**
Mean number of individuals per count			**5.76**	**6.70**	**3.23**	**5.17**	**5.93**	**3.58**	**5.94**	**7.21**	**6.96**	**2.18**

STATUS: R = Resident species, PM = Partial Migrant Species; M = Migrant Species. Indiv: Number of individuals detected.

[RIPARIAN HABITATS: A = All Riparian types; B = Willow-Mesquite-Chino; C = Willow-Mesquite; D = Mesquite; E = Willow; F = Baldcypres-Willow; G = Cottonwood; H = Cottonwood-Willow; I = Cottonwood-Mesquite; J = Sycamores]

Appendix E. ANOVA of the number of individuals per count for the species detected in non-riparian and riparian vegetations in Sonora (January-February 2004-2006) (25-m radius).

SPECIES	Stat	Ind	GENERAL (n=1816)		NO-RIPARIAN (n=944)		RIPARIAN (n=872)		F	Sig.	
			Mean	SE	Mean	SE	Mean	SE			
Elegant Quail	R	9	0.005	0.004	0.000	0.000	0.010	0.009	1.36	0.244	
Gambel's Quail	R	79	0.043	0.012	0.064	0.020	0.021	0.012	3.46	0.063	ns
Montezuma Quail	R	6	0.003	0.002	0.004	0.004	0.002	0.002	0.15	0.696	
Black Vulture	R	70	0.038	0.014	0.062	0.026	0.013	0.008	3.05	0.081	ns
Turkey Vulture	R	31	0.017	0.005	0.027	0.009	0.006	0.003	4.50	0.034	*Nrip
Sharp-shinned Hawk	PM	1	0.001	0.001	0.001	0.001	0.000	0.000	0.92	0.338	
Cooper's Hawk	PM	2	0.001	0.001	0.000	0.000	0.002	0.002	2.18	0.140	
Red-tailed Hawk	R	8	0.004	0.002	0.005	0.003	0.003	0.002	0.28	0.599	
American Kestrel	PM	5	0.003	0.001	0.002	0.001	0.003	0.002	0.29	0.587	
Killdeer	R	25	0.014	0.004	0.004	0.002	0.024	0.009	5.40	0.020	*Rip
Northern Jacana	R	4	0.002	0.002	0.000	0.000	0.005	0.005	1.09	0.297	
Spotted Sandpiper	M	49	0.027	0.004	0.001	0.001	0.055	0.008	47.85	0.000	**Rip
Least Sandpiper	M	6	0.003	0.003	0.000	0.000	0.007	0.007	1.09	0.297	
Wilson's Snipe	M	6	0.003	0.002	0.000	0.000	0.007	0.003	4.92	0.027	*Rip
Band-tailed Pigeon	R	1	0.001	0.001	0.001	0.001	0.000	0.000	0.92	0.338	
White-winged Dove	R	113	0.062	0.015	0.039	0.015	0.087	0.026	2.57	0.109	ns
Mourning Dove	R	173	0.095	0.023	0.109	0.040	0.080	0.019	0.39	0.532	ns
Inca Dove	R	34	0.019	0.007	0.015	0.010	0.023	0.009	0.37	0.543	ns
Common Ground-Dove	R	24	0.013	0.007	0.001	0.001	0.026	0.014	3.65	0.056	ns
White-tipped Dove	R	8	0.004	0.002	0.004	0.002	0.005	0.002	0.01	0.905	
Greater Roadrunner	R	15	0.008	0.002	0.009	0.003	0.007	0.003	0.33	0.565	ns

SPECIES	Stat	Ind	GENERAL (n=1816)		NO-RIPARIAN (n=944)		RIPARIAN (n=872)		F	Sig.	
			Mean	SE	Mean	SE	Mean	SE			
Burrowing Owl	R	1	0.001	0.001	0.001	0.001	0.000	0.000	0.92	0.338	
Broad-billed Hummingbird	R	107	0.059	0.007	0.074	0.010	0.042	0.008	5.40	0.020	*Nrip
White-eared Hummingbird	R	4	0.002	0.001	0.004	0.003	0.000	0.000	2.45	0.117	
Violet-crowned Hummingbird	R	16	0.009	0.002	0.001	0.001	0.017	0.004	13.69	0.000	**Rip
Williamson's Sapsucker	M	1	0.001	0.001	0.001	0.001	0.000	0.000	0.92	0.338	
Plain-capped Starthroat	R	4	0.002	0.001	0.000	0.000	0.005	0.002	4.37	0.037	*Rip
Black-chinned Hummingbird	M	7	0.004	0.001	0.005	0.002	0.002	0.002	1.05	0.306	
Anna's Hummingbird	M	3	0.002	0.001	0.000	0.000	0.003	0.002	3.27	0.071	
Costa's Hummingbird	R	52	0.029	0.004	0.036	0.007	0.021	0.005	3.16	0.076	ns
Calliope Hummingbird	M	1	0.001	0.001	0.001	0.001	0.000	0.000	0.92	0.338	
Broad-tailed Hummingbird	M	3	0.002	0.001	0.000	0.000	0.003	0.002	3.27	0.071	
Rufous Hummingbird	M	8	0.004	0.003	0.000	0.000	0.009	0.006	2.49	0.115	
Unknown Hummingbird	PM	17	0.009	0.003	0.002	0.001	0.017	0.005	9.08	0.003	**Rip
Elegant Trogon	R	1	0.001	0.001	0.000	0.000	0.001	0.001	1.09	0.297	
Belted Kingfisher	M	3	0.002	0.001	0.001	0.001	0.002	0.002	0.42	0.515	
Green Kingfisher	R	56	0.031	0.004	0.000	0.000	0.064	0.009	56.44	0.000	**Rip
Lewis's Woodpecker	M	3	0.002	0.001	0.002	0.001	0.001	0.001	0.25	0.614	
Acorn Woodpecker	R	19	0.010	0.004	0.017	0.006	0.003	0.003	3.48	0.062	ns
Gila Woodpecker	R	215	0.118	0.010	0.105	0.013	0.132	0.015	1.80	0.180	ns
Red-naped Sapsucker	M	17	0.009	0.002	0.004	0.002	0.015	0.004	5.63	0.018	*Rip
Ladder-backed Woodpecker	R	64	0.035	0.005	0.028	0.006	0.042	0.007	2.32	0.128	ns
Hairy Woodpecker	R	2	0.001	0.001	0.002	0.001	0.000	0.000	1.84	0.175	
Arizona Woodpecker	R	6	0.003	0.002	0.006	0.003	0.000	0.000	4.15	0.042	*Nrip
Northern Flicker	R	21	0.012	0.003	0.016	0.004	0.007	0.003	3.18	0.075	ns

SPECIES	Stat	Ind	GENERAL (n=1816)		NO-RIPARIAN (n=944)		RIPARIAN (n=872)		F	Sig.	
			Mean	SE	Mean	SE	Mean	SE			
Gilded Flicker	R	25	0.014	0.003	0.026	0.006	0.000	0.000	15.79	0.000	**Nrip
Northern Beardless-Tyrannulet	R	15	0.008	0.002	0.004	0.002	0.013	0.004	3.09	0.079	ns
Tufted Flycatcher	R	2	0.001	0.001	0.000	0.000	0.002	0.002	2.18	0.140	
Greater Pewee	R	1	0.001	0.001	0.000	0.000	0.001	0.001	1.09	0.297	
Western Wood-Pewee	M	1	0.001	0.001	0.000	0.000	0.001	0.001	1.09	0.297	
Willow Flycatcher	M	1	0.001	0.001	0.000	0.000	0.001	0.001	1.09	0.297	
Gray Flycatcher	M	29	0.016	0.003	0.008	0.003	0.024	0.005	7.12	0.008	**Rip
Dusky Flycatcher	M	10	0.005	0.003	0.002	0.001	0.009	0.006	1.38	0.240	
Pacific-slope Flycatcher	M	8	0.004	0.002	0.002	0.001	0.007	0.003	2.37	0.124	
Cordilleran Flycatcher	PM	1	0.001	0.001	0.000	0.000	0.001	0.001	1.09	0.297	
Western Flycatcher	M	5	0.003	0.001	0.000	0.000	0.006	0.003	5.47	0.019	
Buff-breasted Flycatcher	R	2	0.001	0.001	0.001	0.001	0.001	0.001	0.00	0.952	
Empidonax sp.	M	148	0.081	0.007	0.012	0.004	0.157	0.013	116.42	0.000	**Rip
Black Phoebe	R	222	0.122	0.010	0.004	0.002	0.250	0.019	177.40	0.000	**Rip
Eastern Phoebe	M	3	0.002	0.001	0.001	0.001	0.002	0.002	0.42	0.515	
Say's Phoebe	PM	29	0.016	0.003	0.008	0.003	0.024	0.006	5.56	0.018	*Rip
Vermilion Flycatcher	R	50	0.027	0.004	0.001	0.001	0.056	0.009	38.52	0.000	**Rip
Dusky-capped Flycatcher	R	18	0.010	0.003	0.005	0.002	0.015	0.005	3.53	0.061	ns
Ash-throated Flycatcher	R	83	0.046	0.006	0.076	0.011	0.013	0.004	27.70	0.000	**Nrip
Nutting's Flycatcher	R	6	0.003	0.001	0.001	0.001	0.006	0.003	3.03	0.082	
Brown-crested Flycatcher	R	13	0.007	0.002	0.009	0.004	0.005	0.002	1.17	0.279	
Great Kiskadee	R	5	0.003	0.001	0.000	0.000	0.006	0.003	5.47	0.019	
Social Flycatcher	R	1	0.001	0.001	0.000	0.000	0.001	0.001	1.09	0.297	
Cassin's Kingbird	PM	8	0.004	0.002	0.003	0.002	0.006	0.003	0.55	0.459	

SPECIES	Stat	Ind	GENERAL (n=1816)		NO-RIPARIAN (n=944)		RIPARIAN (n=872)		F	Sig.	
			Mean	SE	Mean	SE	Mean	SE			
Loggerhead Shrike	PM	24	0.013	0.003	0.017	0.004	0.009	0.003	2.06	0.151	ns
Bell's Vireo	PM	3	0.002	0.001	0.001	0.001	0.002	0.002	0.42	0.515	
Plumbeous Vireo	M	4	0.002	0.001	0.001	0.001	0.003	0.002	1.18	0.277	
Cassin's Vireo	M	6	0.003	0.002	0.000	0.000	0.007	0.003	4.92	0.027	
Hutton's Vireo	R	5	0.003	0.001	0.005	0.002	0.000	0.000	4.61	0.032	
Warbling Vireo	PM	7	0.004	0.002	0.000	0.000	0.008	0.003	5.96	0.015	
Black-throated Magpie-Jay	R	8	0.004	0.003	0.000	0.000	0.009	0.007	2.05	0.152	
Mexican Jay	R	16	0.009	0.004	0.013	0.007	0.005	0.004	1.08	0.299	ns
Common Raven	R	26	0.014	0.004	0.021	0.007	0.007	0.003	3.11	0.078	ns
Horned Lark	R	11	0.006	0.004	0.012	0.007	0.000	0.000	2.48	0.116	
Violet-green Swallow	PM	39	0.021	0.012	0.041	0.023	0.000	0.000	3.04	0.081	ns
Northern Rough-winged Swallow	PM	1	0.001	0.001	0.000	0.000	0.001	0.001	1.09	0.297	
Mexican Chickadee	R	13	0.007	0.004	0.014	0.008	0.000	0.000	2.73	0.099	
Bridled Titmouse	R	51	0.028	0.008	0.034	0.011	0.022	0.010	0.63	0.428	ns
Verdin	R	405	0.222	0.014	0.313	0.023	0.124	0.015	47.32	0.000	**Nrip
Bushtit	R	17	0.009	0.007	0.002	0.002	0.017	0.014	1.20	0.273	ns
White-breasted Nuthatch	R	12	0.007	0.002	0.011	0.004	0.002	0.002	3.54	0.060	
Brown Creeper	R	5	0.003	0.002	0.005	0.003	0.000	0.000	2.09	0.148	
Cactus Wren	R	153	0.084	0.009	0.144	0.017	0.018	0.005	48.81	0.000	**Nrip
Rock Wren	R	16	0.009	0.002	0.016	0.004	0.001	0.001	10.00	0.002	**Nrip
Canyon Wren	R	7	0.004	0.002	0.005	0.003	0.002	0.002	0.82	0.367	
Sinaloa Wren	R	19	0.010	0.003	0.004	0.003	0.017	0.005	5.64	0.018	*Rip
Happy Wren	R	6	0.003	0.001	0.000	0.000	0.007	0.003	6.57	0.010	
Bewick's Wren	R	43	0.024	0.004	0.021	0.005	0.026	0.006	0.45	0.504	ns

SPECIES	Stat	Ind	GENERAL (n=1816)		NO-RIPARIAN (n=944)		RIPARIAN (n=872)		F	Sig.	
			Mean	SE	Mean	SE	Mean	SE			
House Wren	PM	73	0.040	0.005	0.008	0.003	0.075	0.011	37.60	0.000	**Rip
Marsh Wren	M	1	0.001	0.001	0.000	0.000	0.001	0.001	1.09	0.297	
Ruby-crowned Kinglet	M	506	0.278	0.016	0.063	0.011	0.511	0.030	209.68	0.000	**Rip
Blue-gray Gnatcatcher	PM	440	0.242	0.015	0.129	0.016	0.365	0.025	65.25	0.000	**Rip
Black-tailed Gnatcatcher	R	217	0.119	0.012	0.165	0.019	0.069	0.012	17.59	0.000	**Nrip
Black-capped Gnatcatcher	R	84	0.046	0.007	0.022	0.007	0.072	0.012	14.73	0.000	**Rip
Eastern Bluebird	R	9	0.005	0.004	0.009	0.008	0.000	0.000	1.15	0.285	
Hermit Thrush	M	8	0.004	0.002	0.002	0.001	0.007	0.003	2.37	0.124	
American Robin	PM	22	0.012	0.010	0.023	0.019	0.000	0.000	1.35	0.246	ns
Northern Mockingbird	PM	180	0.099	0.035	0.148	0.067	0.046	0.009	2.06	0.151	ns
Bendire's Thrasher	PM	7	0.004	0.002	0.006	0.003	0.001	0.001	2.47	0.116	
Curve-billed Thrasher	R	85	0.047	0.008	0.066	0.014	0.025	0.006	6.79	0.009	**Nrip
American Pipit	M	12	0.007	0.002	0.000	0.000	0.014	0.004	11.32	0.001	
Phainopepla	R	47	0.026	0.005	0.042	0.009	0.008	0.003	12.79	0.000	**Nrip
Olive Warbler	R	3	0.002	0.001	0.003	0.002	0.000	0.000	2.76	0.097	
Orange-crowned Warbler	M	145	0.080	0.008	0.056	0.010	0.106	0.013	9.17	0.002	**Rip
Nashville Warbler	M	14	0.008	0.004	0.004	0.004	0.011	0.006	0.91	0.341	
Lucy's Warbler	PM	3	0.002	0.001	0.000	0.000	0.003	0.002	3.27	0.071	
Crescent-chested Warbler	R	1	0.001	0.001	0.001	0.001	0.000	0.000	0.92	0.338	
Yellow Warbler	PM	14	0.008	0.002	0.015	0.004	0.000	0.000	11.39	0.001	
Yellow-rumped Warbler	M	436	0.239	0.018	0.061	0.018	0.433	0.031	116.18	0.000	**Rip
Black-throated Gray Warbler	M	36	0.020	0.004	0.008	0.003	0.032	0.007	10.77	0.001	**Rip
Townsend's Warbler	M	2	0.001	0.001	0.002	0.002	0.000	0.000	0.92	0.338	
Hermit Warbler	M	4	0.002	0.001	0.004	0.003	0.000	0.000	2.45	0.117	

SPECIES	Stat	Ind	GENERAL (n=1816)		NO-RIPARIAN (n=944)		RIPARIAN (n=872)		F	Sig.	
			Mean	SE	Mean	SE	Mean	SE			
Black-and-white Warbler	M	6	0.003	0.002	0.005	0.003	0.001	0.001	1.76	0.185	
American Redstart	M	2	0.001	0.001	0.001	0.001	0.001	0.001	0.00	0.952	
Northern Waterthrush	M	4	0.002	0.001	0.004	0.002	0.000	0.000	3.69	0.055	
MacGillivray's Warbler	M	12	0.007	0.003	0.000	0.000	0.014	0.006	5.62	0.018	
Common Yellowthroat	PM	170	0.093	0.008	0.031	0.007	0.162	0.015	66.33	0.000	**Rip
Grasshopper Sparrow	PM	1	0.001	0.001	0.001	0.001	0.000	0.000	0.92	0.338	
Wilson's Warbler	M	68	0.037	0.005	0.001	0.001	0.077	0.011	55.95	0.000	**Rip
Painted Redstart	PM	12	0.007	0.002	0.006	0.003	0.007	0.003	0.02	0.892	
Slate-throated Redstart	R	1	0.001	0.001	0.000	0.000	0.001	0.001	1.09	0.297	
Rufous-capped Warbler	R	5	0.003	0.002	0.005	0.004	0.000	0.000	1.77	0.184	
Yellow-breasted Chat	PM	3	0.002	0.001	0.003	0.002	0.000	0.000	2.76	0.097	
Hepatic Tanager	R	13	0.007	0.003	0.002	0.001	0.013	0.005	3.67	0.056	
Summer Tanager	M	1	0.001	0.001	0.000	0.000	0.001	0.001	1.09	0.297	
Green-tailed Towhee	M	174	0.096	0.009	0.033	0.008	0.164	0.017	53.29	0.000	**Rip
Spotted Towhee	PM	17	0.009	0.003	0.014	0.005	0.005	0.002	2.56	0.110	ns
Canyon Towhee	R	56	0.031	0.005	0.045	0.008	0.015	0.005	9.57	0.002	**Nrip
Rufous-winged Sparrow	R	74	0.041	0.010	0.053	0.012	0.028	0.016	1.59	0.207	ns
Cassin's Sparrow	PM	1	0.001	0.001	0.001	0.001	0.000	0.000	0.92	0.338	
Rufous-crowned Sparrow	R	50	0.027	0.008	0.040	0.014	0.014	0.008	2.55	0.111	ns
Five-striped Sparrow	R	7	0.004	0.002	0.007	0.003	0.000	0.000	4.11	0.043	
Chipping Sparrow	PM	515	0.283	0.053	0.136	0.039	0.443	0.102	8.32	0.004	**Rip
Clay-colored Sparrow	M	39	0.021	0.010	0.041	0.020	0.000	0.000	3.88	0.049	*Nrip
Brewer's Sparrow	M	127	0.070	0.023	0.087	0.035	0.050	0.027	0.67	0.413	ns
Black-chinned Sparrow	M	1	0.001	0.001	0.000	0.000	0.001	0.001	1.09	0.297	

SPECIES	Stat	Ind	GENERAL (n=1816)		NO-RIPARIAN (n=944)		RIPARIAN (n=872)		F	Sig.	
			Mean	SE	Mean	SE	Mean	SE			
Vesper Sparrow	M	5	0.003	0.001	0.004	0.002	0.001	0.001	1.56	0.212	
Lark Sparrow	M	255	0.140	0.034	0.073	0.022	0.213	0.066	4.33	0.038	*Rip
Black-throated Sparrow	R	46	0.025	0.007	0.037	0.011	0.013	0.007	3.41	0.065	ns
Savannah Sparrow	PM	26	0.014	0.007	0.027	0.014	0.000	0.000	3.62	0.057	ns
Song Sparrow	PM	351	0.193	0.014	0.001	0.001	0.401	0.027	247.84	0.000	**Rip
Lincoln's Sparrow	M	47	0.026	0.006	0.004	0.003	0.049	0.011	16.67	0.000	**Rip
White-crowned Sparrow	M	172	0.094	0.020	0.040	0.016	0.154	0.037	8.40	0.004	**Rip
Dark-eyed Junco	M	60	0.033	0.011	0.062	0.021	0.001	0.001	7.65	0.006	**Nrip
Yellow-eyed Junco	R	21	0.012	0.005	0.022	0.009	0.000	0.000	5.58	0.018	*Nrip
Northern Cardinal	R	134	0.074	0.008	0.051	0.008	0.099	0.013	9.78	0.002	**Rip
Pyrrhuloxia	R	41	0.023	0.006	0.009	0.004	0.037	0.011	5.48	0.019	*Rip
Black-headed Grosbeak	PM	10	0.005	0.003	0.004	0.004	0.007	0.005	0.17	0.677	ns
Blue Grosbeak	PM	3	0.002	0.002	0.000	0.000	0.003	0.003	1.09	0.297	
Lazuli Bunting	M	5	0.003	0.001	0.000	0.000	0.006	0.003	3.90	0.048	
Varied Bunting	M	4	0.002	0.001	0.001	0.001	0.003	0.002	1.18	0.277	
Red-winged Blackbird	PM	32	0.018	0.011	0.000	0.000	0.037	0.024	2.57	0.109	ns
Western Meadowlark	PM	21	0.012	0.011	0.021	0.021	0.001	0.001	0.82	0.365	ns
Brewer's Blackbird	M	1	0.001	0.001	0.001	0.001	0.000	0.000	0.92	0.338	
Great-tailed Grackle	R	21	0.012	0.007	0.009	0.005	0.014	0.014	0.09	0.763	ns
Streak-backed Oriole	R	34	0.019	0.003	0.001	0.001	0.038	0.007	28.87	0.000	**Rip
Bullock's Oriole	M	1	0.001	0.001	0.000	0.000	0.001	0.001	1.09	0.297	
Scott's Oriole	PM	2	0.001	0.001	0.002	0.002	0.000	0.000	0.92	0.338	
House Finch	R	222	0.122	0.013	0.133	0.018	0.110	0.018	0.76	0.382	ns
Pine Siskin	M	1	0.001	0.001	0.001	0.001	0.000	0.000	0.92	0.338	

SPECIES	Stat	Ind	GENERAL (n=1816)		NO-RIPARIAN (n=944)		RIPARIAN (n=872)		F	Sig.	
			Mean	SE	Mean	SE	Mean	SE			
Lesser Goldfinch	R	124	0.068	0.013	0.018	0.008	0.123	0.026	15.48	0.000	**Rip
Lawrence's Goldfinch	M	5	0.003	0.002	0.000	0.000	0.006	0.005	1.60	0.206	
House Sparrow	R	2	0.001	0.001	0.002	0.002	0.000	0.000	0.92	0.338	

Stat = Residency status: R=Resident, PM= Partial Migrant, M= Migrant; Ind = Number of individuals detected; F and Sig.(p) correspond to the ANOVA results presented only for the most common species.

Appendix F. ANOVA of the number of individuals per count for the species recorded in undisturbed and disturbed riparian vegetations in Sonora (January-February 2005-2006) (25-m radius).

SPECIES	Stat	Ind	GENERAL (n=433)		UNDISTURBED RIPARIAN (n=218)		DISTURBED RIPARIAN (n=215)		F	Sig.	
			Mean	SE	Mean	SE	Mean	SE			
Wood Duck	M	2	0.0046	0.0046	0.0000	0.0000	0.0093	0.0093	1.0140	0.3145	
Mallard	PM	25	0.0577	0.0226	0.0459	0.0203	0.0698	0.0406	0.2790	0.5977	ns
Cinnamon Teal	M	3	0.0069	0.0069	0.0138	0.0138	0.0000	0.0000	0.9862	0.3212	
Green-winged Teal	M	3	0.0069	0.0069	0.0138	0.0138	0.0000	0.0000	0.9862	0.3212	
Common Merganser	M	15	0.0346	0.0210	0.0642	0.0414	0.0047	0.0047	2.0165	0.1563	ns
Elegant Quail	R	8	0.0185	0.0185	0.0367	0.0367	0.0000	0.0000	0.9862	0.3212	
Gambel's Quail	R	8	0.0185	0.0146	0.0275	0.0275	0.0093	0.0093	0.3890	0.5332	
Great Blue Heron	R	10	0.0231	0.0079	0.0229	0.0121	0.0233	0.0103	0.0004	0.9839	
Great Egret	R	5	0.0115	0.0051	0.0046	0.0046	0.0186	0.0092	1.8628	0.1730	
Green Heron	PM	4	0.0092	0.0046	0.0046	0.0046	0.0140	0.0080	1.0352	0.3095	
Black Vulture	R	4	0.0092	0.0092	0.0000	0.0000	0.0186	0.0186	1.0140	0.3145	
Turkey Vulture	R	4	0.0092	0.0056	0.0183	0.0112	0.0000	0.0000	2.6502	0.1043	
Common Black-Hawk	R	1	0.0023	0.0023	0.0000	0.0000	0.0047	0.0047	1.0140	0.3145	
Red-tailed Hawk	R	1	0.0023	0.0023	0.0000	0.0000	0.0047	0.0047	1.0140	0.3145	
American Kestrel	PM	2	0.0046	0.0033	0.0000	0.0000	0.0093	0.0066	2.0375	0.1542	
Killdeer	R	14	0.0323	0.0121	0.0092	0.0092	0.0558	0.0225	3.7157	0.0546	
Spotted Sandpiper	M	35	0.0808	0.0135	0.0826	0.0187	0.0791	0.0196	0.0167	0.8972	ns
Least Sandpiper	M	6	0.0139	0.0139	0.0000	0.0000	0.0279	0.0279	1.0140	0.3145	
Wilson's Snipe	M	5	0.0115	0.0061	0.0046	0.0046	0.0186	0.0113	1.3245	0.2504	

SPECIES	Stat	Ind	GENERAL (n=433)		UNDISTURBED RIPARIAN (n=218)		DISTURBED RIPARIAN (n=215)		F	Sig.	
			Mean	SE	Mean	SE	Mean	SE			
White-winged Dove	R	30	0.0693	0.0240	0.0138	0.0138	0.1256	0.0461	5.4739	0.0198	*D
Mourning Dove	R	29	0.0670	0.0228	0.0229	0.0189	0.1116	0.0415	3.8146	0.0515	ns
Inca Dove	R	3	0.0069	0.0069	0.0000	0.0000	0.0140	0.0140	1.0140	0.3145	
White-tipped Dove	R	3	0.0069	0.0040	0.0092	0.0065	0.0047	0.0047	0.3206	0.5715	
Greater Roadrunner	R	5	0.0115	0.0061	0.0092	0.0065	0.0140	0.0104	0.1535	0.6954	
Broad-billed Hummingbird	R	9	0.0208	0.0069	0.0413	0.0135	0.0000	0.0000	9.2156	0.0025	
Violet-crowned Hummingbird	R	14	0.0323	0.0085	0.0275	0.0111	0.0372	0.0129	0.3234	0.5699	
Black-chinned Hummingbird	PM	1	0.0023	0.0023	0.0046	0.0046	0.0000	0.0000	0.9862	0.3212	
Anna’s Hummingbird	M	2	0.0046	0.0033	0.0046	0.0046	0.0047	0.0047	0.0001	0.9922	
Costa’s Hummingbird	R	11	0.0254	0.0089	0.0275	0.0129	0.0233	0.0122	0.0577	0.8103	
Broad-tailed Hummingbird	PM	2	0.0046	0.0033	0.0092	0.0065	0.0000	0.0000	1.9815	0.1599	
Rufous Hummingbird	M	7	0.0162	0.0120	0.0000	0.0000	0.0326	0.0241	1.8472	0.1748	
Unidentified Hummingbird	PM	13	0.0300	0.0094	0.0459	0.0169	0.0140	0.0080	2.8806	0.0904	
Belted Kingfisher	M	1	0.0023	0.0023	0.0046	0.0046	0.0000	0.0000	0.9862	0.3212	
Green Kingfisher	R	35	0.0808	0.0143	0.0688	0.0172	0.0930	0.0229	0.7179	0.3973	ns
Gila Woodpecker	R	61	0.1409	0.0215	0.0872	0.0212	0.1953	0.0372	6.4143	0.0117	*D
Red-naped Sapsucker	M	7	0.0162	0.0061	0.0138	0.0079	0.0186	0.0092	0.1590	0.6903	
Ladder-backed Woodpecker	R	17	0.0393	0.0099	0.0459	0.0142	0.0326	0.0138	0.4515	0.5020	ns
Northern Flicker	R	4	0.0092	0.0046	0.0138	0.0079	0.0047	0.0047	0.9793	0.3229	
Northern Beardless-Tyrannulet	R	4	0.0092	0.0046	0.0092	0.0065	0.0093	0.0066	0.0002	0.9889	
Tufted Flycatcher	R	2	0.0046	0.0033	0.0092	0.0065	0.0000	0.0000	1.9815	0.1599	
Western Wood-Pewee	PM	1	0.0023	0.0023	0.0046	0.0046	0.0000	0.0000	0.9862	0.3212	

SPECIES	Stat	Ind	GENERAL (n=433)		UNDISTURBED RIPARIAN (n=218)		DISTURBED RIPARIAN (n=215)		F	Sig.	
			Mean	SE	Mean	SE	Mean	SE			
Gray Flycatcher	M	10	0.0231	0.0072	0.0413	0.0135	0.0047	0.0047	6.5056	0.0111	
Western Flycatcher	PM	3	0.0069	0.0040	0.0138	0.0079	0.0000	0.0000	2.9861	0.0847	
Buff-breasted Flycatcher	R	1	0.0023	0.0023	0.0046	0.0046	0.0000	0.0000	0.9862	0.3212	
Empidonax sp.	M	108	0.2494	0.0235	0.2890	0.0346	0.2093	0.0315	2.8939	0.0896	ns
Black Phoebe	R	121	0.2794	0.0269	0.3303	0.0401	0.2279	0.0355	3.6470	0.0568	ns
Eastern Phoebe	M	1	0.0023	0.0023	0.0000	0.0000	0.0047	0.0047	1.0140	0.3145	
Say's Phoebe	PM	8	0.0185	0.0065	0.0092	0.0065	0.0279	0.0113	2.0951	0.1485	
Vermilion Flycatcher	R	11	0.0254	0.0082	0.0046	0.0046	0.0465	0.0158	6.5442	0.0109	
Dusky-capped Flycatcher	R	7	0.0162	0.0069	0.0183	0.0112	0.0140	0.0080	0.1014	0.7503	
Ash-throated Flycatcher	R	2	0.0046	0.0033	0.0092	0.0065	0.0000	0.0000	1.9815	0.1599	
Loggerhead Shrike	PM	7	0.0162	0.0061	0.0092	0.0065	0.0233	0.0103	1.3475	0.2464	
Plumbeous Vireo	PM	2	0.0046	0.0033	0.0092	0.0065	0.0000	0.0000	1.9815	0.1599	
Cassin's Vireo	M	4	0.0092	0.0046	0.0138	0.0079	0.0047	0.0047	0.9793	0.3229	
Warbling Vireo	PM	1	0.0023	0.0023	0.0046	0.0046	0.0000	0.0000	0.9862	0.3212	
Verdin	R	36	0.0831	0.0155	0.0917	0.0244	0.0744	0.0191	0.3113	0.5771	ns
Cactus Wren	R	7	0.0162	0.0069	0.0000	0.0000	0.0326	0.0138	5.6377	0.0180	
Canyon Wren	R	2	0.0046	0.0033	0.0092	0.0065	0.0000	0.0000	1.9815	0.1599	
Sinaloa Wren	R	5	0.0115	0.0061	0.0138	0.0079	0.0093	0.0093	0.1337	0.7148	
Happy Wren	R	2	0.0046	0.0033	0.0046	0.0046	0.0047	0.0047	0.0001	0.9922	
Bewick's Wren	R	7	0.0162	0.0069	0.0183	0.0091	0.0140	0.0104	0.1014	0.7503	
House Wren	PM	39	0.0901	0.0145	0.1101	0.0222	0.0698	0.0186	1.9297	0.1655	ns
Ruby-crowned Kinglet	M	295	0.6813	0.0492	0.8945	0.0759	0.4651	0.0589	19.9077	0.0000	**U

SPECIES	Stat	Ind	GENERAL (n=433)		UNDISTURBED RIPARIAN (n=218)		DISTURBED RIPARIAN (n=215)		F	Sig.	
			Mean	SE	Mean	SE	Mean	SE			
Blue-gray Gnatcatcher	PM	219	0.5058	0.0395	0.5138	0.0571	0.4977	0.0547	0.0413	0.8390	ns
Black-tailed Gnatcatcher	R	3	0.0069	0.0040	0.0046	0.0046	0.0093	0.0066	0.3484	0.5553	
Black-capped Gnatcatcher	R	53	0.1224	0.0220	0.1147	0.0284	0.1302	0.0337	0.1247	0.7241	ns
Hermit Thrush	M	5	0.0115	0.0051	0.0183	0.0091	0.0047	0.0047	1.7784	0.1831	
Northern Mockingbird	PM	12	0.0277	0.0112	0.0229	0.0189	0.0326	0.0121	0.9862	0.3212	
Curve-billed Thrasher	R	6	0.0139	0.0065	0.0046	0.0046	0.0233	0.0122	2.0636	0.1516	
American Pipit	M	10	0.0231	0.0072	0.0046	0.0046	0.0419	0.0137	6.7385	0.0098	
Orange-crowned Warbler	M	40	0.0924	0.0161	0.1055	0.0218	0.0791	0.0236	0.6760	0.4114	ns
Nashville Warbler	M	5	0.0115	0.0061	0.0092	0.0065	0.0140	0.0104	0.1535	0.6954	
Yellow-rumped Warbler	M	200	0.4619	0.0422	0.5275	0.0614	0.3953	0.0577	2.4569	0.1177	ns
Black-throated Gray Warbler	M	12	0.0277	0.0085	0.0413	0.0150	0.0140	0.0080	2.5650	0.1100	
Black-and-White Warbler	M	1	0.0023	0.0023	0.0046	0.0046	0.0000	0.0000	0.9862	0.3212	
American Redstart	M	1	0.0023	0.0023	0.0000	0.0000	0.0047	0.0047	1.0140	0.3145	
MacGillivray's Warbler	M	1	0.0023	0.0023	0.0000	0.0000	0.0047	0.0047	1.0140	0.3145	
Common Yellowthroat	PM	99	0.2286	0.0249	0.2661	0.0392	0.1907	0.0306	2.2888	0.1310	ns
Wilson's Warbler	M	28	0.0647	0.0131	0.0872	0.0212	0.0419	0.0152	2.9943	0.0843	ns
Painted Redstart	PM	1	0.0023	0.0023	0.0046	0.0046	0.0000	0.0000	0.9862	0.3212	
Hepatic Tanager	R	7	0.0162	0.0083	0.0000	0.0000	0.0326	0.0167	3.8721	0.0497	
Green-tailed Towhee	M	79	0.1824	0.0239	0.2294	0.0375	0.1349	0.0291	3.9424	0.0477	*U
Spotted Towhee	PM	2	0.0046	0.0033	0.0092	0.0065	0.0000	0.0000	1.9815	0.1599	
Canyon Towhee	R	10	0.0231	0.0097	0.0229	0.0102	0.0233	0.0167	0.0003	0.9869	
Rufous-winged Sparrow	R	9	0.0208	0.0155	0.0413	0.0307	0.0000	0.0000	1.7817	0.1826	

SPECIES	Stat	Ind	GENERAL (n=433)		UNDISTURBED RIPARIAN (n=218)		DISTURBED RIPARIAN (n=215)		F	Sig.	
			Mean	SE	Mean	SE	Mean	SE			
Chipping Sparrow	PM	116	0.2679	0.1128	0.0963	0.0393	0.4419	0.2233	2.3522	0.1258	ns
Lark Sparrow	M	79	0.1824	0.0905	0.0275	0.0194	0.3395	0.1808	2.9840	0.0848	ns
Black-throated Sparrow	R	3	0.0069	0.0069	0.0000	0.0000	0.0140	0.0140	1.0140	0.3145	
Song Sparrow	PM	252	0.5820	0.0420	0.6514	0.0633	0.5116	0.0547	2.7844	0.0959	ns
Lincoln's Sparrow	M	17	0.0393	0.0104	0.0367	0.0143	0.0419	0.0152	0.0612	0.8048	ns
White-crowned Sparrow	M	84	0.1940	0.0614	0.0688	0.0305	0.3209	0.1193	4.2437	0.0400	*D
Northern Cardinal	R	51	0.1178	0.0216	0.1330	0.0302	0.1023	0.0308	0.5061	0.4772	ns
Pyrrhuloxia	R	21	0.0485	0.0209	0.0138	0.0102	0.0837	0.0408	2.8033	0.0948	ns
Black-headed Grosbeak	PM	2	0.0046	0.0033	0.0092	0.0065	0.0000	0.0000	1.9815	0.1599	
Lazuli Bunting	M	3	0.0069	0.0052	0.0000	0.0000	0.0140	0.0104	1.8320	0.1766	
Varied Bunting	PM	2	0.0046	0.0033	0.0092	0.0065	0.0000	0.0000	1.9815	0.1599	
Red-winged Blackbird	PM	31	0.0716	0.0480	0.0000	0.0000	0.1442	0.0965	2.2633	0.1332	ns
Streak-backed Oriole	R	24	0.0554	0.0124	0.0642	0.0190	0.0465	0.0158	0.5109	0.4751	ns
House Finch	R	65	0.1501	0.0325	0.1560	0.0433	0.1442	0.0486	0.0328	0.8563	ns
Lesser Goldfinch	R	77	0.1778	0.0471	0.3257	0.0910	0.0279	0.0173	10.1968	0.0015	**U
Lawrence's Goldfinch	M	5	0.0115	0.0095	0.0183	0.0183	0.0047	0.0047	0.5173	0.4724	

Stat = Residency status: R=Resident, PM= Partial Migrant, M= Migrant; Ind = Number of individuals detected; F and Sig.(p) correspond to the ANOVA results presented only for the most abundant species. U = undisturbed riparian, D = Disturbed riparian.